Structural Engineering

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某双线变三线道岔连续梁桥设计

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摘 要：在高速铁路网“四横四纵”规划顺利实施完成的背景下，国家又开始重视一些重要城市之间的互联互通，由于有些车站设在桥上，一些道岔难免要布置在桥梁段内。本文结合杭绍台城际铁路双线变三线道岔连续梁实体工程，利用Midas civil 2015 有限元软件计算分析，介绍了其主梁构造、受力特点和计算分析结果。希望对同类型的桥梁设计提供借鉴。

关键词：道岔；连续梁；设计

Design of the Double-Line to Triple-Line Switch Continuous Beam

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Abstract:

With the successfully implement and completion of the “ four vertical and four horizontal ” system of the national high speed railway network, the country begins to attach importance to interconnection of among some major cities again. Because some train stations are located on the viaduct, some switches are inevitably arranged on the bridge. Using “Midas civil 2015” for calculation and analysis, this paper introduces the girder structure, the loading features and the analyzing and calculating results of the double-line to triple-line switch bridge of Hangzhou-Shaoxing-Taizhou Inter-city Railway. Reference is provided for design of the same type of bridge..

keywords:switch; continuous beam; design

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Numerical Simulation and Model Experimental on Bending Characteristics of Parallel Wire Strands

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Abstract: In order to analyse bending stiffness and bending stress of strand composed of discrete parallel steel wires under tension and bending loads, the bending characteristics of strand were simulated and tested. Firstly, the layered element model of strand is proposed and established, and the calculation method of ultimate friction force between layers is given. Secondly, a set of support and loading system for strand tension-bending experiment model is designed. The stress and deformation of strand composed of 61 steel wires under tension-bending load are tested. The results of numerical simulation and test show that: (1) The layered element model can truly simulate stress and deformation characteristics of strand; (2) Uniform winding force and axial force of strand have significant effects on non-uniform stress and deformation of strand after the slip of wires; (3) The effective length of strand will affect the non-uniform stress only when the slip area of steel wire is large enough; (4) The slope between non-uniform stress and rotation angle at the end of strand reflects the bending stiffness of strand, which decreases with the increase of slip area between layers of strand; (5) Under the same rotation angle, the greater the uniform winding force or the smaller the axial force, the greater flexural rigidity of strand and the greater non-uniform stress and deformation. The research results can provide valuable reference for calculating the bending stress of cable..

Key words: Parallel wire strands; Bending characteristics; Numerical simulation; Model experimental; Layered slip element model

大跨径拱柱梁全固结体系钢箱桁肋拱桥设计

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摘　要：本文介绍了宜宾至昭通高速公路控制性工程——白水江特大桥主桥的方案比选、结构设计、施工方案，通过静力和动力分析，验证了设计方案的合理性和安全性，同时总结了该桥设计的三项重要创新点，可为建设条件或桥型设计提供参考。

关键词：宜昭高速；白水江特大桥；全固结体系；钢箱桁肋拱桥

Design of Steel Box Truss Rib Arch Bridge with Long Span and Fully Consolidated System of Arch-Column-Beam

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Abstract:

This paper introduces the scheme selection, structural design and construction scheme of Baishuijiang Bridge, a controllable project of Yibin-Zhaotong Expressway. Through static and dynamic analysis, the rationality and safety of the design scheme are verified. At the same time, three important innovations in the design of the bridge are summarized, which can provide reference for construction conditions or bridge type design..

keywords: Yibin-Zhaotong Expressway; Baishuijiang Bridge; Fully Consolidated System; Steel Box Truss Rib Arch Bridge

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低高度敞口式钢桁架桥结构研发及参数敏感性分析

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摘　要：低高度梁能有效降低梁高，减小工程规模，降低工程造价，具有较强的工程实践意义。本文以某跨堤桥梁为研究对象，通过MIDAS/Civil建立全桥有限元模型，运用参数对比方法，探讨桥梁在杆件尺寸变化、宽跨比、高跨比等因素下，整体结构刚度、强度、稳定性变化规律。主要结论如下：1）杆件尺寸对桥梁整体静力性能有一定影响，上弦杆钢管直径对桥梁整体稳定影响较大；2）桥梁宽度的增加，对桥梁整体挠度、下弦杆最大拉应力、纵横梁最大压应力影响较大，对结构整体稳定影响较小；3）桁架高度的增加对桥梁整体稳定影响有限，对桥梁整体挠度及下弦杆应力影响较大。研究结论可为同类桥梁设计提供参考。

关键词：关键词：低高度；敞口式；钢桁架；杆件尺寸；宽跨比；高跨比

Structural Behavior and Parameter Sensitivity Analysis of Low and Open Steel Truss Bridge

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（ANHUI TRANSPORT CONSULTING & DES IGN INSTITUTE CO., LTD.）

Abstract:

Low-height beams can effectively reduce the height of beams, reduce the scale of the project and reduce the cost of the project, which has strong practical significance. In order to clarify the mechanical behavior of the low and high open steel truss bridge structure, this paper takes a cross embankment bridge as the research object, establishes the full bridge finite element model by MIDAS/Civil, and uses the parameter comparison method to discuss the changes of the stiffness, strength and stability of the whole structure under the factors such as the size change of the bar, the width span ratio, the high span ratio and so on. Law. The main conclusions are as follows: 1) the size of the rod has a certain effect on the overall static performance of the bridge, the diameter of the steel pipe of the upper chord has a great influence on the overall stability of the bridge; 2) the increase of the width of the bridge has great influence on the overall deflection of the bridge, the maximum tensile stress of the lower chord, the maximum compressive stress of the longitudinal and horizontal beams, and less influence on the overall stability of the structure; 3) The increase of truss height has limited influence on the overall stability of the bridge, and has a greater influence on the overall deflection of the bridge and the stress of the lower chord. The conclusion can provide reference for similar bridge design..

keywords:key words: low Altitude; open type; steel truss; rod size; width span ratio; high span ratio

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上飞雁式梁拱组合体系桥梁边中跨比例研究

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摘　要：通过对不同边跨长度的上飞雁式梁拱组合桥进行有限元分析，研究边中跨比对上飞雁式梁拱组合桥受力特性的影响规律，并探寻上飞雁式梁拱组合桥边中跨比的合理区间。研究表明：上飞雁式梁拱组合桥的典型受力特点是分叉区拱圈存在明显负弯矩效应；上飞雁式梁拱组合桥边中跨比的合理下限值受边跨支反力控制，其合理上限值受分叉区拱圈的负弯矩情况控制，其合理区间宜为 0.267~0.395；当边中跨比取值较小时，对整体结构的内力及挠度控制较为有利；可通过对分叉区构造进行优化提高上飞雁式梁拱组合桥边中跨比的合理上限值。

关键词：关键词：上飞雁式；梁拱组合桥；边中跨比；合理区间；参数类比

Reasonable Interval Analysis of Side-To-Mid Span Ratio of Upper Flying Bird Style Beam-Arch Composite Bridge

Li Long，Liang Changhai，Dai Zhengjun，Lu Yuangang
（ANHUI TRANSPORT CONSULTING & DES IGN INSTITUTE　CO., LTD.）

Abstract:

Through the finite element analysis of the upper flying bird style beam-arch composite bridge with different side span lengths, the influence of side-to-mid span ratio on the mechanical characteristics of the upper flying bird style beam-arch composite bridge is studied, and the reasonable range of side-to-mid span ratio of the upper flying bird style beam-arch composite bridge is explored.The results show that the typical mechanical characteristics of the upper flying bird style beam-arch composite bridge are obvious negative moment effect in the arch ring of the bifurcation zone；The reasonable lower limit value of side-to-mid-span ratio of upper flying bird style beam-arch composite bridge is controlled by side-span reaction force, and its reasonable upper limit value is controlled by negative bending moment of arch ring in bifurcation zone, and its reasonable range is 0.267~0.395；It is more advantageous to control the internal force and deflection of the whole structure when the ratio of side to midspan is small；Reasonable upper limit value of side-to-mid-span ratio of upper flying bird style beam-arch composite bridge can be improved by optimizing the structure of bifurcation zone..

keywords:upper flying bird;style beam-arch composite bridge; side-to-mid span ratio;　reasonable interval; parameter analogy

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地下连续墙在拱桥基础中的应用分析

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摘　要：地下连续墙基础是一种新型的桥梁基础，在日本的桥梁工程中得到了大量应用并取得了良好的社会经济效益，但是地下连续墙基础的承载机理和基础-地基共同作用规律尚未清楚，在我国还没有形成较为成熟的设计计算方法；本文通过对某高速有推力拱桥的地下连续墙基础的水平变位、承载能力验算及有限元模拟分析，为地下连续墙的设计提供参考。

关键词：地下连续墙基础；水平变位；承载能力

Application Analysis of Diaphragm Wall in Arch Bridge Foundation

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（ANHUI TRANSPORT CONSULTING & DES IGN INSTITUTE　CO., LTD.）

Abstract:

Diaphragm wall foundation is a new type of bridge foundation, which has been widely used in bridge engineering in Japan and achieved good social and economic benefits. However, the bearing mechanism of diaphragm wall foundation and the law of foundation-foundation interaction are not clear, and there is no mature design and calculation method in our country. In this paper, the horizontal displacement, carrying capacity checking and finite element simulation analysis of the diaphragm wall foundation of a high-speed thrust arch bridge are carried out to provide reference for the design of the diaphragm wall..

keywords: Diaphragm wall foundation; Horizontal displacement; Carrying capacity

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中央扣对大跨度空间缆索悬索桥静动力特性影响研究

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摘　要：为探讨不同中央扣联结形式对空间缆索悬索桥静、动力特性的影响，以宝塔坪特大桥为研究背景，建立了该桥 3 种不同联结模式下的三维空间静、动力计算模型，针对 3 种不同中央扣联结形式下结构的静、动力响应做了对比分析。研究结果表明：静力方面，中央扣对活载下加劲梁的竖向挠度影响较小，但会减小梁端纵向位移，并将增大跨中加劲梁轴力；动力方面：中央扣的设置提高了结构的反对称扭转频率，推迟了纵飘振形的出现，增大了结构的抗扭转刚度和纵向刚度。

关键词：空间缆索

Research on the Influence of Central Buckling on Static and Dynamic Characteristics of Long-Span Space Cable Suspension Bridge

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Abstract:

In order to explore the influence of different central buckling connection forms on the static and dynamic characteristics of space cable suspension bridges, taking Baotaping Bridge as the research background, the three-dimensional static and dynamic calculation model of the bridge under three different coupling modes is established, and the static and dynamic responses of the three different central interlocking structures are compared. The results show that: (1) In terms of statics, the central buckle has little effect on the vertical deflection of stiffened beams under live load, but it will reduce the longitudinal displacement of the end of beams and increase the axial force of stiffened beams in the middle of span; (2) In dynamic aspect, the setting of central buckle improves the anti-symmetrical torsion frequency of the structure, delays the appearance of longitudinal vibration, and increases the torsional stiffness and longitudinal stiffness of the structure..

keywords:spatial cable

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无伸缩缝桥梁在浙江省实践及适用性研究

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摘　要：为了解决中小跨径桥梁频发更换伸缩缝引发交通中断的难题，以及改善车辆过桥时“跳车”引起不适的行车体验，为此，浙江省建造了三座不同结构形式的无伸缩缝桥梁。首先对已建三座无伸缩缝桥梁的建设条件、结构形式和运行状况等进行了分析、调研和总结，针对出现的病害提出了改进、预防措施；然后采用有限元数值分析方法，研究了对比了整体式桥台桥梁和普通桥梁的受力机理和主要影响因素。最后，结合浙江省地基情况和分类，得出如下结论：沿海如宁波、温州、绍兴、杭嘉湖等软弱土地基地区，适宜建造整体式桥台无伸缩缝桥梁；衢州、舟山和丽水等多山地丘陵地区，土质较好，适宜建造半整体式桥台无伸缩缝桥梁。

关键词：整体式桥台；半整体式桥台；无伸缩缝桥梁；软土地基；硬土地基；有限元

Study on Applicability of Jointless Bridge in Zhejiang Province

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Abstract:

In order to solve the problem of traffic interruption caused by replacement of expansion joints frequently in small and medium-sized span bridges and improve the driving experience caused by "jumping off" when vehicles cross the bridge, three jointless bridges with different structural forms were built in Zhejiang Province. This paper analyzes, investigates and summarizes the construction conditions, structural forms and operating conditions of three bridges without expansion joints, and proposes improvement and preventive measures for diseases. This paper compared theory of mechanics and influencing factors between IAB and normal bridge by using FEM. We draw a conclusion that Ningbo, Wenzhou, Shaoxing, Hangzhou, Huzhou, Jiaxing, etc, where are distributed soft soil foundation is suitable to construct IABs, and Quzhou, Lishui, Zhoushan, etc, where are distributed stiff soil foundation is suitable to construct semi-integral abutment bridge by combining soil classification of Zhejiang Province..

keywords: Integral abutment bridge; Semi-integral abutment bridge; Jointless bridge; Soft soil foundation; Stiff soil foundation; FEM

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脊骨梁斜拉桥主梁设计关键技术研究

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摘　要：G3W 德州至上饶高速孔城河特大桥主桥为非对称独塔混合梁斜拉桥，主跨为 165m 钢箱梁，边跨为 85m 预应力混凝土箱梁，梁截面均采用大悬臂脊骨箱梁型式，宽度为 30.5m，两侧悬臂各长 9.85m，合计约占箱梁全宽 2/3。较常规箱梁，这种大悬臂脊骨箱梁节省材料约 30%。针对主梁构造的关键技术问题，分析了主梁断面形式对脊骨梁扭转效应的贡献、支撑形式对桥面板受力影响等，并利用研究成果对箱梁结构进行了细节设计及优化，保证了桥梁安全及合理的受力性能。本文的相关研究方法可为后续类似桥梁设计提供参考。

关键词：独塔斜拉桥；混合梁；大悬臂；脊骨箱梁；细节设计；扭转效应

Research on Key Technologies of Main Girder Design of Cable-Stayed Bridge with Backbone Girders

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Abstract:

The Kong-cheng-he Bridge in Dezhou-Shangrao Expressway(G3W) is an asymmetric single pylon hybrid girder cable-stayed bridge. Its main span is 165m steel box girder and the side span is 85m pre-stressed concrete box girder. The cross-section of the girders are all adopted the type of box girder with large cantilever spine. The width of the box girder is 30.5m and the cantilevers on both sides are 9.85m in length, accounting for about 2/3 of the total width of the box girder. Compared with conventional box girder, this kind of large cantilever backbone box girder may save about 30% material. Aiming at the key technical problems of the main girder construction, the contribution of the main girder section form to the torsion effect of the backbone girder and the influence of the support form on the force of the bridge deck are analyzed, and the detailed design and optimization of the box girder structure are carried out by using the research results to ensure the safety and reasonable mechanical performance of the bridge. The relevant research methods in this paper can provide reference for the follow-up similar bridge design..

keywords:single tower cable-stayed bridge;　hybrid beam;　large cantilever;　backbone box girder;　detail design;　torsion effect

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The Vertical Bearing Capacity of CCFST Piles

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Abstract: Steel casing pipes (SCPs) are extensively and increasingly used as cofferdam structures in the construction of bridge pile foundations in water environments. SCPs, together with reinforced concrete (RC) piles, form composite concrete-filled steel tube piles (CCFSTPs), which differ significantly from ordinary RC piles in vertical bearing capacity. In this study, the vertical bearing capacity of a CCFSTP was examined through a centrifugal model test with the buried depth of the steel tube (hST) and the modulus of the soil mass in the steel-tube soil compaction zone (ESTSC_zone) as variables. The load-settlement curves, axial force curves and pile-side friction resistance curves were obtained for the CCFSTP. The test results show that increasing hST within a range of 12 cm significantly increases the ultimate vertical bearing capacity of the CCFSTP, and further increasing hST beyond 12 cm produces a continuous increase in the ultimate vertical bearing capacity of the CCFSTP only to an insignificant extent. In addition, increasing ESTSC_zone increases the ultimate vertical bearing capacity of the CCFSTP to a relatively small extent. Furthermore, calculating formulations about the vertical allowable bearing capacity of CCFSTP were put forward, which will provide reliable theoretical basis and technical support for the design and construction of CCFSTPs.

Key words: Geotechnical engineering; Composite concrete-filled steel tube pile; Centrifuge model test; Vertical bearing capacity

胶膜连接 CFRP 板/钢搭接接头的性能试验

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摘　要：针对 CFRP 板/钢搭接接头连接的糊状胶粘剂粘层厚一致性控制较难、铅垂向成形可能不易等问题，将糊状胶粘剂换成胶膜，并对该胶膜连接的 CFRP 板/钢搭接接头进行了破坏模式、有效黏结长度、传力规律、黏结-滑移本构、承载力等的试验研究，试验制作了胶膜连接的 5 种粘结长度共 15 个 CFRP 板/钢双搭接接头试件。结果表明：所用胶膜的连接强度高于 CFRP 板层间强度（即碳纤维与树脂基体的粘聚强度）；常温下，所用胶膜连接的 CFRP 板/钢搭接接头有效黏结长度约为 80 mm；加载初期，剪应力最大值位于接头钢板端；继续加载，其位置向接头 CFRP 板端移动；加载末期，其位置位于距接头钢板端 20mm（L≤80mm）或者 50mm（L≥120mm）处；胶粘剂连接的 CFRP 板/钢搭接接头界面黏结-滑移本构为近似三角形，而胶膜连接的 CFRP 板/钢搭接接头界面黏结-滑移模型为近似梯形，胶膜连接接头的延性大为提升；所用胶膜连接接头界面峰值剪应力、断裂能、界面刚度等代表值（可视为准平均值）分别为四种典型商品胶粘剂连接接头的 1.2~3.0 倍、1.6~5.7 倍和 5.4~7.5 倍；在黏结长度不小于有效黏结长度条件下，所用胶膜连接接头的抗拉承载力代表值为四种典型商品胶粘剂连接接头的 1.38~4.25 倍；胶膜连接接头的抗拉承载力、最大位移的变异系数与糊状胶粘剂连接接头相差不大。

关键词：胶膜；CFRP 板；有效黏结长度；双搭接接头；破坏模式；黏结-滑移本构

Performance Test of CFRP Laminate/Steel Lap Joint with Film Adhesive Connection

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（Changsha University of Science and Technology）

Abstract:

In order to solve the problems of difficult uniformity control of paste adhesive thickness and possibly difficult vertical forming of CFRP laminate/steel lap joints, paste adhesive was replaced by film adhesive. The experimental study on failure modes, effective bonding length, force transfer law, bond-slip constitution and bearing capacity of CFRP laminate/steel lap joint with connection of the film adhesive were carried out, and a total of 15 CFRP laminate/steel double lap joint specimens with 5 kinds of bonding lengths after connection of film adhesive were made. The results show that the bonding strength of the film adhesive used is higher than interlaminar strength of the CFRP laminates (i.e. the bonding strength between carbon fibers and resin matrix).The effective bonding length of the CFRP laminate/steel lap joint jointed by the film adhesive at room temperature is about 80 mm.At the beginning of loading, the maximum shear stress is located at the end of the joint steel plate.Its position moves towards the end of the joint CPRP laminate when the loading continues.At the end of loading, its position is located at 20 mm when L is less than 80 mm or 50 mm when L is

greater than 120 mm) from the end of the joint steel plate.The bond-slip constitutive of CFRP laminate/steel lap joint bonded by adhesives is approximate triangle, while the bond-slip model of CFRP laminate/steel lap joint bonded by film adhesive is similar trapezoid, and the ductility of the joint connected by film adhesive is greatly improved.The representative values of peak shear stress, fracture energy and interfacial stiffness of the joint connected by film adhesive ,which can be regarded as quasi mean value,were 1.2-3.0 times,1.6-5.7 times and 5.4-7.5 times of those of four typical commercial adhesives, respectively.The representative value of tensile strength of the joint connected by film adhesive are 1.38-4.25 times for joints connected by four typical commercial adhesives when the bonding length is not less than the effective bonding length.The variation coefficients of tensile strength and maximum displacement of joint connected by film adhesive are little difference with those of joints connected by paste adhesives..

keywords:film adhesive; CFRP laminate; effective bonding length; double lap joint; failure mode; bond-slip constitutive

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高温对 CFRP 板/钢界面力学性能的影响

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摘　要：针对结构加固常用胶粘剂耐高温性能差的现象，采用一种新型高强度胶粘剂-环氧载体胶膜，运用动态热机械分析法获得了胶膜的动态力学性能温度谱，制作了 9 个 CFRP 板/钢双搭接接头试件，分别在三个不同环境温度下进行拉伸，并对试件的破坏模式、承载力、传力规律等进行了研究。结果表明：胶膜的玻璃转化温度为 69.5℃，在玻璃转化温度附近，胶膜的储能模量会数量级下降；温度为 40℃、55℃时，试件的破坏模式为 CFRP 板层离，温度为 70℃时，破坏模式为钢/胶层界面破坏与 CFRP 板层离，温度达到胶膜玻璃转化温度时，胶膜与钢板的黏结强度明显降低；试件的极限承载力随温度升高而降低，70℃试件极限承载力相对 40℃下降 8.4%；温度越高，试件的有效黏结长度越长，150kN 时，三个温度下试件的有效传力长度分别约为 115mm、135mm、175mm，实际工程加固时应根据环境温度选择合适的 CFRP 黏结长度；加载过程中，峰值剪应力逐渐向接头 CFRP 板端移动，在同等荷载作用下（如 150kN），环境温度越高试件的界面峰值剪应力位置距钢板端的距离越远，界面剥离程度越大。

关键词：胶膜；高温；双搭接接头；玻璃转化温度；有效黏结长度

Effect of High Temperature on Mechanical Properties of Interface Between CFRP Laminate and Steel

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Abstract:

In view of the poor high temperature resistance of common adhesives for structural reinforcement, a new type of high strength adhesive-epoxy carrier film adhesive was used. Temperature spectrum of dynamic mechanical properties of the film adhesive were obtained by dynamic thermomechanical analysis. Nine CFRP laminate/steel double lap joint specimens were fabricated and stretched at three different ambient temperature. The failure modes, bearing capacity and force transfer rule of the specimens were also studied. The results show that the glass transition temperature of the film adhesive is 69.5℃, and the storage modulus of the film adhesive decreases by orders of magnitude near the glass transition temperature. The failure mode of the specimens are CFRP delamination at 40℃and 55℃. At 70℃, the failure modes are steel/adhesive interface debonding and CFRP delamination. When the temperature reaches the glass transition temperature of the film adhesive, the bond strength of the film adhesive decreases obviously. The ultimate bearing capacity of specimens decreases with the increase of temperature. The ultimate bearing capacity of specimens at 70℃ decreases by 8.4% compared with that at 40℃. The higher the temperature is, the longer effective bond length of specimens is. At 150 kN, the effective force

transfer length of the specimens at three temperature are about 115 mm, 135 mm and 175 mm, respectively. The appropriate bond length of CFRP should be selected according to the ambient temperature in actual engineering reinforcement. During the loading process, the peak shear stress gradually moves to the end of CFRP laminate. Under the same load (e.g. 150 kN), the higher the ambient temperature is, the farther the distance between the peak shear stress and the end of steel plate is, the greater the degree of interface debonding is..

keywords:film adhesive; high temperature; double lap joint; glass transition temperature; effective bond length

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预应力 UHPC 箱梁隔板连通式齿块局压性能试验研究

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（长沙理工大学）

摘　要：为获得密集横隔板 UHPC 箱梁“隔板连通式齿块”锚固区的局部承压性能及受力特征，以某拟建 UHPC 箱梁桥为工程背景，通过大吨位张拉试验及非线性有限元模型对 UHPC 箱梁锚固区进行了精细化受力分析，得到了以下结论：锚固区拉伸开裂应力所对应的材料拉伸强度类型为直接拉伸强度，结合 UHPC 材料的拉伸应变硬化特征，锚固区受力状态宜采用直接拉伸应变值进行表征。“隔板连通式齿块”中“局部弯曲效应”和“径向力效应”均不显著，但“劈裂力效应”和“隔板弯曲效应”较为明显且为导致“隔板连通式齿块”承载失效的重要因素。背景工程中尺寸小巧的“隔板连通式齿块”张拉到 4700kN 时无开裂风险，采用 25 束钢绞线锚固同样能满足结构的承载能力要求，可在实际工程中广泛采纳。UHPC 锚固区拉应变值即便进入到了 UHPC 的拉伸应变硬化阶段仍能正常使用，为建造经济化在设计中应充分利用 UHPC 的拉伸应变硬化特征。

关键词：桥梁工程；UHPC 薄壁箱梁；齿块锚固区；局部作用效应；足尺张拉试验

Experimental Study on Local Compressive Performance for the Diaphragm-Anchor Block Integrated Anchorage System of the Prestressed UHPC Box Girder

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Abstract:

In order to obtain the mechanical behavior and local bearing capacity of the anchorage zone of the diaphragm－anchor block integrated anchorage system (DABIAS) in the UHPC continuous box-girder with densely distributed diaphragms, the mechanical behavior analysis of the anchorage zone of UHPC box-girder was carried out in detail by a large-tonnage tension test and an non-linear finite element method, taking a newly built UHPC box-girder bridge as the engineering background. The conclusions were as follows: The types of the material tensile strength corresponding to the tensile cracking stress of the anchorage zone is the direct tensile strength. Combined with the tensile strain-hardening characteristic of UHPC, the stress state of the anchorage zone should be characterized by the direct tensile strain value. The local bending effect and radial-force effect of the DABIAS are not obvious, but the bursting-force effect and diaphragm-bending effect are obvious, and it is a major factor to lead to the failure for the anchorage zone. When the load was stretched to 4700 kN, there is no risk of cracking for the small-sized anchor block of the DABIAS in the engineering background. Similarly, the prestressing tendon with 25 steel strands can meet the bearing capacity of the structure well. It can be widely adopted in the actual engineering. The UHPC anchorage zone can be used in normal even when the tensile strains of UHPC material enter the

strain-hardening domain. Thus, in order to reduce the project cast, the strain-hardening characteristic of UHPC should be fully utilized in design..

keywords:bridge engineering; UHPC thin-walled box girder; tooth block anchorage zone; local action effect; full scale experiment experiment

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弯梁桥销轴支座的设计与分析

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摘　要：弯梁桥由于其特殊的形状要求，使其受力特征不同于普通直梁桥，对支撑体系的要求更高，并且在温度荷载作用下容易产生较大支座反力。为了减少弯梁在温度荷载作用下的水平反力，本文将支座和销轴组合形成一种新型弯梁桥约束体系——销轴支座。利用 ANSYS 有限元软件，研究了弯梁桥在整体升降温、横向温度梯度作用下，普通支座和销轴支座两种不同支承形式下的支反力。通过计算分析对比发现，销轴支座能有效的减少弯梁温度荷载作用下的支座反力。

关键词：弯梁桥；支座设计；销轴支座

Design and Analysis of Curved Beam Bridge Pin Bearing

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Abstract:

Abstract: Due to the special shape, the force characteristics of curved beam bridges are different from ordinary straight beam bridges, which have higher requirements on the supporting system and tend to generate larger bearing reaction forces under temperature load. In order to reduce the horizontal reaction force of the curved beam bridge under the temperature load, this paper combines the support and pin to form a new type of constraint system － pin and axle bearing. In this paper, ANSYS finite element software is used to study the supporting reaction of the general support and pin bearing of the curved girder bridge under the action of the overall temperature gradient and transverse temperature gradient. Through calculation analysis and comparison, it is found that the pin bearing can effectively reduce the reaction force of the bearing under the temperature load..

keywords:curved girder bridge; bearing design; pin and axle bearing

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梁桥倾覆机理、破坏模式与计算方法研究

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摘　要：本文在系统调研多座独柱墩梁桥倒塌现场的基础上，提出梁桥倾覆的 3 个阶段和 3 种可能的破坏模式，得出梁桥抗倾覆包括变形体转动、自重和刚体转动三部分，并在对现有倾覆计算方法进行分类的基础上，建立了与破坏模式相适应的倾覆计算方法。以浙江上虞春晖桥、哈尔滨三环路鸿福路段和赣粤高速河源出口匝道桥为算例，综合比较各种倾覆计算方法的适用性和准确性。研究结果表明，首先，横向转动到一定角度滑动是梁桥倾覆的主要破坏模式，尤其是对于半径小于一定程度的曲线梁桥；其次，2018 版公路钢筋混凝土及预应力混凝土桥涵设计规范中新提出的倾覆计算方法本质上是基于变形体转动，未考虑刚体转动和自重的有利影响，可较保守的计算梁桥倾覆承载力；第三，自重通过箱梁线型或支座尺寸参与抗倾覆，考虑支座尺寸影响的变形体转动倾覆承载力计算结果更接近于实际倾覆荷载；最后，综合考虑变形体转动、自重和刚体转动的几何非线性有限元模型可以较好的模拟独柱墩梁桥倾覆极限承载力。

关键词：破坏模式；计算方法；独柱墩梁桥；倾覆过程

Research on the Overturning Failure Mode of Girder Bridges and Applicability of Calculation Methods

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Abstract:

Basing on the systematic investigation of the collapsed wreckage of several single-column pier beam bridges, this paper proposes three stages and three possible failure modes of overturning and concludes that the anti-overturning of girder bridge includes deformable-body rotation, self-weight and rigid-body rotation. Moreover, the overturning calculation method suitable for the failure mode is established by classifying the existing overturning calculation methods. To comprehensively compare the applicability and accuracy of those methods, calculations are executed in three bridges (the Chunhui Bridge in Zhejiang Shangyu, the bridge in Hongfu section in Harbin and the ramp bridge of Ganyue Expressway).The result shows that, first of all, transverse rotation to a certain angle is the main failure mode of overturning, especially for curved girder bridges with a radius less than a certain degree; Second, the new calculation method proposed in JTG 3362-2018 is rested on deformable-body rotation essentially, which can calculate the overturning capacity of girder bridge conservatively without considering the positive effects of self-weight and rigid-body rotation; Third, self-weight resists overturning by the line type of box girder or the size of bearing. The calculation results of ultimate capacity are closer to the actual overturning load considering deformable-body and self-weight. Finally, geometric nonlinear finite element model considering the three parts of

overturning is the best way to calculate the ultimate capacity..

keywords: Failure mode; Calculation method; Single-column pier bridge; Overturning Process

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基于大型剪切试验的桩侧阻力探究

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摘　要：为探明不受桩端等因素影响的桩侧阻力，通过大型剪切试验，着重研究了桩基础侧面土体深度以及黏性土含水率变化对桩侧阻力的影响规律并采用积分法计算了桩侧阻力。结果表明，当桩基础侧面土体深度超过一定值时，若黏性土处于坚硬状态，则黏性土含水率变化将基本不会影响桩侧阻力的大小；当黏性土含水率略小于塑限时，含水率的减小将不再影响桩侧阻力，据此可以得出合理含水率；通过大型剪切试验并按积分法分段对桩侧阻力进行计算，分析本文计算方法与规范中经验公式法产生差异的原因，以期为桩侧阻力计算提供新思路。

关键词：桩基础；桩侧摩阻力；大型剪切试验；积分法；经验公式法

Research on the Pile Side Resistance Based on Large Shear Test

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Abstract:

In order to find out the pile side resistance which is not affected by the pile end and other factors, through the large shear test, the influence law of the soil depth on the side of the pile foundation and the change of the moisture content of the viscous soil on the pile side resistance is studied emphatically, and the pile side resistance is calculated by the integral method. The results show that when the soil depth of the pile exceeds a certain value, if the viscous soil is in a hard state, the change of the moisture content about the viscous soil will not affect the pile side resistance. When the moisture content of viscous soil is slightly less than the plastic time limit, the decrease of water content will no longer affect the pile side resistance, according to which the reasonable water content can be obtained. Based on the large shear test and integral method, the pile side resistance was calculated. This paper analyzes the reasons for the difference between the calculation method and the empirical formula method in the specification, in order to provide a new idea for the calculation of pile side resistance..

keywords:pile; pile side resistance; large shear test; integration method; empirical formula method

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Buckling Analysis of a Long Span Steel Cable-Stayed Bridge

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Abstract: Buckling has always been one of the key problems in cable-stayed bridge design. For long span steel cable-stayed bridges, the main girder and the tower both have thin-wall sections, so the overall and local buckling stability of the structure will be more prominent. Based on a 500m steel cable-stayed bridge, buckling analysis of the structure is conducted in this paper. The buckling coefficient and instability mode for different load combinations are obtained. The process of instability failure is also obtained through elastoplastic analysis as supplement. At last, the relationship between buckling and structural ultimate capacity is discussed..

keywords:buckling analysis; steel bridge; instability failure; ultimate capacity

滞后应变对 RC 压弯结构套箍加固后极限承载力的影响研究

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摘　要：为探究 RC 压弯结构在“服役—加固—再服役”过程中的滞后应变对其加固后极限承载力的负面影响，分析了滞后应变影响下 RC 偏压柱在套箍加固后可能存在的破坏模式，并在考虑混凝土材料非线性与滞后应变条件下计算了一套箍加固 RC 柱极限承载力 M-N 关系曲线。对比分析结果显示，在小偏心先期恒载工况下，出现了原结构先于加固层到达极限的破坏模式，同时截面极限弯矩最大减少了 14.5%，极限轴力减少了 3.9%；在大偏心先期恒载工况下，截面除出现原结构先于加固层破坏的情况，还会出现加固层混凝土压溃时，原截面应力水平反而降低的情况。

关键词：滞后应变；偏心柱；加固；极限承载力；M-N 关系

Study on the Influence of Hysteresis Strain on Ultimate Bearing Capacity of Eccentric RC Column Strengthened with Stirrup

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（Chongqing Jiaotong University）

Abstract:

To explore the negative impact of hysteresis strain,which happened in the process of "service-strengthening-service", on ultimate bearing capacity of strengthened eccentric RC column, the failure mode of the eccentric RC column after the ferrule reinforcement under the influence of hysteresis strain is analyzed,and the MN curve of a ferrule -reinforced RC columns is calculated considering the material nonlinearity of concrete and hysteresis strain. The analysis results show that under the condition of small eccentricity of initial dead load, the failure mode of the original structure before the reinforcement layer appeared, while the ultimate bending moment of the strengthened section is reduced by 14.5% and the ultimate axial force is reduced by 3.9%; Under the condition of great eccentricity of initial dead load,in addition to he failure mode of small eccentricity, there is also a case where the stress level of the original section is lowered when the concrete of the reinforcement layer is crushed..

keywords:hysteresis strain；eccentric RC column；reinforcement；Ultimate bearing capacity；M-N relationship

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拉索钢丝电化学腐蚀进程的元胞自动机模拟方法

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摘　要：为了模拟拉索在实际环境中的腐蚀演化进程并探究氯离子在腐蚀过程中对腐蚀产生的影响，基于金属电化学腐蚀的基本原理建立了模拟拉索钢丝电化学腐蚀进程的元胞自动机模型，将腐蚀系统中的关键元素抽象成 4 种元胞类型，并将整个拉索腐蚀系统离散成 500×500 的元胞网格，通过定义的局部规则模拟钢丝在介观尺度上的腐蚀演化过程，分析了腐蚀性溶液浓度和腐蚀概率对钢丝腐蚀进程的影响，研究发现：当元胞自动机特征参数选取合理，并适当加大中心元胞与切线方向上的邻居元胞的接触概率，蚀坑形貌也就越接近真实形貌。元胞自动机模拟产生的蚀坑形貌与实际蚀坑形貌十分接近；钢丝腐蚀面积随时间不断变大的同时腐蚀速率也将逐步增快，表明一旦钢丝腐蚀出现蚀坑，钢丝腐蚀面积越来越大的同时其腐蚀速率也将越来越快；在拉索腐蚀的过程中具有氯离子的腐蚀性元胞具有主导地位，无氯离子的腐蚀元胞的腐蚀概率对钢丝腐蚀速率的影响不大，控制并减少周边环境中氯离子的浓度是减缓拉索腐蚀的有效途径。

关键词：拉索；腐蚀；元胞自动机；氯离子；蚀坑

Simulation on the Evolution Process of Cable Electrochemical Corrosion Based on Cellular Automata

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Abstract:

In order to simulate the corrosion evolution process of the cable in the actual environment and explore the influence of chloride ion on the corrosion process, a cellular automaton model for simulating the electrochemical corrosion process of the cable was established based on the basic principle of metal electrochemical corrosion. The entire cable corrosion system, key elements of which were idealized as four cell types, was discretized into a 500×500 cell grid, and its corrosion evolution process was simulated on the mesoscopic scale by the defined local rules. The effects of corrosive solution concentration and corrosion probability on the corrosion process of steel wire were analyzed. It has been found that if the characteristic parameters of cellular automata are selected reasonably, the morphology of the crater generated by cellular automata simulation is similar to actual etch pit morphology. It is also discovered that the pitting area and corrosion rate of the steel wire increases gradually with time. The corrosive cell with chloride ions has a significant effect on the process of cable corrosion, but the corrosion of corroded cells without chloride ions has little effect on the corrosion rate of the wire, which indicates that reducing the concentration of chloride ions in the surrounding environment is an effective way to mitigate corrosion cable..

keywords:stayed cable; corrosion; cellular automata; chloride ion; corrosion pit

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Global Trade and the Maritime Transport Revolution

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Abstract: What is the role of transport improvements in globalization?We argue that the nineteenth century is the ideal testing ground: maritime freight rates fell on average by 50% while global trade increased 400% from 1870 to 1913. We estimate the first indices of bilateral freight rates and directly incorporate these into a standard gravity model. We also take the endogeneity of bilateral trade and freight rates seriously and propose an instrumental variables approach. The results are striking: we find no evidence that the maritime transport revolution was the primary driver of the late-nineteenth-century global trade boom.

Key words: TRANSPORT REVOLUTION

装配式宽幅连续箱梁桥剪力滞效应研究

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摘　要：为系统研究装配式宽幅连续箱梁桥成桥后的剪力滞效应，本文从装配式宽幅连续箱梁桥剪力滞分布规律、不同宽跨比、不同湿接缝宽度及不同配筋形式对剪力滞效应的影响四个方面出发，通过建立实体有限元模型和理论分析进行研究。模型依托一座三跨一联连续箱梁桥，通过改变上述影响参数进行研究。通过数据分析得到装配式宽幅连续箱梁桥的剪力滞分布规律、随湿接缝的变化规律、宽跨比的变化规律及不同配筋方式对剪力滞效应的影响。通过上述研究，得出的结论可以为该类桥型提出较为系统、实用的关于剪力滞的设计建议。

关键词：装配式宽幅连续箱梁；剪力滞效应；实体有限元分析；湿接缝；宽跨比；截面配筋

Research on Shear Lag Effect of Assembling Wide Continuous Box Girder Bridge

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Abstract:

In order to systematically study the shear lag effect of assembled wide continuous box girder bridge after completion,this paper studies the shear lag effect of assembled wide continuous box girder bridges through the establishment of solid finite element model and theoretical analysis from four aspects: distribution law of shear lag, different width-span ratio, different wet joint width and different reinforcement forms. The model relies on a three-span and one-link continuous box girder bridge to study by changing the aforementioned influencing parameters. Through data analysis, the distribution of shear lag, the variation of wet joints, the variation of width-span ratio and the influence of different reinforcement methods on shear lag effect of assembled wide continuous box girder bridge are obtained. Through the above research, the conclusion can provide more systematic and practical design suggestions on shear lag for this type of bridge..

keywords:assembled wide continuous Box Girder; shear lag effect; Solid finite element analysis; Wet joint; Wide span ratio; section reinforcement

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Study on Limit Value of Width-Thickness Ratio of Thin-Walled Box Concrete Arch Ring

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Abstract: The limit value of width-thickness ratio of thin-walled box concrete arch bridge is derived with the elastic plate theory and the equivalent-strut theory of arch, and a new approach of determining the sectional form on the basis of the limit of width-thickness ratio is put forward. The theoretical results are verified by six existing box concrete arch bridges. Results show that local buckling occurs when the width-thickness ratio of Mu Peng large bridge is smaller than the limit value deduced in this paper, in addition, the sectional forms of the six existing box concrete arch bridges with this new approach are consistent with their actual forms. The limit value of width-thickness ratio deduced in this paper is reasonable and this new approach of determining sectional form is simple and rational to apply in engineering..

Key words: Box section of concrete arch bridge; Local bucking; The theory of elastic and thin plate; The theory of equivalent strut; The limit of width-thickness ratio

高墩大跨连续刚构桥施工及运营期安全风险评估

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摘　要：本文根据《公路桥梁和隧道工程设计安全风险评估指南（试行）》提供的方法，按照结构分析、风险源辨识、风险估测、评估结果的流程，对宜宾至昭通高速公路彝良至昭通段的高墩大跨连续刚构桥——牛街特大桥进行了安全风险评估，并根据评估结果，针对主要风险源提出应对措施，为施工图设计、桥梁施工及后期管养提供参考。

关键词：连续刚构桥；初步设计；安全风险评估

Safety Risk Assessment of High Pier and Long Span Continuous Rigid Frame Bridge in Construction and Operation Period

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Abstract:

According to the method provided in the "Guidelines for Safety Risk Assessment of Highway Bridge and Tunnel Engineering Design (Trial Implementation)", according to the flow of structural analysis, risk source identification, risk assessment and evaluation results, the safety risk assessment of Niujie Bridge, a long-span continuous rigid frame bridge with high piers in Yiliang-Zhaotong section of Yibin-Zhaotong Expressway, is carried out. The Countermeasures of risk sources are put forward to provide reference for construction drawing design, bridge construction and later management and maintenance..

keywords:continuous rigid frame bridge; preliminary design; risk assessment

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多跨连续钢箱拱桥拱脚关键位置疲劳性能分析

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摘　要：疲劳是钢结构耐久性的重要影响因素，由于钢结构设计不合理等众多因素，会导致钢结构出现疲劳裂纹，随着行车荷载的不断作用，裂纹发展成裂缝，从而影响桥梁的正常使用。本文通过 ansys 有限混合单元法构建全桥模型，对多跨连续钢箱拱桥拱脚节点进行疲劳性能分析，通过影响线加载拟选用 7 个关键部位，依据结构的构造细节和应力幅Δσ确定关键节点疲劳寿命，分析关键高应力区关键位置疲劳寿命，验收构造设计合理性，为同类桥梁疲劳损伤分析和计算提供指导。

关键词：多跨拱桥；拱脚节点；疲劳；使用寿命；混合单元

Fatigue Performance Analysis of Key Positions of Arch Foot of Multi-Span Steel Arch Bridge

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Abstract:

Fatigue is an important factor affecting the durability of steel structures. Many factors, such as unreasonable design of steel structures, will lead to fatigue cracks in steel structures,thus affecting the normal use of bridges. In this paper, the full bridge model is constructed by ANSYS finite mixed element method, and the fatigue performance of arch foot joints of multi-span continuous steel box arch bridge is analyzed. Seven key parts are selected through influence line loading. The fatigue life of key joints is determined according to structural details and stress amplitude_. The fatigue life of key high stress areas is analyzed, and the rationality of acceptance structure design is checked. The analysis and calculation of labor damage provide guidance..

keywords:multi-span　arch bridge; arch foot; fatigue; life prediction; mixed　element

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考虑徐变恢复的混凝土徐变效应分析

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摘　要：为了解决准确计算混凝土在复杂变化应力作用下的徐变计算问题，首先采用符合工程实际的徐变恢复模型修正在简单应力作用下弹性老化理论计算值；其次，推广到复杂阶梯应力作用下徐变计算中；再次，应用到连续变化应力的徐变计算中，提出统一的徐变计算数学表达式；最后，引入徐变及徐变恢复稳定系数，提高徐变计算效率，对多种典型应力历史进行徐变计算对比。结果表明：应力递增时，修正弹性老化理论与弹性老化理论徐变理论计算值相同；应力递减时，两种方法差异理论计算值逐渐增大，700d 徐变理论计算值差异可达 84%；两种方法差异和应力历史有关，其差异由小到大分别为递增应力、波动应力、递减应力历史；修正弹性老化理论细致考虑递减应力下的徐变恢复效应，为混凝土徐变计算提供了较为准确的计算模式。

关键词：桥梁工程；徐变；弹性徐变理论；双函数法；变化应力；徐变恢复

Creep Effect Analysis of Considering Creep Recovery

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Abstract:

In order to solve the problem of accurately calculating the creep of concrete under complex varying stress，firstly, the creep recovery in accordance with the engineering practice is used to modify the theoretical value of elastic aging theory under simple stress history; Secondly, the modify method is extended to the creep calculation of complex stepped stress history; Thirdly, it is applied to creep calculation of continuous varying stress history and a unified mathematical expression is proposed for creep calculation under continuous stress history; Finally, the stability factor of creep and creep recovery is introduced to improve the creep calculation efficiency, and the theoretical calculation and comparative analysis of creep strain for various typical stress histories are carried out. The results indicate that the modified elastic aging theory is the same as the theoretical creep strain value of elastic aging theory；the different between the two methods is gradually increased，and the difference of creep theoretical calculated values in 700d is up to 84%. The difference between the two methods is related to the stress history, and the difference is from small to large, which is increasing stress history, fluctuating stress history, decreasing stress history. The modified elastic aging theory carefully considers the creep recovery effect under decreasing stress, and provides a more accurate calculation mode for concrete creep calculation..

keywords:bridge engineering; creep; elastic creep theory; two function method; varying stress; creep recovery

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USE ABC-PBS Concept in Design and Construction of Cow Camp Road Bridge over Rosalie Canal

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Abstract: As one of the renovation ideas based on the Accelerated Bridge Construction (ABC), GRS-IBS has been applied to many bridge constructions. Because of the system' s lower cost, short construction time, and smooth transition from roadway pavement to bridge and resistance to the seismic vibrations, it is widely applied in single span bridge design and construction. This paper addressed some new practices in the Florida Department of Transportation: 1) integral diaphragm design, analysis and construction; 2) elimination of traditional bearing pads from gird bridge and integrated the end diaphragm with Florida-I beams; 3) no expansion joint introduced at roadway surface. Therefore, the bridge is designed for 75-year service maintenance free.

Key words: Accelerated Bridge Construction; Integral diaphragm design; No expansion joint; Road bridges

基于 WIM 数据的不同车辆轴限下桥梁加固费用研究

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摘　要：摘要：超载车辆过桥会造成桥梁结构损伤，对过桥车辆进行限载可以有效地提高其服役年限，进而减少其维修加固费用。为了确定不同车辆轴限水平下，车辆对桥梁造成的累积损伤，并评估桥梁的维修加固费用，根据 WIM 数据统计得到各车型轴重数据，基于总重不变原则，提出车辆轴重重分配方法，基于此方法得到不同限载水平下的车辆轴重数据并计算得到车辆总重，利用双峰正态函数拟合得到总重分布函数。基于车辆总重分布函数，计算典型桥梁在不同限载水平下的疲劳损伤度，进而分析不同限载值对桥梁养护成本的影响。结合实例分析验证该方法的可行性，得到限载值与桥梁养护成本关系曲线，所得结论可为限载标准的制定提供参考。

关键词：桥梁限载；车重分布；轴重重分配；养护成本

Study on the Cost of Bridge Maintenance Under Different Axle Load Limits Based on WIM Data

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Abstract:

Abstract: Overweight vehicles will cause damage to the bridge structure. Therefore, limiting the vehicle load on the bridge can effectively improve its service life and reduce its maintenance and reinforcement costs. In order to determine the cumulative damage caused by the vehicles and the maintenance and reinforcement costs of the bridge under different load-limiting levels, a new kind of axle load redistribution method under different axle load limits was proposed based on the WIM data and the principle of weight invariance. Based on the method, axle load of each vehicle under different axle load limits was obtained and the vehicle weight was calculated. Afterwards, the distribution function of vehicle weight was obtained by fitting the bimodal normal function. On the basis of the vehicle weight distribution function, the fatigue damage degree of typical bridges under different axle load limits was calculated, and then the influence of different axle load limits on the maintenance cost of bridges was analyzed. Combined with the case analysis, the feasibility of the method was verified, and the relationship between the axle load limits and the bridge maintenance cost was obtained. The conclusions can provide reference for the load-limiting specification..

keywords:vehicle weight limit on bridge; vehicle weight distribution; axis weight redistribution; maintenance cost

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空间缆索悬索桥不同吊装顺序主缆横向顶撑研究

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摘　要：针对空间缆索悬索桥空缆与成桥状态横向线形差别大，施工过程中吊索易弯折，不同施工方案缆索系统及横向撑杆内力和变形复杂的问题，以重庆宝塔坪特大桥为背景，通过对不同施工方案缆索系统及撑杆内力和变形的分析，揭示了不同施工方案对主缆偏位、吊索偏角、撑杆内力的影响规律。研究结果表明：顶撑点越多，顶撑完成时主缆横向线形与理想线形差异越小，吊索横向偏角也越小，吊索越容易安装；施工过程中，吊索横向偏角对吊装顺序不敏感，除空缆状态外，吊索横向偏角最大值均出现在顶撑完成时；同种吊装方案、不同顶撑方案下，顶撑点越少，撑杆所受到的压力越大。

关键词：横向顶撑

Research on Spatial Cable Suspension Bridge for Different Lifting Sequences and Different Lateral Jacking Method

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Abstract:

The spatial cable suspension bridge has a large lateral deviation between the free cable state and the finished bridge state,The sling is easy to bend during the construction process, and the internal force and deformation of the cable system and the lateral support of the main cable are complicated in different construction schemes.In response to the above problems,Chongqing Baotaping Bridge was selected as the engineering background.Through the analysis of internal forces and deformations of cable systems and struts by different construction schemes,it reveals the influence of different lifting sequence and different top support schemes on main cable deviation, sling angle and internal force of strut. The results show that the more supporting points, the smaller the difference between the transverse line shape and the ideal line shape of the main cable when the top support is completed, the smaller the lateral angle of the sling, the easier the sling is installed. During the construction process, the lateral drift angle of the sling is not sensitive to the lifting sequence. Except for the state of empty cable, the maximum lateral drift angle of the sling occurs when the struts are completed; Under the same hoisting scheme, the lower the top support point, the greater the pressure on the brace..

keywords:lateral support

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TMD Parameters Research for Nonlinear Vibration Control

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Abstract: The effect of Tuned Mass Damper (TMD) parameters on the control of suspended structures under in-plane swing motion mode is studied in this paper. Analysis shows that the principles of TMD control and vibration based monitoring by accelerometer for in-plane swing motion mode are unified. At first, simplified calculation models of suspended structures with TMD are developed in different installation conditions. Results show that only the normal TMD is valid in control of in-plane swing motion mode of suspended structures. Then, the simplified calculation model of the suspended structure with accelerometer is developed to analyse in-plane swing motion mode monitoring. The model is similar with that of the suspended structures with TMD. As a result, the phenomenon of tangential accelerometer and inclinometer data are zero can be explained. Moreover, a vibration based state monitoring method based on normal acceleration data is proposed. At last, the experiment is carried out to measure in-plane swing motion mode of suspended structures using inclinometer and accelerometer. It verifies the aforementioned theoretical and numerical analysis of control of in-plane swing motion mode of suspended structures with TMD.

Key words:vibration control and monitoring; tuned mass damper (TMD); non-linear numerical analysis; in-plane swing motion mode

人行玻璃悬索桥施工过程分析及索鞍顶推方案研究

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摘　要：以辽宁凤凰山玻璃悬索桥为工程背景，采用Midas软件进行了缆索找形，建立了成桥状态的有限元模型，然后在其基础上，根据施工过程进行了倒装分析，得到了空缆状态下的主缆内力和线形，为施工过程的主缆放样提供依据；以空缆线形为基础，重新进行了正装分析，对施工过程中的索鞍偏移量进行了计算，给出了索鞍分阶段顶推的施工顺序和有限元模拟方法，以期对类似结构的施工阶段计算提供参考。

关键词：悬索桥；人行桥；施工过程；索鞍偏移量

Analysis of Construction Process of Pedestrian Glass Suspension Bridge and Research on Cable Saddle Pushing Scheme

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Abstract:

Taking phoenix Glass Suspension Bridge of Liaoning Province as the engineering background, the Midas software was used to find the cable shape, and the finite element model of the bridge state was established. Then, based on the construction process, the flip-chip analysis was carried out according to the construction process, and the cable was obtained. The internal force and linear shape of the main cable provide the basis for the main cable lofting during the construction process; based on suspender shape, the formal analysis is re-executed, and the saddle offset during the construction process is calculated. The construction sequence of the pushing of the saddle and the finite element simulation method are used to provide reference for the calculation of the construction phase of similar structures..

keywords:suspension bridge; pedestrian bridge; construction process; the offset of the cable saddle

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考虑锚箱加劲板构造设计的吊索张拉方案研究

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摘　要：自锚式悬索桥在索股锚固端设置强大的加劲板以改善局部受力状况，由于悬索桥主缆有强烈的几何非线性，在吊索张拉过程中，散索套竖向位置发生较大的变化，为避免在实际施工中，索股与加劲板发生位置冲突，造成索股的损坏，结合某实际工程，分析在吊索张拉过程中索股与锚固段主缆的夹角变化，进行吊索张拉方案对优化。结果表明，在吊索张拉过程中，不同张拉方案夹角变化有较大的差别；施工过程中，应选取合理的吊索张拉方案，以避免出现施工事故。

关键词：自锚式悬索桥；吊索张拉；锚箱加劲板；索股冲突；优化

Study on Cable Tension Scheme Considering Structure Design of Anchor Box Stiffening Plate

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Abstract:

The self-anchored suspension bridge installs strong stiffening plate at the anchorage end of strand to improve the local stress condition. Because of the strong geometric nonlinearity of the main cable of the suspension bridge, the vertical position of the loose cable sleeve changes greatly during the tension of the suspension cable. In order to avoid the collision between the strand and the stiffening plate in the actual construction, the damage of the strand is caused by the collision between the strand and the stiffening plate. The angle between the strand and the main cable of the anchorage section is changed during the tension process, and the tension schemes of the sling are compared. The results show that the angle changes of different tensioning schemes are quite different in the process of suspension tension, and reasonable suspension tension schemes should be selected in the construction process to avoid construction accidents..

keywords: self-anchored suspension bridge;　sling tension;　anchor box stiffener;　cable strand conflict;　optimization

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大跨悬索桥加劲梁吊装过程中强静风安全性研究

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（西南交通大学）

摘　要：为了适应主缆线形剧烈变化，处于施工中的大跨悬索桥常采用临时连接件暂时连接梁段，如遇台风，临时连接件可能面临强度破坏，从而影响大跨悬索桥的施工安全。依托虎门二桥坭洲水道桥，采用梁单元模拟法对加劲梁吊装关键阶段进行模拟，分析临时连接件群刚度对应力的影响。合龙阶段分别采用提高临时连接件强度、在桥塔处采用柔性连接代替刚性连接等措施降低临时连接件应力，提高加劲梁吊装过程中安全性。通过有限元计算验证，这两种方法均可以有效削减应力峰值，降低临时连接件应力。

关键词：大跨度悬索桥；临时连接件；加劲梁吊装；静风安全性；梁单元模拟法

Study on Aerostatic Safety of Long-Span Suspension Bridge in process of Hoisting and Installation of Stiffening Girder

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Abstract:

Long-span suspension bridge in construction often use temporary connectors to link stiffening girder segments for purpose of accommodating sharp changes of main cable shape. While encountering typhoon, strength failures of temporary connectors may occur, thereby affecting construction safety of the bridge. Relying on the Nizhou Waterway Bridge of the Second Humen Bridge, beam simulating method is used to simulate the bridge during the process of hoisting and installation of stiffening girder, stiffness variation of temporary connectors group is applied to analyze the stress. Measures including increasing the stiffness of temporary connectors and using flexible connections instead of rigid connections are applied to reduce the stress and improve safety. These two measures are both verified by finite element analysis to be effective in reducing the stress and its peak..

keywords:long-span suspension bridge;　temporary connector;　stiffening girder hoisting and installation;　aerostatic safety;　beam simulating method

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空间缆悬索桥主缆横撑结构设置方案和受力特性研究

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摘　要：为研究空间缆索悬索桥施工中体系转换所需横撑数目，横撑在施工中受力变化，以及合理的吊梁顺序。以某地锚式空间缆索体系悬索桥为研究对象，以主缆吊点横向坐标差值为控制条件，推导所需横撑数目，并对比不同方案下主缆吊点的横向偏位与吊索安装偏角。并针对横撑合理设置方案，研究不同吊梁顺序时横撑受力变化，并调整施工阶段中横撑拆除时机，得到梁段吊装时吊索倾角与成桥倾角差值。结果表明，通过考虑吊点横向偏位和吊索安装偏角，可初步确定所需要横撑数目，吊梁顺序对横撑受力影响较大，在空间缆索悬索桥设计时要充分考虑到施工中横撑设计，本文可为同类型空间缆索悬索桥横撑设计提供参考。

关键词：空间缆索悬索桥；桥梁施工；横向顶撑；吊梁

Research on Setting Scheme and Mechanical Characteristic of Lateral Support of Suspension Bridge with Spatial Cable

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Abstract:

To analyze the number of lateral supports required for structural transform in the construction of suspension bridges with spatial cable, get force changes of lateral supports during construction and reasonable beam lifting order. Taking A suspension bridge with spatial cable as the background project, the transverse deviation of cable’s lifting point is taken to be control index to derive the number of lateral support needed. On the basis of reasonable setting of lateral supports, the variation of lateral support force during the whole process of beams hoisting is studied. Then the construction phase is adjusted based on the variation of force to obtain a reasonable construction procedure, so that the deviation of hangers’ inclination angle and transverse deviation of cable can be calculated. The result of background project shows that the requirements of deviation of hangers’ inclination angle and transverse deviation of cable can be used to estimate the number of lateral supports, the order of beams hoisting makes a difference to the force of lateral supports. Design of lateral supports should be taken into consideration adequately when a spatial cable suspension bridge is designed. The background project can be used as a reference for the design of similar bridge..

keywords:suspension bridge with spatial cable; bridge construction; lateral support; beam hoisting

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基于多自由度耦合系统的斜拉索自激共振机理研究

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摘　要：针对斜拉桥的自激共振问题，本文建立了斜拉桥索-梁-塔多自由度耦合系统，利用 MATLAB 平台的 Simulink 仿真模块，对多自由度系统的耦合共振模型进行了数值仿真分析。结果显示，当子系统的索、梁、塔固有振动频率比达到 1：2：1 时，耦合系统将发生共振现象。各自由度的初始扰动对其位移响应有轻微的激励作用，而梁的初始响应还将激励共振索产生剧烈振动，此时索和塔的位移曲线呈现明显的“拍频”耦合特性。当系统内多个子系统满足共振条件时，其耦合共振将加剧，加剧的耦合共振也呈现周期性，且具有鲜明的非线性关系。此外，本文还针对耦合非线性振动探究了减振途径。本文研究方法将传统数值分析与现代仿真模型软件相结合，模拟仿真其各自由度成桥状态下的非线性共振响应，为斜拉桥实践提供理论指导，以进一步保护桥梁的安全运营。

关键词：斜拉桥；自激共振；Simulink；耦合系统

Self-Excited Resonance Mechanism of Stay Cable Based on Multi-Degree-Of-Freedom Coupling System

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Abstract:

Aiming at the problem of self-excited resonance of cable-stayed bridge, this paper establishes the cable-beam-tower multi-degree-of-freedom coupling system, and makes numerical simulation analysis on the coupling resonance model of the multi-degree-of-freedom system by using Simulink simulation module of MATLAB platform. The results show that when the natural vibration frequency ratio of cable, beam and tower reaches 1:2:1, the coupling system will have resonance phenomenon. The initial disturbance of each degree of freedom has a slight excitation effect on its displacement response, while the initial response of the beam will also stimulate the resonant cable to produce violent vibration, at this time, the displacement curve of the cable and the tower presents an obvious "beat frequency" coupling characteristic. When multiple subsystems in the system satisfy the resonance condition, the coupling resonance will be intensified, and show periodicity, with a distinct nonlinear relationship. In addition, the method of vibration reduction for coupled nonlinear vibration is explored. The research method in this paper combines the traditional numerical analysis with the modern simulation model software to simulate the nonlinear resonance response under the state of the bridge with each degree of freedom, which provides theoretical guidance for the cable-stayed bridge practice and further protects the safe operation of the bridge.

keywords: Cable-stayed Bridges; Self-excited resonance; Simulink; coupled systems

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超宽混凝土箱梁足尺模型水化热温度场试验研究

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摘　要：超宽箱梁为大体积混凝土且结构复杂，施工水化热易引起温度裂缝。针对超宽箱梁开展了足尺模型水化热温度场试验研究，获得该类箱型结构施工阶段水化热温度场，并与有限元模拟结果分析比较。结果表明实测结果与理论计算值基本吻合；混凝土水化热温度时程曲线变化规律总体上相近，且约 180 小时后温度趋于一致；箱梁风嘴中心水化热温度最大峰值高达 75 ºC 左右，且高温持续时间长，应采取降温措施；忽略箱梁浇筑时间差异对水化热温度峰值大小影响较小。

关键词：超宽箱梁；大体积混凝土；水化热；温度测试

Study on the Full-scale Model Test of Hydration Heat Temperature Field of Concrete Box Girder with Super Wide Scale

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Abstract:

The box girder with super wide scale is large volume concrete and its structure is complex, and the the hydration heat during construction is easy to cause the temperature crack.Through the experimental research of hydration heat temperature field of its full-scale model, we obtained hydration heat temperature field distribution of the box type structure on construction stage which finite element simulation results are analyzed and compared with.The results show that the measured results are basically accordant with theoretical values; time history curve of hydration heat temperature of concrete is similar in general, hydration heat temperature peak of upwind surface of box girder is as high as 75 degrees,and high temperature time has a long duration,which should take measures to cool down;the time difference between the pouring time of box girder has little effect on the peak value of temperature which caused by hydration heat。.

keywords:box girder with super wide scale; mass concrete; hydration heat; temperature measurement

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Experimental Study on Torsional Behavior of Spatial Main Cable for a Self-Anchored Suspension Bridge

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Abstract: In order to understand the torsional behavior of the spatial main cable between two saddles for a self-anchored suspension bridge during the transition process from construction state to completed state, a scaled model (1:15) was prepared and tested. Firstly, the cable anchorage system and cable measurement device were designed. Then, a serie of model tests under different preloading angles and different tensioning forces were carried out. Finally, the regularity of the torsional properties and torsional effects were revealed on the basis of the measured twist angle of the cable section. The experimental study shows that the transverse pre-deflection angle of the cable clamp plays a decisive influence on the torsional angle of the main cable near the cable clamp, but at adjacent cable clamps, this influence can almost be negligible. The torsional angle changed linearly within adjacent clamps. When the angle of the inclination of the hanger is larger (smaller) than the pre-deflected angle of the cable clamp, the cable clamp will cause the main cable section to twist in the positive (reverse) direction. With the increase of the hanger force, the direction of hanger force passes through the cross-sectional center of the main cable, resulting in an unchanged twisting angle. The torsion angle of the main cable changes linearly with the pre-deflection angle of the cable clamp. In the design stage, the finite element software is used to analyze the parameters of the pre-deflection angle of the cable clamp to determine the reasonable pre-deflection angle of the cable clamp and effectively reduce the torsional deformation of the main cable section.

Key words: Spatial cable; Model test; Main cable; Self-anchored suspension bridge; Torsional property; Torsional effect

考虑初始几何缺陷的大跨径上承式钢管混凝土拱桥非线性稳定分析

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摘　要：钢管混凝土拱桥以钢管和内填混凝土材料协同受力，在充分满足结构抗压强度的同时大大节省了混凝土材料的使用。由于其施工方便，施工时间短，能够极大程度上提高了桥梁的跨越能力，因此在山区桥梁结构中的得到广泛推广。但是随着大跨度钢管混凝土的跨径不断增大，拱桥稳定性问题显得尤为突出。结构一旦稳定性不足，发生失稳破坏，拱桥结构会在没有征兆下发生整体垮塌，极大的影响了交通的正常使用，重则对影响人生安全，对社会造成不可估量的社会影响和经济损失。本文通过对一座跨径为 300m 的上承式钢管混凝土拱桥建立 Midas 有限元模型，并通过不同倍数模态偏位作为结构初始几何缺陷施加到模型结构中，考虑由于拱肋初始挠度缺陷导致的桥梁结构变化，对该模型进行特征值屈曲分析，进行桥梁非线性稳定分析。结果表明，考虑几何缺陷的非线性对该上承式拱桥稳定性有较大影响，主要表现为稳定性系数随施加的初始缺陷值增加而衰减，因此上承式拱桥稳定性分析时考虑几何非线性才能真实模拟工程实际情况。

关键词：非线性稳定

Nonlinear Stability Analysis of Long Span CFST Arch Bridge Considering Initial Geometric Imperfections

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Abstract:

Concrete-filled steel tube arch bridge with steel pipe and filled concrete material under synergy, fully meet the compressive strength of the structure while saving the use of concrete materials. Due to its convenient construction and short construction time, it can greatly improve the bridge's ability to span and is widely popularized in the mountainous bridge structure. However, with the span of large-span CFST increasing, arch stability problems are particularly prominent. Once the stability of the structure is insufficient, instability damage occurs, the arch bridge structure will collapse without warning, a great impact on the normal use of traffic, heavy impact on the safety of life, cause immeasurable social impact and economic loss to society. In this paper, a finite element model of Midas is established for a 300m span CFST arch bridge, and applied to the model structure through different geometric modal deviation as the initial geometric defects of the structure, consider the structural changes of the bridge due to the initial deflection of arch rib, eigenvalue buckling analysis of the model was carried out, bridge nonlinear stability analysis. The results show, the nonlinearity considering geometrical defects has a great influence on the stability of the over-arch bridge, it is shown that the stability factor decays with increasing initial defect value, Therefore, when considering the geometric nonlinearity in the stability analysis of the through arch bridge, the

actual situation of the project can be simulated..

keywords: Nonlinear stability

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轨道专用连续刚构桥施工线形控制

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摘　要：钢-混混合梁的使用不仅能提高梁桥结构跨越能力和还能保证结构全寿命周期的经济性，是连续刚构桥设计发展的一种趋势。在建的重庆嘉华嘉陵江轨道专用桥为大跨度连续刚构轨道桥，主跨跨中设置了整体吊装钢箱段，施工步骤复杂，线形控制难度大且要求精度高，本文通过悬臂浇筑与钢箱梁吊装施工过程的准确模拟与分析，得到合理的混凝土施工节段标高、准确的钢箱梁制造线形以及钢混结合段与钢箱梁吊装段合拢控制方法。为桥梁顺利合拢和轨道正常运营提供可靠的依据。

关键词：混合梁连续刚构桥；施工线形控制；钢箱梁

Linear Control for Tunnel's Special Rigid Frame Bridge

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Abstract:

In use of steel-concrete composite beams can not only improve the structure’s spanning capacity of the bridge, but also ensure the economic efficiency of the whole life cycle of the structure, which is a trend of continuous rigid frame bridge’s design. The tunnel’s special bridge of Jialing River in Jia Hua which is now under construction is long-span continuous rigid frame bridge, the main span is across a set of integral lifting of steel box section, construction procedure is complex, the linear control is difficult and has high accuracy requirement, this article is focus on the accurate simulation and analysis of cantilever casting and steel box girder hoisting construction process to get the reasonable section’s elevation for concrete construction, accurate steel box girder’s linear and enclosure control method of steel-concrete mixed section’s and steel box girder hoisting section’s. It provides reliable basis for bridge enclosure and normal operation of the track in later period.

keywords: rigid frame bridge with composite beam; linear control for construction; steel box beam

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单箱双室截面波形钢腹板组合梁的剪力滞效应分析

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摘　要：摘要：为了研究单箱双室截面波形钢腹板组合箱梁的剪力滞后效应，采用 ANSYS 软件建立了有限元模型，研究了单箱双室截面波形钢腹板组合箱梁在三种集中荷载工况作用下主要截面顶底板的剪力滞横向分布规律，并分析了截面宽度、翼板厚度等因素对剪力滞系数的影响。研究发现：不同性质的荷载对剪力滞效应的分布规律有很大影响。荷载横向位置的变动对纵向上剪力滞效应没有影响且对底板剪力滞系数影响不大。上翼缘剪力滞系数随宽跨比 B /L 的增加而增加，随顶板厚度 t 的增大而逐渐减小，且在纵向距离荷载作用位置越远剪力滞效应越小，减小了因应力集中的影响。在集中力作用位置处出现了显著的应力集中现象，设计时应采取相应措施防止应力集中现象对结构的破坏。

关键词：波形钢腹板；剪力滞效应；单箱双室；几何参数；ANSYS

Analysis of Shear Lag Effect of Single-Box and Double-Cell Corrugated Steel Web Composite Beams

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Abstract:

Abstract:In order to study the shear lag effect of corrugated steel web composite box girder with single box and double chamber section， a finite element model was established by using ANSYS software. The transverse distribution of shear lag in the top and bottom slabs of the main section of corrugated steel web composite box girder with single box and double chamber section under three concentrated loads was studied， and the effects of cross-section width and wing thickness on shear lag coefficient were analyzed. It is found that different loads have great influence on the distribution of shear lag effect. The change of lateral position of load has no effect on the longitudinal shear lag effect and has little effect on the floor shear lag coefficient. The shear lag coefficient of upper flange increases with the increase of width-span ratio B/L， decreases with the increase of roof thickness t， and the shear lag effect decreases with the increase of load location in longitudinal distance， which reduces the effect of stress concentration. There is a significant phenomenon of stress concentration at the position where the concentrated force acts. Corresponding measures should be taken to prevent the damage of the structure caused by the phenomenon of stress concentration..

keywords:corrugated steel webs; shear lag effect; single-box and double-cell; geometric parameters; ANSYS

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钢-混凝土曲线组合梁刚性扭转效应的初参数解

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摘　要：摘要：针对闭口截面钢-混凝土曲线组合梁，利用 M/R 法将其等效为直线梁，根据乌曼斯基约束扭转理论推导了考虑全截面材料差异性的约束扭转控制微分方程，采用初参数法给出了其在集中荷载和均布荷载下简支曲线组合箱梁力学特性的解析解，并与有限元数值结果进行了比较。结果表明，解析解与数值解吻合良好，能更直观地反映曲线组合梁受力性能的影响参数。

关键词：钢混组合；曲线梁；刚性扭转；解析解

Initial Parameter Solution of Rigid Torsion Effect of Steel-Concrete Curved Composite Beams

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Abstract:

Abstract: For the steel-concrete composite beam with closed section, it is equivalent to the linear beam by M/R method. According to the Umansky constraint torsion theory, the differential equation of constrained torsion considering the difference of the full-section material is derived. The analytical solutions of the mechanical properties of simply supported curved box girder under concentrated load and uniform load are given and compared with the finite element numerical results. The results show that the analytical solution is in good agreement with the numerical solution, and can more intuitively reflect the influence parameters of the force performance of the curved composite beam..

keywords: Steel-Concrete Curved Composite Beams; Rigid torsion; Analytical solution

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Shearing Behavior of Concrete-Encased Variable Cross-Section Box Girder with Corrugated Steel Webs

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Abstract: For the large-span continuous and rigid variable cross-section box girder bridge with corrugated steel webs(CSWs), large shear force produced at the intermediate supports, concrete-encased usually used to improve the shear performance of CSWs. In order to study the shearing behavior of concrete-encased variable cross-section box girder bridge with CSWs, the experimentally models have been investigated. The shearing mechanism of corrugated steel webs with encased concrete (CSWC) , the distribution of shear stress of CSWs and the ratio of shear force between concrete and CSWs are analyzed. The analysis study found that shearing resistance has been significantly improved with encased concrete. Continually, the shearing resistances of CSWs and encased concrete are divided into three stages. At the initial stage of loading, the ratios of the shear force are accorded with the theoretical calculation method. Then, after the encased concrete cracked, the shear ratio of the CSWs was increasing fast while the encased concrete was reducing. At the last stage, after the CSWs yield, the shear ratio of the CSWs was reducing while the encased concrete was increasing.

Key words: Corrugated steel webs; varibale cross-section; shearing behavior; encased concrete; shear distribution

预应力混凝土刚构-连续梁组合体系桥梁合拢次序分析

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摘　要：预应力混凝土刚构-连续梁组合体系桥梁[1-2]是适应墩高高差大、跨数较多桥梁的一种较好的桥型。该桥型多跨，又是组合体系，合拢[3][4]施工成为其设计、施工中的一个关键问题。结合工程实际，计算分析了三种不同合拢次序对主梁成桥线形、运营阶段应力分布及刚构主墩墩顶位移等的影响。设计和施工应结合现场实际情况，结合有限元分析计算，确定最合适的合拢次序。

关键词：预应力混凝土刚构-组合体系

Analysis on Closure Sequences of the Prestressed Concrete Rigid frame-Continuous combined-System Bridge

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Abstract:

Prestressed concrete rigid frame-continuous combined-system bridge is a good brige-type which can adapt large pier height difference and multi-span.Closure are the key problem in design and construction of this bridge-type.Conbined with the engineering practice,influence on alignment under the secondary dead load,stress distribution at operational stage and the pier displacement of three different closure sequences are calculated and analyzed. The design and construction should combine the actual situation of the site and the finite element analysis to determine the most suitable order of closure sequences..

keywords: Prestressed concrete rigid frame-continuous combined-system

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单索面斜塔斜拉桥钢桥塔设计与优化

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摘　要：为了解决钢桥塔在设计与优化中遇到的各种问题，以衢州市桑淤大桥（单索面斜塔斜拉桥）为工程背景，基于有限元软件 ANSYS19.1，首先建立了钢桥塔主塔的板壳有限元基础模型 2 个（模型 I 和模型 II）和优化模型 4 个（模型 III~模型 VI），对其整体应力分布、变形和稳定情况以及检修孔处应力和整体节点板处的角隅应力进行了分析与优化；其次建立了钢桥塔主塔边跨斜拉索钢锚箱的全实体有限元模型 1 个（模型 VII），对其钢锚箱传剪能力进行了分析。结果表明：首先钢桥塔主塔（模型 I 和模型 II）各板件 Mises 应力均小于 345MPa，稳定系数均大于 1.75，满足规范要求[1-6]，且模型 II 主塔各板件最大 Mises 应力（σ2=286 MPa）<模型 I 主塔各板件最大 Mises 应力（σ1=313 MPa），模型 II 稳定系数（f2=9.334）>模型 I 稳定系数（f1=7.115）；对比模型 I 和模型 II 主塔各板件的应力、变形以及稳定情况可知，模型 II 在各方面均优于模型 I，因此推荐采用模型 II 的主塔和主梁的连接构造进行最终的施工图设计，且在模型 II 的基础上对主塔和主梁的连接构造即整体节点板的圆弧半径进行优化分析，最终确定圆弧半径为 2.2m。其次确定钢锚箱承剪板长度为 1m，钢锚箱结构传力顺畅，设计安全经济，合理可靠。

关键词：单索面；斜塔；斜拉桥；钢桥塔；应力分析；稳定；检修孔；钢锚箱

Design and Optimization of Steel Pylon of a Single Cable Plane Cable-Stayed Bridge

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Abstract:

In order to solve various problems encountered in the design and optimization of steel bridge tower, Qunzhou Sangyu Bridge which is a single cable plane cable-stayed bridge with leaning tower was selected for project background, based on software ANSYS19.1, firstly , finite element models with shell elements of main towers of steel bridge tower were established. The stress distribution, deformation, stability, stress at the repair hole and corner stress of integral joint plate were analyzed and optimized one by one. Secondly, a full-body finite element model of the steel anchor box of the main tower side span of the steel bridge tower was established, and the shear transfer of the steel anchor box was analyzed. The results show that，In the first place, the Mises stress of each plate member and stability safety factor of main tower of steel bridge tower all meet regulatory requirements. Also，the maximum Mises stress of each plate of model II main tower < the maximum Mises stress of each plate of model I main tower, the stability safety factor of model II > the stability safety factor of model I. Comparing the stress, deformation and stability of each plate of model I and model II, it can be seen that model II is superior to model I in all respects. So it is recommended

that the final construction drawing design be carried out by using the connection construction between the main tower and the main girder of Model II. On the basis of model II， the connection structure of the main tower and the main girder， i.e. the circular radius of the integral joint plate， was optimized and analyzed. Finally， the circular radius is determined to be 2.2m. In the secondly place, the length of bearing shear plate of steel anchor box is determined to be 1 m. The structure of steel anchor box can transmit force smoothly, and the design is safe, economical, reasonable and reliable..

keywords:single cable plane; leaning tower; cable-stayed bridge; steel bridge tower; stress analysis; stability; repair hole; steel anchor box

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波形钢腹板组合箱梁自振特性研究

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摘　要：摘要：随着对波纹钢腹板组合箱梁研究的深入开展，其自振特性也受到广泛关注.波形钢腹板组合梁截面形式、截面宽度以及横隔板数量的不同对波形钢腹板组合梁自振特性有着很大影响。本文利用有限元分析软件 ANSYS 建立了有限元结构模型，进行了波形钢腹板组合梁的模态分析，通过模态分析得到了波形钢腹板组合箱梁的自振频率、自振周期、振型等，对其自振特性进行了分析比较。数值分析表明：横隔板数量适当增加时波形钢腹板组合箱梁的自振频率会增大，横隔板数量过多波形钢腹板箱梁自振频率随之下降；宽跨比增大时波形钢腹板箱梁的自振频率随之下降；自振频率随着刚度比增大而增大。

关键词：关键词：自振频率；横隔板；宽跨比；刚度比；关键词：自振频率；横隔板；宽跨比；刚度比

Study on the Free Vibration Characteristics of the Box Girder with Corrugated Steel Webs

Liu Chaoxing，Liu Yukun，Li Yunsheng
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Abstract：

Abstract: With the deep research on corrugated steel web composite box girder, its self-vibration characteristics have also received extensive attention. The corrugated steel web composite beam cross-section form, section width and the number of transverse partitions are different for corrugated steel web combination. The self-vibration characteristics of the beam have a great influence. In this paper, the finite element structural model is established by the finite element analysis software ANSYS. The modal analysis of the corrugated steel web composite beam is carried out. The natural vibration frequency, natural vibration period and vibration of the corrugated steel web composite box girder are obtained by modal analysis. Type, etc., its self-vibration characteristics were analyzed and compared. The numerical analysis shows that the natural vibration frequency of the corrugated steel web composite box girder will increase when the number of transverse partitions increases properly. The number of transverse diaphragms will decrease with the natural vibration frequency of the corrugated box girder. The natural vibration frequency of the steel web box girder decreases; the natural vibration frequency increases with the increase of the stiffness ratio.

keywords:natural vibration frequency; transverse diaphragm; wide span ratio; stiffness ratio; natural vibration frequency; transverse diaphragm; wide span ratio; stiffness ratio

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波形钢-混凝土组合桥面板负弯矩区开裂弯矩分析

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（安徽省交通规划设计研究总院股份有限公司）

摘　要：本文首先介绍淮南孔李淮河大桥所采用的新型波形钢—混凝土组合桥面板的结构体系。针对该新型组合桥面，推导出考虑了配筋率影响的负弯矩区开裂弯矩的计算公式；并进行参数化分析，设定的参数变量包括配筋率、波折板厚度和桥面板总厚度，分析上述变量参数对其负弯矩区开裂弯矩的影响曲线，为后续该组合桥面板的设计提供参考和理论依据。

关键词：波形钢；组合桥面板；开裂弯矩；配筋率；参数化

Crack-Resistant Moment of Corrugated Steel Plate and Concrete Composite Bridge Deck in Negative Moment Region

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Abstract：

This paper first introduces the structural system of the new corrugated steel plate andconcrete composite bridge deck used in the Huai'nan Kongli Huaihe River Bridge. For the new composite deck, the calculation formula of the crack moment of the negative moment zone considering the influence of the reinforcement ratio is derived. Parametric analysis is carried out. The parameter variables include the reinforcement ratio, the thickness of the corrugated plate and the total bridge deck. Thickness, analyze the influence curve of the above variable parameters on the crack moment of the negative moment region, and provide reference and theoretical basis for the design of the composite bridge deck.

keywords:corrugated; composite bridge deck; crack-resistant moment; reinforcement ratio; parameterization

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单箱三室截面波形钢腹板组合箱梁的扭转效应分析

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（石家庄铁道大学）

摘　要：为了研究波形钢腹板结构参数对箱梁扭转特性的影响，利用 ANSYS 有限元软件，建立了单向三室截面波形钢腹板组合箱梁桥的有限元模型，将偏心荷载分解为对称荷载、扭转荷载和畸变荷载，并分别施加于有限元模型上，得到了单箱三室波形钢腹板组合箱梁的扭转效应和畸变效应，并对波形钢腹板厚度、横隔板数目等参数进行了分析。结果表明：横隔板的设置对降低畸变翘曲应力有明显效果，合理设置一定数目的横隔板，对于提高箱梁的抗扭性能，降低截面翘曲程度有很大的帮助；增大波形钢腹板的厚度能增大箱梁的扭转刚度，减小结构的畸变效应，但单纯的增加钢腹板厚度来增大箱梁的抗扭性能，其效率会随着厚度的增加而降低。

关键词：波形钢腹板组合箱梁；扭转；畸变；单箱三室

Torsion Effect Analysis of Single - Box Three - Chamber Composite Box Girder with Corrugated Steel Webs

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（Shijiazhuang Tiedao University）

Abstract:

Corrugated steel web pick to: in order to research the influence of structure parameters on the box girder torsion characteristics, using the finite element software ANSYS, established a one-way 3 rooms section corrugated steel web composite box girder bridge finite element model of the eccentric load is decomposed into symmetric load, torsion load and distortion load, and on the finite element model respectively, got the single box 3 rooms the torsion effect of corrugated steel web composite box girder and distortion effect, and the parameters such as thickness of corrugated steel web plate and diaphragm plate number are analyzed. The results show that the setting of diaphragm has obvious effect on reducing distortion and warping stress. Increasing the thickness of corrugated steel webs can increase the torsional stiffness of the box girder and reduce the distortion effect of the structure, but simply increasing the thickness of the steel webs can increase the torsional resistance of the box girder, and its efficiency will decrease with the increase of the thickness.

keywords:corrugated steel web composite box girder; Reverse; Distortion; Single box 3 rooms

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装配化桥梁可拆卸开孔钢管连接件抗剪性能研究

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（长沙理工大学）

摘　要：摘要：为满足预制钢-混凝土组合桥梁快速装配化施工，提出一种可拆卸的开孔钢管连接件。通过设计不同钢管壁厚，开孔板条宽度与高度等参数的开孔方钢管连接构造试件，开展水平推出试验，研究其抗剪承载力、抗剪刚度、剪切破坏模式及相对滑移特征。考虑材料与接触非线性，建立推出试件高效精细有限元模型，进行与方钢管具有相同用钢量、板厚、开孔形式的圆钢管连接件抗剪性能对比分析。研究结果表明：可拆卸钢管连接件不仅具有开孔板连接件相当的抗剪承载力，而且比焊钉连接件更好的延性；增加钢管壁厚能有效提高其抗剪刚度与强度，改变底部开孔形状对连接件的抗剪刚度影响较小，但对强度影响较大；圆管与方管连接件具有相当的剪切屈服强度，但方管连接件的极限抗剪强度更高，而圆管连接件的延性更好。研究结果可为快速装配化钢-混凝土组合桥梁连接件设计提供理论基础。

关键词：桥梁工程；可拆卸连接件；推出试验；抗剪性能

Study on Shear Performance of Demountable Perforated Steel-Tube Connector for Accelerated Assembly Construction Bridge

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Abstract:

Abstract: A demountable perforated steel-tube shear connector is proposed to satisfy the accelerated assembly construction of precast steel－concrete composite bridges. Push-out tests using different parameters, including the wall thickness of the steel tube and height and width of the steel strips in a perforated plate, were carried out to investigate the shear strength, shear stiffness, failure modes, and relative slip characteristics of demountable perforated square steel-tube shear connectors. By considering the nonlinear behavior of materials and interface between steel and concrete, an efficient finite-element (FE) model was established and validated. A comparison of the shear performance between a square and a circular steel tube connector with the same thickness, perforated shape, and steel weight was conducted using the verified FE models. The experimental and FE analytical results demonstrate that the demountable perforated steel-tube shear connectors possessed not only the equivalent shear strength of perforated rib connectors but also better ductility than the welded stud connectors. The shear strength and stiffness can be improved by increasing the wall thickness of the steel tube. The perforated shape slightly affected the shear stiffness but largely affected the shear strength. The square and circular steel-tube connectors have almost the same shear-yield strength. However, the square steel-tube connector has higher ultimate shear strength, whereas the circular steel-tube connector exhibits better ductility. All the results can provide a theoretical basis for the design of connector for steel-concrete composite bridge by accelerated

assembly construction.

keywords:bridge engineering; demountable connector; push-out test; shear performance

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Influence of Steel Casing Length on Vertical Bearing Characteristics of Steel Tube-Reinforced Concrete Piles

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Abstract: As the cofferdam structure of pile construction in water, the application of steel casing is more and more extensive, and the steel casing is sometimes no longer recycled because of the difficulty of demolition, so as to form composite pile together with reinforced concrete materials. The present paper aims at investigating the influence of steel casing length on vertical bearing characteristics of steel tube-reinforced concrete piles, in which centrifugal model test was utilized. The results show that steel casing length has great influence on vertical bearing characteristics of steel tube-reinforced concrete piles. When the length of steel casing is less than one third of the pile length, the skin friction of steel tube-reinforced concrete piles will appear double peak phenomenon. When the length of steel casing is greater than one third of the pile length, the double peak phenomenon will gradually disappear. Additionally, the axial force of steel tube-reinforced concrete piles drops faster along the pile body than reinforced concrete pile without steel casing. Moreover, the simple formula for calculating the vertical ultimate bearing capacity of steel tube-reinforced concrete piles is put forward in order to provide theoretical guidance for the design and construction.

Key words:steel tube-reinforced concrete piles; steel casing; centrifugal model test; vertical bearing characteristics

Optimization Method for Solving the Reasonable Arch Axis of Long-Span CFST Arch Bridges

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Abstract: With the continuous construction of 500m-class CFST arch bridge such as Hejiang Changjiang River Bridge (Bosideng bridge) and Hejiang Changjiang Highway Bridge, The deviation between the arch axis formed by the existing arch axis optimization method and pressure line is large, the arch axis optimization method of CFST Arch bridge needs to be explored in depth.According to the essence of the arch axis optimization of the CFST Arch Bridge with truss cross-section--to ensure the optimal stress state of each major member of the main Arch Rib, this paper presents an optimal method for the arch axis of Long-span CFST Arch Bridge--the minimum method of the main pipe eccentricity.The first is to reduce the bending moment of the main pipes by the iterative method of the main pipe eccentricitye, then a smooth and reasonable arch axis can be fitted by the cubic spline interpolation function with the theory of compiling the MATLAB calculation program . At the end of this article, taking Bosideng bridge as example, the whole optimization procedure is shown.The results show that compared with the optimal arch axis linetypes of parabola, catenary and other traditional arch axis optimized by the minimum method of bending energy, the minimum method of the arch axis eccentricity and so on, the bending moment of the main steel pipes optimized the proposed method has substantially smaller and has been distributed more uniformly along the arch axis span; on the other hand, the mechanical properties in the finished bridge state are improved on the index of strength, stiffness and stability, verifying the feasibility of the optimization theory of the arch axis of CFST arch bridge with truss cross-section.

Key words: Concrete-filled steel tubular (CFST) arch bridge; Arch axis optimization; The minimum method of the main pipe eccentricity; The cubic spline interpolation function; Iteration method

带挂梁的 T 型刚构桥承载能力状态评估

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摘　要：为了解某运营中带挂梁的 T 型刚构桥实际工作状态的安全性与最不利受力状态下的承载能力，运用结构有限元分析软件对该桥进行了仿真分析，分析其在设计荷载作用下结构变形与应力状态。同时，对该桥进行实桥静荷载试验，并与仿真分析结果相对，分析其实际承载能力和运营状态。最后，对结构混凝土材质状况指标进行分析评定，确定结构混凝土构件实际工作状态，为桥梁养护与维修提供理论依据。

关键词：桥梁工程，承载能力

State Evaluation of Bearing Capacity of T-Type Rigid Frame Bridge with Suspended Beams

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Abstract:

In order to understand the safety of a T-type rigid frame bridge with suspended beams in actual working state and the bearing capacity under the most unfavorable loading state, the finite element analysis software was used to simulate the bridge and analyze its structural deformation and stress state under the design load. At the same time,the static load test of the bridge is carried out, and compared with the simulation results,the actual bearing capacity and operation status of the bridge are analyzed.Finally,the index of material condition of structural concrete is analyzed and evaluated, and the actual working state of structural concrete components is determined,which provides theoretical basis for bridge maintenance and repair..

keywords:bridge engineering，; bearing capacity

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腐蚀预应力混凝土梁疲劳性能退化研究

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（长沙理工大学）

摘　要：考虑锈蚀方式和锈蚀程度对部分预应力混凝土梁疲劳性能的影响，通过电化学快速锈蚀试验得到仅钢绞线锈蚀、普通钢筋和钢绞线均锈蚀的两类梁。对试验梁开展了静力和疲劳试验，研究了不同疲劳循环次数后梁的刚度退化、混凝土疲劳裂缝宽度和分布特征、普通钢筋及混凝土应变、钢绞线断丝分布和失效模式。研究结果表明：试验梁疲劳寿命随腐蚀程度的增加迅速减小，仅钢绞线锈蚀梁的刚度退化、裂缝宽度和应变增长均符合快速增长—稳定—快速增长的“三阶段”规律。在相同疲劳次数下，普通钢筋和钢绞线同时锈蚀梁的挠度、裂缝数量和应变大于仅钢绞线锈蚀梁。钢绞线锈蚀后预应力混凝土梁的失效形式由普通钢筋疲劳断裂转为钢绞线疲劳断裂。

关键词：锈蚀疲劳

Fatigue Performance Degradation of Corroded Prestressed Concrete Beams

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Abstract:

This paper considers the effect of corrosion mode and corrosion degree on the fatigue performance of partially prestressed concrete beams. An accelerated corrosion test is performed to obtain two types of test beams: beams with prestressing strands corrosion, and beams with reinforcing bar and prestressing strands corrosion. Static and fatigue tests are conducted. The stiffness degradation, the fatigue cracks width and distribution characteristics of concrete, strain of reinforcing bar and concrete, distribution of prestressing strands fracture and failure modes of the beams after various fatigue cycles were discussed. The results show that the fatigue life is significantly reduced as corrosion level increases. The stiffness degradation, the crack width and strain growth of the beams with only prestressing strands corrosion experience three stages: initial fast increasing stage, stable stage and fast increasing stage. After a same fatigue cycle, the deflection, the number of cracks and the strain of beams with reinforcing bar and prestressing strands corrosion are larger than those of only prestressing strands corroded beams. The failure mode of prestressed concrete beams with prestressing strands corrosion changes from fatigue fracture of reinforcing bars to fatigue fracture of prestressing strands..

keywords:corrosion fatigue

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基于压力差测试的竖向位移实时监测方法

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摘　要：针对目前广泛采用的液位连通管式位移测量方法存在的主要问题，在分析了连通管两端液面面积比、管道摩擦力对竖向位移测量精度的影响的基础上，阐述了基于压力差测试竖向位移的原理及测试系统的实现方法，研发了基于压力差测试的竖向位移测量系统，实现了竖向位移的实时、远程、精确测量。对比实验研究结果表明，该位移测量技术及其设备具有优于 0.1mm 的测量分辨率和较高的灵敏度，可适用于工程中多种结构的竖向变形量测，并在桥梁荷载试验时挠度测量中得到了成功应用，验证了其具有多点同步实时测量、布设及操作便捷、低成本等优点。结合一些工程问题，探索性提出了改进方向并进行了方案设计。

关键词：竖向位移；测量方法；压力差；对比实验；设备开发；误差分析；桥梁荷载试验

Method of Vertical Displacement Real-Time Monitoring Based on Differential Pressure Measurment

Zhu Shifeng，Zhu Cixiang
（CCCC Road & Bridge Special Engineering Co. , Ltd.）

Abstract:

In light of the problems in vertical displacement measuring based on the liquid level sensing system, the factors influencing the accuracy of vertical displacement measurement were analyzed, such as cross-sectional area ratio of the two vertical pipes and duct friction. The principle of vertical displacement measurement based on differential pressure connecting pipe and the realization of the measurement system were expounded. A measuring equipment based on MEMS(Micro-Electro-Mechanical System) and connecting pipe technology was developed for convenient, high-precision, real-time remote monitoring of the vertical displacement, and comparative experiments were carried out. The initial experimental results show that the resolution of this equipment is higher than 0.1 mm in vertical displacement measurement, and the sensitivity is relatively high. The daily needs for many structures was met for vertical displacement monitoring and measurement. It has been successfully applied in bridge deflection measurement of the bridge static load test, it shows that the system had many advantages such as multi-point synchronous real-time monitoring, low implementation cost, easy to operate and so on.For some engineering problems, the improvement directions were proposed and the scheme design was carried out..

keywords:vertical displacement ; measuring method ; differential pressure ; comparative experiments; equipment development; error analysis ; bridge static loading test

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钢-混组合梁桥抗火性能研究综述

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摘　要：钢-混组合梁桥具有整体性强、抗震性能好、施工简便等众多优点，在桥梁工程领域得到广泛应用。然而钢-混组合梁桥抗火性能较差，火灾场景下钢梁的材料性能退化很快，结构的强度和刚度急剧下降，导致钢-混组合梁的承载能力大大降低，结构最终因承载力不足而发生倒塌破坏。本文总结了国内外在钢-混组合梁桥抗火领域的研究成果，介绍了相关火灾试验、数值模拟的研究进展，对抗火性能研究中的火源模型、温度场分布、材料热力学性能退化、结构火灾响应进行了综述性介绍，为钢-混组合梁桥抗火性能研究提供一定的指导。

关键词：钢-混组合梁桥；抗火性能；倒塌破坏；火灾试验；数值模拟

A Review of Research on Fire Resistance of Steel-Composite Girder Bridges

Chen Wei，Shen Ruili，Xue Songling，Miao Rusong，Bai Lunhua
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Abstract:

Steel-composite girder Bridges have the advantages of strong integrity, good seismic performance and simple construction. They are widely used in the field of bridge engineering. However, the fire-resistant performance of the steel-concrete composite girder bridges is not much ideal. The material performance of the steel beam in the fire scenario degrades rapidly. Besides, the strength and stiffness of the structure decline sharply, making the bearing capacity of the steel-concrete composite beam reduce greatly. Thus, the structure collapses due to the insufficient bearing capacity. This paper summarizes the work or achievements of domestic and foreign steel girder bridge. It also introduces the progress of relevant fire test and numerical simulation. Fire model, temperature field distribution and thermodynamic performance degradation of materials and structural fire response were summarized in this paper as well. It provides some guidance for the steel-concrete composite girder bridges on fire resistance..

keywords: Steel-concrete composite girder bridges; fire resistance; collapse destruction; fire test; numerical simulation

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适用于普通公路大件设备运输的桥梁通过性评估体系研究

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（四川省公路规划勘察设计研究院有限公司）

摘　要：为保障大件设备顺利运输及沿线桥梁的结构安全，需要对相关桥梁开展通过性评估工作。本文以四川省政府重点项目“神华天明电厂新建工程”大件设备运输保障工作为依托，提出了一套适用于普通公路大件设备运输的桥梁通过性评估体系。按前、中、后三个工作阶段对评估体系进行了分解，并介绍了检测、检算及评估等各个环节的工作内容及重点。该评估体系不仅保障了依托工程大件设备运输任务的顺利完成，也可为今后同类项目提供参考。

关键词：公路桥梁；大件运输；承载能力；桥梁通过性评估

Study of Bridge Passage Capacity Assessment System for Large-Scale Equipment Transportation on Highway

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Abstract:

To ensure the success of large-scale equipment transportation and the safety of bridge structure in transit,it is necessary to assess the passage capacity of related bridges. Depending on the large-scale equipment transportation for a newly built project of Shenhua Tianming Power Plant,this paper proposes a bridge passage capacity assessment system for large-scale equipment transportation on highway.The assessment system could be divided into 3 phases: the first section, middle section and the last section.This paper introduces the contents and key points of all phases,such as detection,check-calculation,assessment,etc.The assessment system not only has guaranteed the accomplishment of the large-scale equipment transportation task,but also can provide good references for the similar projects in future..

keywords:highway bridge; large-scale transportation; bridge bearing capacity; bridge passage capacity assessment

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基于 WIM 数据的车道疲劳荷载模型研究

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摘　要：为确定公路桥梁横向车道位置的疲劳车辆荷载模型，以 WIM 系统测得的 31 天车辆荷载数据，对超车道、行车道及慢车道这三个车道的车辆荷载参数进行统计，遴选各车道典型代表车型，并采用多峰正态分布拟合轴重及轴距的概率分布模型；基于等效疲劳损伤原理获取各车道车型等效轴重及轴距，求解对应的疲劳损伤贡献值，最终确定各车道的标准疲劳车辆模型。结果表明：车道不同，疲劳荷载模型的车型不同，超车道为四轴卡车，行车道及慢车道为六轴卡车；各车道疲劳车辆模型的车重差异性较大，超车道最小为 16t，行车道次之，为 23t，慢车道最大，为 55t；行车道与慢车道的疲劳车辆模型车型相同，但车重差异较大；为了更接近实际交通流状况，应采用车道疲劳车辆模型进行桥梁结构及构件疲劳损伤分析及寿命评估。

关键词：桥梁工程；疲劳荷载模型；疲劳损伤贡献值；车辆荷载特性

Research on Fatigue Load Model on Different Lanes Based on Weigh-In-Motion Data

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Abstract:

In order to determine the fatigue vehicle load model on different transverse lane, as overtaking lane, carriageway and slow lane of highway bridge, 31-day vehicle load data monitored by Weigh-In-Motion (WIM) system were used for analyzing statistical parameters of vehicle load, and the representative vehicle model were obtained, and the muti-normal distribution were used to describe probabilistic distributions of axle weight and axle distance. Based on the principle of equivalent fatigue damage, the equivalent axle weight and distance of each vehicle lane were obtained, and the corresponding fatigue damage contribution value was solved, and the standard fatigue vehicle model of each vehicle lane was finally determined. The results show that the fatigue load model is different between different lanes, the overtaking lane is four-axle truck, and the traffic lane and slow lane are six-axle truck. The vehicle weight of the fatigue vehicle model in each lane varies greatly. The minimum overtaking lane is 16t, followed by the traffic lane, which is 23t, and the maximum slow lane, which is 55t.The fatigue vehicle model of the traffic lane is the same as that of the slow lane, but the vehicle weight is different. When the lane fatigue vehicle model is used to evaluate the fatigue damage and life of bridge structures and components, it would be more accurate to the actual traffic flow..

keywords:bridge engineering; fatigue load model; fatigue damage contribution; vehicle load characteristics

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三塔悬索桥实桥索夹螺杆预紧力变化分析

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摘　要：本文在综述双塔悬索桥吊索索夹螺杆紧固力变化的基础上，以世界上首座建成的千米级多塔连跨悬索桥—泰州大桥为例，根据泰州大桥现场吊索索夹螺杆紧固力检测和紧固工作的结果，分析成桥及运营后三塔悬索桥索夹螺杆紧固力的变化特征，为悬索桥缆索体系养护工作的科学开展提供借鉴和依据。

关键词：三塔悬索桥；索夹；螺杆紧固力；索塔

The Research of Screw Force in Suspension Bridge with Three Towers

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（1.江苏泰州大桥有限公司；2.CCCC Highway Consultants Co.,Ltd.）

Abstract:

This article is based on the analysis of screw force change in Twin tower suspension bridge. Taking Taizhou Bridge as an example, which is the world's first built kilometer-level multi-tower suspension bridge. This article analyzes the variation characteristics of the screw force in three-tower suspension bridge after completion according to the result of screw force detection and fastening work of Taizhou Bridge, in order to provide reference for the scientific development of cable system maintenance work in suspension bridge..

keywords: Suspension Bridge With Three Towers; Cable Clamp; Screw Force; Tower

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某曲线匝道桥桥面板破损空洞病害应急检测与加固

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摘　要：桥面板破损空洞属于诸多桥梁应急事件中发生概率较高的一种，本文以实际应急事件案例为依托，提出了应急事件发生后的快速检测内容及流程，并对应急检测重点及应急检测结果进行分析。根据检测结果及病害原因提出维修加固的重点，并进行承载能力验算，为类似应急事件的检测与加固提供一定的经验借鉴。

关键词：桥面板；破损空洞；应急检测

Emergency Detection and Reinforcement of Damage Cavity Disease in Bridge Deck of Some Curved Ramp Bridge

Zhang Yongbin，Wang Xing
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Abstract：

The bridge panel damage cavity is a kind of high probability of occurrence in bridge emergency. Based on the actual emergency case, this paper proposes the content and process of rapid detection after the emergency, and analyses the key points and results of emergency detection. According to the detection results and the causes of disease, this paper proposes the key points of maintenance and reinforcement, carries out the bearing capacity verification, and provides a reference for the similar emergency detection and reinforcement..

keywords:the bridge panel; damage cavity; emergency detection

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骑跨式吊索模态分析及索力计算实用公式

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（西南交通大学）

摘　要：由于骑跨式吊索自身构造特点，使得根据测试频率计算吊索索力时，索长及边界条件的影响很不明晰，增加了拟合索力计算公式的困难。通过数值模拟计算，研究分析了骑跨式吊索不同方向振型特点、索抗弯刚度对模态分析的影响和减震架对长吊索振型的影响；结合杭瑞洞庭湖大桥实测吊索数据，拟合出吊索等效长度并与销铰式吊索索力计算公式相结合，提出适用于骑跨式吊索的索力计算公式；最后，利用骑跨式短吊索试验实测数据，验证本文索力公式的实用性。

关键词：悬索桥；骑跨式吊索；频率法；模态分析；索力测试

Modal Analysis of Straddle Slings and Practical Formula for Cable Force Calculation

Shen Ruili，Cai Zhenshan
（Southwest Jiaotong University）

Abstract:

Due to the structural characteristics of the straddle sling, the influence of cable length and boundary conditions is unclear when calculating the sling cable force according to the test frequency, which increases the difficulty of fitting the cable force calculation formula. Through the numerical simulation, the influence of the vibration mode characteristics of the straddle sling in different directions, the bending stiffness of the cable on the modal analysis and the influence of the damper on the vibration mode of the long sling are studied; combined with the measured sling data of Hangrui Dongting Lake Bridge, the equivalent length of the sling is fitted and combined with the calculation formula of the pin sling cable force, and the formula for calculating the cable force for the straddle sling is proposed. Finally, the practical data of the straddle sling test is used to verify the practicability of the cable force formula..

keywords:suspension bridge; straddle sling; frequency method; modal analysis; cable force calculation

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某连续梁桥静动载试验研究

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摘　要：以某连续梁桥为工程背景，基于现场静动载试验方法，对该桥建成后的实际承载力进行了研究。首先，详细介绍了静载过程中应变和挠度测点的布置方式；然后，利用荷载效应等效原则．结合连续梁桥结构的内力分布特点，确定了现场荷载试验中典型截面的最不利荷载工况。结合有限元 MIDAS/CIVIL 的程序计算结果，将理论计算结果与主梁截面应变、挠度和结构振动特性实测结果进行对比分析。研究结果表明，静载试验的应变实测值和挠度实测值均小于理论计算值．满足相关规范要求；实测基频高于理论计算值，桥梁结构整体强度和刚度满足设计荷载及正常使用的要求。

关键词：连续梁桥；荷载试验；校验系数；振动特性

Static and Dynamic Load Test of a Continuous Beam Bridge

Zhou Xian Gong，Shen Chuan Dong
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Abstract:

Taking a continuous girder bridge as an engineering background, based on the field static and dynamic load test method, the actual bearing capacity of the bridge is studied. Firstly, the layout of strain and deflection measurement points in static load process is introduced in detail. Then, the most disadvantageous load condition of typical section in field load test is determined by using the principle of load effect equivalence and combining the internal force distribution characteristics of continuous beam bridge structure. Combining the results of finite element MIDAS/CIVIL program calculation, the theoretical calculation results are compared with the measured results of cross-section strain, deflection and structural vibration characteristics of the main girder. The results show that the measured values of strain and deflection in static load test are less than those in theoretical calculation and meet the requirements of relevant codes; the measured fundamental frequency is higher than that in theoretical calculation; and the overall strength and stiffness of bridge structure meet the requirements of design load and normal use..

keywords:continuous girder bridge, load test, check coefficient, vibration characteristics

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The Selection Principle and Method of Urban Bridge Health Monitoring Based on PCA

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Abstract: The types and property of urban bridge and their standard of judgement are complex. In the face of the contradiction between the high cost of health monitoring and the large amount of urban bridges, Principal Component Analysis (PCA) is introduced to select the urban bridge. The basic information of urban bridges have been decided as safety factors and importance factors, and the procedure to use PCA have been settled. With PCA and Barrel Principle, the evaluation system to select urban bridge has been established. In addition, this paper takes Beijing as example to use this model. The result shows that this model can consider both the speciality of each city and the generality of urban bridge.

Key words: bridge engineering; urban bridge; bridge health monitoring; barrel principle; PCA

近期典型桥梁事故回顾、分析与启示

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摘　要：本文对 1813 年至 2018 年期间的 584 起桥梁事故进行分析，将桥梁倒塌原因分为施工、自然灾害、设计、意外荷载、耐久性等五类。各原因在倒塌事故中所占比例分别为 42.1%、30.0%、11.6%、12.7%、3.6%。除自然灾害外，设计施工不合理为主要原因，而事故发生大多是多种原因综合的结果。本文以近几年 9 起典型桥梁倒塌事故为例，分析比较了各种倒塌桥梁的主要破坏模式。在此基础上，得到以下启示：首先，国内大部分梁桥上部结构的平面外位移约束构造不足，在任何一个平面内都不应该是可变体系是国内桥梁设计施工中需要注意的一个问题。其次，在应用新工艺、新结构和拆除旧桥时，应加强各种施工工况下的验算。第三，建议加强桥梁巡查，预防和禁止汽车超载以及桥梁附近大规模堆载。第四，应注重桥梁结构尤其是斜拉桥和悬索桥等特大桥梁的日常养护管理，当养护力量不足时，尽量选择养护要求较低的桥型。

关键词：桥梁倒塌；事故分析；现场还原；强度破坏；刚体位移

Review, Analysis and Enlightenment of Recent Typical Bridge Accidents

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Abstract:

Based on the analysis of 584 bridge accidents from 1813 to 2018, causes of bridge collapse are divided into five categories: construction, natural disasters, design, accidental load and durability. The proportion was 42.1%, 30.0%, 11.6%, 12.7% and 3.6% accordingly. In addition to natural disasters, unreasonable design and construction are the main reason, and most accidents are the result of a combination of multiple causes. In this paper, nine typical bridge collapse accidents in recent years are taken as examples to analyze and compare the main failure mode of various collapsed bridges. On this basis, following enlightenments can be obtained: Firstly, most superstructures of girder bridges in China are insufficient out-of-plane displacement restraint structure, and it should not be an unstable system in any plane. It is a problem that needs attentions in the design and construction of domestic bridges. Secondly, strengthening checking calculation under various constructions when using new technologies, new structures and dismantling old bridges. Thirdly, it is suggested that the bridge inspection should be reinforced to prevent the vehicle overloading and large-scale surcharge near bridges. Fourthly, attentions should be paid to the daily maintenance and management of bridge structures, especially cable-stayed bridges, suspension bridges and other large bridges. When the maintenance is insufficient, the bridge with lower maintenance requirements is recommended..

keywords:bridge collapse; accident analysis; restore site; strength failure; rigid body displacement

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基于频率法的短索索力计算公式误差分析

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摘　要：短索索力测试需考虑抗弯刚度和边界条件的影响，其受力模式更接近固支受拉梁模型，目前短索索力受多种因素影响在成桥或运营测试时存在较大误差，本本讨论目前短索索力测试的一些问题，对 4 种实用公式结合文献数据和有限元结果进行了误差分析，研究了造成误差的主要原因，给出了短索索力计算公式使用建议。

关键词：短索索力频率法计算公式

Practical Formular Error Analysis for Estimation of Short Cable Tension by Vibration Method

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Abstract：

The influences of the flexural stiffness and boundary condition of Short Cable shoud be consedered, it’s force mode is closer to the fixed beam model.Because the detection result of short cable are affected by many factorswhen the bridge is complished or operated ,there are some errors.In this paper,some problem in tensile force dection is discussed,error analysis for the four Practical Formular by the use of the paper’s data and finite element results.Main reasons that cause dection error are investigated,and finally some suggestions are presented for the applicetion.

keywords: Short Cable Tensile Force Vrbration frequency method　Practical Formular

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钢绞线束锈蚀的弱漏磁感知研究

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（重庆交通大学）

摘　要：钢绞线束由多根钢绞线组成，与单根钢绞线相比，结构的锈蚀检测更具复杂性，影响因素较多，但更接近实际的拉索结构。本文针对钢绞线束锈蚀的弱漏磁感知问题，采用试验分析和仿真模拟的方法，探究了钢绞线束的弱漏磁分布规律，分析了结构感知角度、锈蚀率、锈蚀根数、锈蚀宽度等因素对漏磁信号的影响。研究结果表明：不同角度感知到的漏磁信号强度有所差异，但规律具有相似性，即切向分量达到最大值，法向分量出现双极值且具有零点；通过处理和分析漏磁信号分量的变化规律，对钢绞线束的锈蚀区域进行判断，这也为拉索结构的锈蚀检测方法提供技术支撑。

关键词：钢绞线束；锈蚀；弱漏磁

Study on Weak Magnetic Flux Leakage Sensitivity of Steel Strands Corrosion

Yang Wenqi，Zhou Jianting，Xia Runchuan，Liao Leng
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Abstract:

The steel strands are composed of multiple steel strands. Compared with a single steel strand, the structural corrosion detection is more complicated and has many influencing factors, but it is closer to the actual cable structure. In this paper, the weak magnetic leakage sensing problem of steel strands rust was analyzed. The method of experimental analysis and simulation was used to investigate the weak magnetic flux leakage distribution of steel strands, and the effects of structural sensing angle, corrosion rate, number of rust and rust width on magnetic flux leakage signals were analyzed. The results show that the intensity of the magnetic flux leakage signals perceived By different angles is different, but the law has similarity, that is, the tangential component reaches the maximum value, the normal component appears bipolar and has zero point. By processing and analyzing the magnetic flux leakage signal component, the change rule is to judge the rust area of the steel strand, which also provides technical support for the rust detection method of the cable structure..

keywords:steel strands; corrosion; weak magnetic flux leakage

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基于漏磁效应的锈蚀钢筋混凝土结构抗弯承载力评估

吉祥，周建庭，赵庆缘
（重庆交通大学）

摘　要：摘要：针对现役钢筋混凝土桥梁严重锈蚀，致使其抗弯承载力严重退化的问题，采用漏磁无损检测技术，开展了钢筋混凝土结构锈蚀检测试验，探索其锈蚀后漏磁信号与抗弯承载力之间的特征关系。首先对 10 片试验梁采用电化学加速锈蚀，然后对锈蚀后的试验梁进行漏磁信号采集，最后开展抗弯承载力试验来验证锈蚀钢筋混凝土结构抗弯承载力。结果表明：随锈蚀时长增加，漏磁信号峰值增加，且抗弯承载力下降，当在连续锈蚀过程中，漏磁信号峰值不再增加，试验梁完全丧失抗弯承载力下

关键词：关键词：漏磁检测；漏磁信号；抗弯承载力

Flexural Capacity Assessment of Corroded Reinforced Concrete Structure Based on leakage magnetic

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Abstract:

Abstract: In view of the serious corrosion of reinforced concrete bridges in service, which leads to the serious degradation of their flexural capacity, the magnetic flux leakage (MFL) nondestructive testing technology is used to detect the corrosion of reinforced concrete structures to explore the relationship of corrosion of reinforced concrete between flexural capacity and magnetic flux leakage signals. In the experiment, firstly the ten test beams were rusted by the electrochemical accelerated method. Then the magnetic flux leakage signal was collected from the rusted test beams. Finally, flexural capacity test was carried out to verify the bending capacity of corroded reinforced concrete structure. Research shows that the peak value of MFL signal increases with the increase of the corrosion duration, and the flexural bearing capacity decreases. When the peak value of MFL signal does not increase during the continuous corrosion process, the test beam completely loses the flexural bearing capacity..

keywords:key words:　magnetic flux leakage detection; magnetic flux leakage signals; flexural capacity

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应用自发漏磁技术监测梁桥内部受拉钢筋应力状态的探讨

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（重庆交通大学土木工程学院）

摘　要：本文运用自发漏磁技术，就钢筋混凝土梁桥内部受拉钢筋应力状态监测问题进行了研究探讨。首先，从理论的 J-A 力磁耦合模型出发讨论了运用自发漏磁技术监测受拉钢筋应力状态的可行性。随后，进行了 12 片试验梁加卸载全过程的自发漏磁监测试验。最后，简要介绍了运用自发漏磁监测技术对 12 座实桥受拉钢筋应力状态的评估应用。结果显示，试验梁自发漏磁监测曲线“界限特征”与变化特征与理论符合较好，在钢筋达到约 0.5 倍屈服应力之后曲线趋于单调变化，证实了实桥评估具备可行性。实桥监测结果表明，自发漏磁对行车中钢筋应力变化敏感。另外，长期行车的循环应力损伤可能使得钢筋自发漏磁基准线偏离初始状态，可以基于“偏离率曲线”对钢筋应力状态乃至应力损伤程度进行定性判断。

关键词：钢筋混凝土梁桥；受拉钢筋；应力状态；自发漏磁；监测

Discussion on Stress State Monitoring of Tensile Steel Bars Embedded in Beam Bridge by Using Self-Magnetic Flux Leakage Technology

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（CHINA）

Abstract:

In this paper, the stress state monitoring of the tensile steel bars inside the reinforced concrete beam bridge is studied by using self－magnetic flux leakage (SMFL) technology. First, the feasibility of monitoring stress state of tensile steel bars is discussed based on a theoretical force-magnetic coupling model, the J－A model. Subsequently, the SMFL monitoring in the loading and unloading processes of 12 tested beams was carried out. Finally, the application of SMFL monitoring in 12 beam bridges are introduced. The results indicate that the "boundary characteristics" and the varying characteristics of the SMFL monitoring curves of the 12 tested beams are in consistent with the theory. The SMFL monitoring curves tends to monotonously varying after the stress of the tensile steel bars greater than about 0.5 times the yield stress, which is very important to the evaluation of bridge. The SMFL monitoring of bridges shows that SMFL is sensitive to the varying stress of the tensile steel bars. In addition, the tensile steel bars of the bridges will be gradually damaged by the cyclic stress of long－term driving, and the reference line of SMFL monitoring curves will be deviated from the initial state. Hence, the stress state and stress damage degree of the tensile steel bars can be qualitative evaluated based on the “deviation rate curve”..

keywords: reinforced concrete beam bridge; tensile steel bars; stress state; self－magnetic flux leakage; monitoring

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钢筋混凝土粘结应力与声发射信号相关性研究

刘定坤
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摘　要：钢筋与混凝土的粘结特性比较复杂，尽管粘结试验迄今已有百年的历史，发表了为数众多的试验资料，但是，目前人们对于钢筋与混凝土粘结的检测手段极其有限，粘结破坏机理复杂，以及试验技术方面的原因等，目前粘结的某些基本问题还有待解决。本文采用声发射技术研究在拉拔试验中，粘结应力沿长度方向上的分布与不同阶段不同位置采集到声音信号并对其进行处理，构建基于 AEWins 的粘结应力与声音信号相关性的试验模型。试验过程中采用了 12mm、16mm、20mm 的带肋螺纹钢筋进行对比试验，并选取了 12mm 的螺纹钢筋进行了钢筋拉伸试验，建立了基于 12mm 螺纹钢筋的荷载-应变数据库，通过数据库，对 12mm 螺纹钢筋浇筑混凝土进行拉拔试验，得出了沿钢筋长度方向上粘结应力的分布。最后加入声发射信号图进行比对，明确了粘结应力与声发射信号之间的关系，通过声音信号幅值的强弱，可判别试件粘结应力的大小及钢筋混凝土内部事件发生的激烈程度，为进一步试验打下了基础。

关键词：钢筋混凝土；声发射技术；粘结应力；分布；相关性

Study On the Correlation Between the Bond Stress and Acoustic Amission Signal of Reinforced Concrete

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Abstract:

The bond properties of steel and concrete is more complex, although the bond test has been 100 years of history, published a large number of test data, but at present people for detection methods of reinforcement and concrete is extremely limited, the bond
failure mechanism is complex, and the test technology and other reasons, some basic issues of bond the remains to be solved. In this paper, the acoustic emission technology is used to study the distribution of bond stress along the length direction in the drawing test, and the sound signals are collected at different positions and processed. The experimental model of bond stress and sound signal correlation based on AEWins is built. In the process of test by 12mm, 16mm and 20mm Ribbed Rebar were tested, and the selection of rebar of 12mm steel tensile test, a load - 12mm rebar strain database, based on the database, the 12mm rebar pouring concrete pull-out test, the distribution along the bar the length of the bond stress. Add figure comparing acoustic emission signal, the bond stress and the relationship between the acoustic emission signal, the amplitude of the signal through the sound intensity, intense degree identification specimen bond stress size and reinforced concrete internal events, the foundation for further tests.

keywords:reinforced concrete；acoustic emission technology；bond　stress；distribution；correlation.

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Modal Identification of Structures by ACP

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Abstract: In this paper, the background and significance of the subject are expounded, and the current research methods and problems of structural modal parameter identification are systematically discussed. The development of blind source separation and its application in structural identification are briefly introduced. The mathematical knowledge, basic principle and preprocessing method of complex pursuit are briefly introduced. The iterative process of the original algorithm uses fixed step size and nonlinear function, which makes the algorithm not adaptive enough. For this reason, the iterative process of the original algorithm is improved according to kurtosis and optimal step size, and an adaptive complex tracking algorithm with wider applicability and better separation effect is formed. A new method to identify structural modal parameters by complex pursuit was developed. The relationship between the dynamic response of multi-degree-of-freedom structural system and the complex pursuit model is discussed. The modal responses and modes of the structure are separated by the complex pursuit algorithm, and the modal frequencies and damping ratios are analyzed by Hilbert transform. Different models are used to verify the reliability of the method in accurately identifying structural modal parameters.

Key words: modal parameter identification; blind source separation; modal responses; a new method

虚拟现实技术在桥梁结构运营安全监测中的应用研究

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（哈尔滨工业大学）

摘　要：摘要：三维全景虚拟现实技术能够为用户提供真实场景还原和环境沉浸感。利用该技术可实现桥梁结构监测数据与运营环境的结合，从而有助于管理人员真实感知桥梁结构运营状态，提升桥梁结构安全运维的管理效率。以某一实际立交桥梁为研究对象，采用三维全景虚拟现实技术与 B/S（浏览器/服务器）架构相结合，研发该立交桥梁结构运营安全监测软件系统；详细介绍了该软件系统的功能模块，并讨论了虚拟现实技术在各功能模块研发中的关键问题。实际应用结果表明，三维全景虚拟现实技术能够满足桥梁结构运营安全监测中的实时监控、信息管理、虚拟漫游、运维管理等多方面的需求，该技术在结构运营安全监测领域具有广阔的应用前景。

关键词：桥梁结构；三维全景虚拟现实技术；结构运营安全监测；软件研发

Application of the Virtual Reality Technology in Structural Safety Monitoring of Bridges

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Abstract:

Abstract: Three-dimensional panoramic virtual reality (VR) technology provides users with real scene reconstruction and immersion. With this technology, the bridge measured data obtained from structural health monitoring system are combined with the operation environment, which helps the managers to truly diagnose the structural condition of bridges; thus, this technique is beneficial to improve the level and efficiency of bridge maintenance. Taking actual bridge as an example, a software system for operational safety monitoring of this bridge is developed，combined the 3-D panoramic VR technology and B/S (Browser/Server) architecture system. The function modules of the software system are introduced in detail, and the key issues of VR technology in the development of each function module are discussed. The results show that the 3-D panoramic VR technology completely meets the needs of real-time monitoring, information management, virtual roaming and maintenance management in bridge structural safety monitoring. It is promising to widen the application of the proposed technique in the field of structural safety monitoring..

keywords: Bridges; Three-dimensional panoramic virtual reality technology; Structural safety monitoring; Software development

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Functional Transformation-Based approach for Distributional Data Analysis in Structural Health Monitoring

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摘　要：目前很多桥梁都安装了结构健康监测系统用于实时监测荷载、环境以及结构响应等信息。经过数十年的发展，结构健康监测系统的设计、安装以及运营都已相对成熟。长期在线监测积累了海量数据，数据处理与分析在结构健康监测中变得越来越重要。概率分布在结构健康监测的许多应用中扮演着非常重要的角色，本文聚焦于监测数据概率密度函数时间序列统计分析方法。概率密度函数本质上属于函数型数据，函数型数据分析是当前统计学的研究热点之一。但是，概率密度函数属于特殊函数，若直接套用针对普通函数的通用函数型数据分析方法一般会遇到诸多问题。本文基于对数分位密度变换、函数型主成分分析等技术提出了一种函数型时间序列分析方法用于结构健康监测数据概率分布时间序列建模与分析，并利用模拟数据验证了方法的有效性。

关键词：结构健康监测；函数型数据分析；概率分布；时间序列

Functional Transformation-Based Approach for Distributional Data Analysis in Structural Health Monitoring

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Abstract:

Structural health monitoring (SHM) systems have been widely incorporated into bridges for collecting information of loads, environment and structural responses. After decades of development, the design, installation as well as operation of SHM systems have become relatively mature. Long-term monitoring has accumulated massive data; data analysis has become increasingly important in structural health monitoring. Probability distributions play a very important role in many applications of structural health monitoring; this study focuses on statistical analysis methods for dataset consist of probability density functions (PDFs) of monitoring data, which is termed distributional data. PDF-valued data (each data item is a PDF) essentially belong to functional data, functional data analysis (FDA) is a relatively new branch of statistics. PDFs belong to special functions, directly applying general FDA methods to PDF-valued data is problematic due to the constrains of PDFs are neglected. In this article, a functional time series analysis method based on log-quantile-density transformation and functional principal component analysis is proposed for modelling distributional time series of structural health monitoring data, and a simulation example is conducted to illustrate and validate the method..

keywords: Structural health monitoring; functional data analysis; probability distributions; time

series

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基于随机减量技术的桥梁涡激共振自动识别研究

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（湖南大学）

摘　要：涡激共振是一种常见的风致振动病害，其致振机理较为复杂，结构健康监测技术可为研究涡激共振提供大量数据。针对如何从海量在线数据中识别涡激共振的问题，本文提出了基于随机减量技术对时域信号进行分析，从而自动识别出涡激共振的方法。通过对信号的随机减量处理，涡激共振与环境振动信号的处理结果有明显的不同，本文通过变异系数反映二者的差异，并定义了阈值进行区分，当随机减量信号的变异系数低于阈值时，判断为涡激共振。通过数值仿真和我国西堠门大桥实测数据验证了本方法的可行性。

关键词：涡激共振；桥梁工程；随机减量技术

Automatic Identification of Bridge Vortex-Induced Vibration Using Random Decrement Method

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Abstract:

Vortex-induced vibration (VIV) has been occasionally observed on long-span steel box-girder bridges. The underlying mechanism of VIV is very complicated and reliable theoretical methods for prediction of VIV have been not established yet. Structural health monitoring (SHM) technology can provide a large amount of data for investigating VIV. In this study, a method based on random decrement technique (RDT) is proposed to identify the VIV response automatically from massive acceleration response without manual intervene. A threshold based on the coefficient of variation (COV) is defined to distinguish the two kinds of responses, namely VIV and wind-induced buffeting. A three-DOF mass-spring-damper system with numerically simulated VIV and random vibration is examined to verify the proposed method. The method is finally applied to the Xihoumen suspension bridge for identifying VIV response from three-month monitoring data..

keywords: Vortex-induced vibrations; random decrement method; key words:　bridge engineering

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Evaluation of the Impact Echo Method for Concrete Bridge Decks with Asphalt Overlays

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Abstract: Asphalt overlays have been commonly used to extend the service life of deteriorated concrete bridge decks. Nonlinear, viscoelastic asphalt has properties that differ considerably from the properties of the underlying portland cement concrete (PCC) deck. The impact echo (IE) method has been extensively used to nondestructively evaluate PCC structures. The method, however, performs differently on asphalt overlays, especially when a membrane is placed between the overlay and the deck. The general recommendation has been to perform IE tests on asphalt overlays in cold weather. The temperature range under which IE can work, however, is still uncertain. This study was conducted to systematically examine IE performance on asphalt overlays. Three PCC specimens with three types of asphalt overlays—asphalt with a liquid membrane, asphalt with a sheet membrane, and asphalt without a membrane—were tested in a temperature chamber. The three PCC specimens had identical designs, materials, and artificial defects. NDE results from the tests indicate that: (1) 32 ° F and below is the appropriate temperature range for IE to detect defects in the underlying deck and (2) membranes can significantly reduce the propagation of waves into the underlying deck.

Key words:concrete bridge decks; asphalt overlays; impact echo; nondestructive evaluation

基于云计算的实时桥梁结构健康状况评估

赵智勇[1]，武光芬[1]，李利军[2]，洪卫星[2]，朱培栋[2]
（1. 江苏前沿交通研究院；2. 南京智行信息科技有限公司）

摘　要：鉴于公路网络中的桥梁由于设计施工原因、载荷超重原因、材料老化原因存在许多安全隐患且人工定期检测无法实时预警垮塌风险与提供量化的养护建议，本研究提出了一种基于测量数据的客观的桥梁结构状况实时评估系统。为满足实时桥梁结构健康状况评估的要求，本系统使用了一种以梁横向载荷分布系数为监测指标的桥梁结构损伤探测方法，通过多元回归分析的方法，去除了环境因素与交通因素径对梁横向载荷分布系数的影响，提高桥梁结构损伤探测的精确度；利用统计学中威尔科克森秩和检验的框架，提高了结构损伤探测的速度；使用了桥梁结构签章的概念，对可能的结构损伤位置与程度进行了评估；结合了云计算技术，提高了系统的可靠性与可拓展性，使得结构健康状况评估从数据采集到自动做出管养建议或预警信息只需要几分钟的时间，显著提高了桥梁管养的效率，真正接近实时结构健康监测的目标，为大规模桥梁结构群的监测提供参考。

关键词：桥梁结构健康监测；云计算；梁横向载荷分布系数

Cloud Based Real-Time Bridge Condition Assessment

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Abstract:

For the reason of defects during bridge design and construction, overload truck traffic, and aging materials, many bridges in the road network have the risk of collapse given the current manual inspection requirement can’t provide quantitative advise for bridge maintenance. In order to achieve the real-time bridge condition assessment, the proposed system utilized the detrended Girder Distribution Factors(GDFs) as the monitoring index where a multiple regression model was adopted to remove the affects of environment and traffic; using the Wilcoxon rank-sum test as the hypothesis test framework increased the speed of bridge damage detection computation; bridge signature was constructed to identify the possible damage location and degree; integrating the cloud computing into the system boosted the overall system reliability and Expandability, which makes it possible that assessing the bridge condition within the minutes of data collection.Such a system improves the bridge management significantly and demonstrates a possible solution for near real-time bridge structural health monitoring of massive bridges in road network..

keywords:bridge structural health monitoring; cloud computing; girder distribution factor

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跨海大桥实测风场特性分析

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摘　要：风场特性实测分析对于实际结构的振动分析具有重大意义，针对位于海域环境下的金塘大桥实测数据，采用统计和频谱分析的方法对桥址处风场参数及拉索风雨激振进行研究。研究结果表明：舟山海域的无量纲幂指数与强风作用下小于规范建议值，而顺风向湍流度大于规范值，桥址处顺风向和竖向脉动紊流功率谱与桥规所采取的风谱相比在低频处偏低，高频处偏高。主跨长索由于采用了螺旋线，表面凹坑以及阻尼器，拉索风雨激振得到有效控制，但仍需注意由于较高的紊流度而引起高阶涡激振动的几率增大。

关键词：海域环境；风场特性；健康监测；斜拉索

Analysis of Wind Field Characteristics of Sea-Crossing Bridge

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Abstract:

The actual measurement analysis of the characteristics of wind field is of great significance for the vibration analysis of the actual structure. For the measured data of the Jintang Bridge in the sea, the wind field parameters and the wind -rain induced vibration of stayed cables are studied by statistical and spectrum analysis methods. The results show that the dimensionless power exponents and strong winds in Zhoushan sea area are smaller than the recommended values, while the downwind turbulence is greater than the normative value. The power spectrum of the downwind direction and vertical pulsation turbulence at the bridge site and the wind spectrum adopted by the bridge gauge The high frequency is higher than the low frequency. Due to the use of spiral lines, surface pits and dampers, wind-rain induced vibration is effectively controlled, but it is still necessary to pay attention to the increase of the probability of high-order vortex-induced vibration due to high turbulence..

keywords:sea environment; characteristics of wind field; health monitoring; stayed-cables

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承台-桩基组合结构在波浪作用下的群桩效应研究

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摘　要：跨海桥梁由于身处复杂的海洋环境中，下部结构往往会承受较大的波浪荷载，而跨海大桥下部结构大都采用承台-桩基组合结构，桩基通常又以群桩形式存在，群桩受到的波浪力往往成为结构的控制荷载，而承台结构的存在会影响群桩的受力特性，因此研究承台-桩基组合结构的群桩效应具有重要的工程意义和科研价值。本文利用 CFD 软件 FLOW-3D 软件，基于粘性不可压缩流体的雷诺时均 N-S 方程及 RNG k-ε 湍流模型，采用有限差分法对控制方程进行离散，建立了波浪与圆形承台-桩基组合结构相互作用的数值模型，并基于此数值模型研究了圆形承台-桩基组合结构在波浪作用下的群桩效应以及冲刷作用。

关键词：承台尺寸；圆形承台；组合结构；群桩效应；FLOW-3D；冲刷监测

Reasearch on Pile Group Effect of Composite Structures Under Wave Action

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Abstract:

Most of the crossing-sea bridge's substructure adopts the cap-pile composite structure. The wave force is the control load of the pile group structure, and the pile cap will affect the force characteristics of the pile group. In this paper, using FLOW-3D, based on Reynolds time-averaged NS equation and RNG k-ε turbulence model, the finite difference method is used to discretize the governing equations, and the numerical model of the interaction between wave and combined structure is established. Based on the numerical model, the group pile effect of circular cap-pile composite structures under wave action is studied..

keywords:cap size; circular cap; combined structure; group pile effect; FLOW-3D; scour monitoring

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Prestress Monitoring of a Steel Strand in an Anchorage Connection Using Piezoceramic Transducers and Time Reversal Method

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Abstract: Steel strands are widely used in cable stay or suspension bridges. The safety and stability of steel strands are important issues during their operation period. Steel strand is subjected to various types of prestress loss which loosens the wedge anchorage system, negatively impacting the stability of the structure and even leading to severe accidents. In this paper, the authors propose a time reversal (TR) method to monitor the looseness status of the wedge anchorage system by using stress wave based active sensing. As a commonly used piezoceramic material, Lead Zirconate Titanate (PZT) with a strong piezoelectric effect is employed. In the proposed active sensing approach, PZT patches are used as sensors and actuators to monitor the steel strand looseness status. One PZT patch is bonded to the steel strand, one PZT patch is bonded to the wedges, and another PZT patch is bonded to the barrel. There are three different interfaces of the wedge anchorage system to monitor the steel strand looseness status. The TR method is utilized to analyze the transmitted signal between PZT patches through the wedge anchorage system. Compared with the peak values of the TR focused signals, it can be found that the peak value increases as the wedge anchorage system tightness increases. Therefore, the peak value of the TR focused signal can be used to monitor the tightness of the steel strand. In addition, the experimental results demonstrated the time reversal method’s reliability, sensitivity and anti-noise property.

Key words:piezoceramics; Lead Zirconate Titanate (PZT); prestress monitoring; steel strand; wedge anchorage system; time reversal method

Automatic Structural Crack Detection Based on Fully Convolutional Networks

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Abstract: Cracks are a potential threat to the safety and endurance of civil infrastructures, and therefore careful and regular structural crack inspection is needed during their long-term service periods. Many image processing approaches have been developed for structural crack detection. However, like traditional edge detection algorithms, these methods are easily disturbed by the environmental effect. The convolutional neural networks (CNNs) are newly developed methods and have excellent performances in the image classification tasks. This study proposes a fully convolutional network (FCN) called Ci-Net for structural crack identification. Pixel-level labeled image training data are obtained from the online dataset. Four indices are adopted to evaluate the performance of the trained Ci-Net. Crack images from an indoor concrete beam test are adopted for validation of its structural crack recognition capacity. The recognition results are also compared with those obtained by the edge detection methods. It indicates that Ci-Net exhibits a better performance over the edge detection methods in structural damage detection.

Key words: Structural Health Monitoring; Structural Crack Detection; Deep Learning; Convolutional Neural Networks; Fully Convolutional Networks

Stochastic Characterization of Wind Properties Using Structural Health Monitoring Data

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Abstract: This paper aims to conduct a stochastic characterization of wind field characteristics nearby an arch bridge based on long-term monitoring data from an instrumented structural health monitoring (SHM) system. The fluctuating wind characteristics are first presented by analyzing the real-time wind monitoring data. A genetic algorithm (GA)-based finite mixture modeling approach is proposed to formulate the joint distribution of the wind speed and direction. For the probability density function (PDF) of the wind speed, a two-parameter Weibull distribution is applied, and a von Mises distribution is selected to present the PDF of the wind direction. The parameters of finite mixture models are estimated by the GA-based parameter estimation method. The effectiveness of the proposed direct probabilistic modeling approach is validated by use of one-year of wind monitoring data, and compared with the traditional angular-linear (AL) distribution-based indirect modeling approach in terms of the Akaike's information criterion (AIC), Bayesian information criterion (BIC) and R2 value. Results indicate that the proposed GA-based finite mixture modeling approach fits the measured data better than the AL distribution-based indirect modeling approach. In addition, the joint distribution of the wind speed and direction will facilitate the wind-resistant design and wind-induced fatigue assessment of long-span bridges.

Key words: Structural Health Monitoring; Wind Field Characteristics; Joint Probability Density Function; Finite Mixture Distribution; Genetic Algorithm

Computer Vision-Based Identification of Structural Dynamic Characteristics

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Abstract: As a convenient and effective tool for monitoring of the structural behaviors of civil infrastructure, the machine vision-based sensing technology integrated with digital image processing algorithm has achieved great progress in the field of structural health monitoring (SHM). The prominent advantages of this kind of measurement technology mainly include non-contact, long-distance and high-resolution. Up to now, various types of vision-based systems have been developed and applied in structural performance monitoring of engineering structures, however, seldom investigations are relevant to monitoring of structural dynamic characteristics. In this paper, the method for multi-point synchronous measurement of structural dynamic displacement is proposed. The structural modal parameters are identified using measured multi-point dynamic displacements and fast Fourier transform. A simple-supported rectangle steel beam model is established for conducting experiments to investigate (i) comparison study on the measurement results obtained by the vision-based system and the accelerometer, (ii) the effect of the measurement distance on the accuracy of the vision-based system, and (iii) the feasibility of different types of targets (LED lamp and black spot). The experimental results show that the proposed vision-based method is effective, accurate and stable for structural dynamic response monitoring and modal parameter identification.

Key words:structural health monitoring; vision-based technology; digital image processing algorithm; structural dynamic response; modal parameter identification

基于光纤光栅的机场航站楼扰动区承台大体积混凝土监测

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摘　要：目前，大体积混凝土在车站、桥梁、机场等大型工程中的应用越来越广泛，但是仍有很多工程存在大体积混凝土结构的温度裂缝问题，影响到了工程的整体质量，破坏建筑的安全性和实用性。为了有效监测大体积混凝土在浇筑后的温度以及应变的变化，本文利用光纤光栅传感系统，在青岛胶东国际机场的施工现场对浇筑后的扰动区承台大体积混凝土进行了为期 4 天的持续监测，并在后续以天为单位进行监测。测得结果显示，在浇筑后的 4 天内，其中部温度主要维持在 57~63℃之间，第二天为温度最高的时期。边部温度在第一天达到 64℃之后缓慢下降，第 4 天降至 48℃，并测得浇筑后 4 天内其内部应变缓慢下降，之后温度曲线逐渐平稳。测试结果表明，光纤光栅传感系统可以很好的监测大体积混凝土浇筑后的温度及应变情况，而且可以在后续持续监测结构在施工及正常使用阶段的状态，为结构安全提供了保障。

关键词：光纤光栅；大体积混凝土；机场扰动区；结构健康监测

Large Volume Concrete Monitoring of Bearing Platform in the Disturbance area of Airport Terminal Based on Fiber Bragg Grating

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Abstract:

At present, the applications of large volume concrete in large projects such as railway stations, bridge and airports are more and more extensive. However, there are still many temperature crack problems of large volume concrete structure which affect the overall quality of the project, destroy the safety and practicability of the building. In order to effectively monitor the temperature and strain changes of large volume concrete after pouring, this paper used the fiber Bragg grating sensing system to continuously monitor the large volume concrete of the bearing platform in the disturbed area of airport terminal of 4 days at the construction site of Qingdao jiaodong international airport. Then, follow-up monitoring was conducted on a daily basis. Measured results show that 4 days after pouring, temperature in the middle is mainly maintain between 57 ~ 63 ℃, the next day for the period of maximum temperature. Temperature of edge in slow decline after the first day of 64℃, the fourth day has fallen to 48 ℃. And it was found that the internal strain decreased slowly within 4 days after pouring and then gradually stabilized. From the structure result，it can be obtained that the fiber Bragg grating sensing system can well monitor the temperature and strain of the large volume concrete after pouring, and can continuously monitor the state of the structure in the construction and normal use stage in the follow-up, providing a guarantee for the safety of the structure..

keywords:fiber Bragg grating; large volume concrete; disturbance region of airport; Structural health monitoring

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适用于桥梁监测的光纤光栅二维倾角传感器

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摘　要：本文针对大型桥梁工程结构健康监测提出了一种光纤光栅二维倾角传感器。该传感器以力的平衡原理为理论基础，利用两根相互垂直的光纤将质量球固定在传感器中央，传感器倾斜时质量球在传感器底板平面内产生重力分量，从而使两根光栅产生波长变化。通过传感元件的力学模型及光纤光栅传感原理对倾斜角度与质量球重力分量的关系进行了分析，给出了倾斜角度、倾斜方向与光纤光栅波长漂移量之间的关系表达式。结果表明，该光纤光栅二维倾角传感器测量精度高，线性度良好，具有温度自补偿功能，具有较好的桥梁工程应用前景。

关键词：倾角传感器；光纤光栅；结构健康监测

Fiber Bragg Grating (FBG) 2D Inclination Sensor for Bridge Monitoring

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Abstract:

In this paper, a fiber Bragg grating (FBG) two-dimensional tilt sensor is proposed for structural health monitoring of large Bridges. The sensor is based on the balance principle of force, and two mutually perpendicular optical fibers are used to fix the mass ball in the center of the sensor. The relationship between the tilt Angle and the gravity component of the mass sphere is analyzed through the mechanical model of the sensing element and the fiber Bragg grating sensing principle. The results show that the sensor has high precision, good linearity, self-compensation function of temperature and good application prospect in bridge engineering..

keywords: Tilt Angle Sensor; Fiber Bragg Grating; Structural Health Monitoring

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桥梁影响线的快速准确识别及其实桥验证

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摘 要：影响线反映桥梁结构的固有特性，监测桥梁在不同使用阶段的影响线状态及其变化趋势，对于评估桥梁服役性能有重要意义。但是，桥梁响应的动力效应等因素增加了准确识别影响线的难度。本文基于正则化理论与B样条曲线提出一种桥梁影响线精确识别方法，使得识别解满足数学最优的同时，更加符合影响线的物理意义。该方法采用基函数扩展法建立新的影响线表达形式，结合吉洪诺夫正则化方法，建立优化目标函数，并求解基函数权重系数。通过实验室钢筋砼三跨连续梁和简支钢筋混凝土梁桥的试验验证，表明了该影响线识别方法具有较高的识别精度，并具备工程应用的良好潜力。

关键词：桥梁；影响线；B样条曲线；试验验证

A Fast and Accurate Identification Method of Bridge Influence Lines and Its Field Verification

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Abstract:

Influence line (IL) reflects inherent characteristics of bridge structures. Monitoring bridge IL conditions and its changing trends at different stages of life cycle, it is of great significance for evaluating service performance of bridge. IL could be identified based on vehicle information and vehicle-induced bridge response. However, the inevitable interference factors such as dynamic effect in the bridge response make it difficult to accurately identify IL. In this study, a bridge IL identification method is proposed based on regularization theory and B-spline curves, which enable the identified IL not only satisfies mathematical optimal but also conforms to physical meaning. The basis function expansion method is first introduced to make an alternative representation of IL, then integrated with the Tikhonov regularization method, the optimization objective function is established to determine weight coefficients of the function. The feasibility of proposed method is verified through experimental verification on a three-span continuous reinforced concrete beam in laboratory and a simple-supported RC beam bridge. Results indicate that the identification method has a high accuracy, and thus has a promising prospect for further engineering applications.

keywords: bridge; influence line; regularization; B-spline curve; experimental verification

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Bridge Influence Line Identification Based on Sparse Regularization Method

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Abstract: Bridge influence line (BIL) is a promising tool for the real applications in the fields of bridge Weight-in-Motion (BWIM), model updating, damage identification and load carrying capacity evaluation. The key of such applications is how to obtain the accurate results of BIL. To accurately identify BIL based on bridge dynamic responses induced by a moving vehicle, two critical problems including how to construct a general representation function of BIL and how to deal with the ill-posed inverse problem, should be properly resolved. This paper proposes a novel approach based on sparse regularization technique for BIL identification. The identified BIL results are accurate, indicating that the proposed sparse regularization techniques are effective to improve the quality of BIL identification. It is also shown that the proposed approach is not sensitive to the noise interference and configuration of testing vehicle.

Key words: BIL identification; inverse problem; sparse regularization; monitoring system

Mode Identification by the Reducing Influence of Excitation

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Abstract: In practical engineering, the structures are always excited by non-white noise. It conflicts with the assumption of mode identification in time domain, such as eigensystem realization algorithm (ERA). This paper proposes a mode identification method based on ERA using frequency response function. The ratio of the cross-power and auto-power spectral density functions of the measurement signals is calculated. The inverse Fourier transform of the multiplication of the ratio is the performed, which is the virtual impulse response and can be used to identify modes by ERA. It is validated by a numerical example. The results show that virtual impulse response can have much better free decayed behavior than natural excitation technique, and identify very precise modal parameters.

Key words: Mode identification; eigensystem realization algorithm; frequency response function; impulse response

The Vertical Displacement Induced by Temperatures in a Complicated Long-Span Arch Bridge

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Abstract: Establishing the relationship between structural responses and environmental effects is a significant issue for extracting reliable structural damage indexes. Based on long-term monitoring data obtained from the Jiubao Bridge, the time-histories of the effective temperatures and the vertical displacements in the bridge deck and the correlation of temperature and vertical displacement are investigated. The results indicate that the vertical displacement has strong and nonlinear relationship with the effective temperature in the same cross-section. The conclusion is expected to provide reference for the design and evaluation of arch bridges.

Key words: Long-span bridge; displacement; temperature; arch bridge

Wireless Sensor Placement for Structural Health Monitoring Considering Information and Network

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Abstract: Optimal sensor placement is essential to design an effective structural health monitoring (SHM) system for a large-scale structure. Due to some attractive features of wireless sensor networks (WSNs), the extensive utilization of WSN-based SHM systems is promoted. When finding the optimal wireless sensor placement (OWSP), the performance of the WSNs is emphasized except the performance of data because wireless sensors are generally equipped with limited energy resources and bandwidths. Unfortunately, the two objectives are in conflict with each other and difficult to be optimized simultaneously. In the paper, the OWSP is formulated as a multi-objective optimization problem with the aim of finding a wireless sensor configuration trade-off modal independency and energy efficiency while maintaining the connectivity of the whole WSN. A multi-objective firefly algorithm (MOFA) is developed to find the Pareto front in the OWSP. A directive movement strategy is employed to drive fireflies to fly toward the Pareto front, while the nondirective movement approach is introduced to keep the diversity of the firefly population. Numerical simulation of a cable stayed bridge is performed to demonstrate the effectiveness of the MOFA. The results indicate that the developed MOFA is capable of capturing the Pareto optimal wireless sensor configurations with high accuracy and efficiency. Many wireless sensor configurations are provided to meet the demand of excellent modal independency or the requirement of high energy efficiency.

Key words: structural health monitoring; wireless sensor network; optimal sensor placement; energy

基于应变监测的桥面板弯曲变形测量

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摘 要：本文提出了一种基于应变测量的弹性支撑桥面板变形监测方法，该监测方法主要是将梁的变形监测理论拓展为二维平面内的变形监测，建立全桥面的二维应变多项式目标函数，并利用最小二乘法拟合求得目标函数的系数向量，再通过二次积分代入具体的边界条件求出桥面板的挠度函数，即可获得板任意位置的变形状态。对弹性支撑桥面板采用多种加载方式进行数值模拟和噪声模拟，实验结果与理论模拟相符，验证了该方法的可行性。这种弯曲变形监测方法能够保证精度的条件下以低成本和简易设备监测板的弯曲变形，对结构的健康监测和安全评估等具有重要的理论意义与工程应用价值。

关键词：桥梁变形监测

Monitoring of Bending Deformation of Bridge Deck Based on Strain Measurement

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Abstract:

This paper proposes a deformation monitoring method of elastically supported bridge deck based on strain monitoring, which mainly expands the deformation monitoring theory of beam to become the deformation monitoring of two-dimensional plate, and derives the deformation monitoring theory of plate by creating tow-dimensional polynomial function which represents the strain field using a least-squares surface-fitting algorithm. Various loading tests were experimentally performed through numerical simulation and simulation of noise. Good agreements between experimental results and theoretical simulation verified the feasibility of the method. By ensuring the accuracy of results, this method can monitor the bending deformation of the plate with low cost and simple equipment, which has important theoretical significance and engineering application value for the structure health monitoring and safety evaluation.

keywords: Bridge deformation monitoring

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基于动态缩聚和 L1 正则化的有限元模型修正

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摘 要：本文基于动态缩聚法和 L1 正则化方法提出了一种精确高效的有限元模型修正方法。该方法通过改进的动态缩聚法将整体结构运动方程转化为尺寸非常小的缩聚系统运动方程。结构响应及响应灵敏度基于缩聚系统计算能提高其计算效率，将其应用于基于灵敏度的有限元模型修正方法能大幅改善模型修正的效率。当结构监测数据少于其设计参数时，有限元模型修正问题可能成为病态问题，无法得到精确结果。由于有限元模型仅在局部位置存在建模误差即设计参数具备稀疏性，本文采用 L1 正则化方法求解模型修正病态问题。其通过在目标函数中附加 L1 正则化项限制设计参数的稀疏性。最后，本文提出的有限元模型修正方法的精度和效率通过一简支梁模型得到了验证。

关键词：结构健康监测；有限元模型修正；动态缩聚法；L1 正则化

Finite Element Model Updating Using Dynamic Condensation and L1 Regularization Approach

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Abstract:

This paper proposes an efficient finite element model updating method using dynamic condensation and L1 regularization approach. An improved dynamic condensation approach is derived to condense the vibration equation of the global structure into a much smaller one after a simplified process. The structural responses and response sensitivities are calculated based on the condensed model, which helps to improve the efficiency of the sensitivity-based finite element model updating greatly. The finite element model updating can be an ill-posed problem if the number of measured data available is smaller than that of the designed structural parameters. Since the designed structural parameters are sparse as modelling error often occurs only at several locations, the L1 regularization approach is employed to solve the ill-posed problem. It adds an extra L1 regularization item in the objective function to ensure the sparsity of designed parameters. Finally, the superiorities of the proposed model updating method in precision and efficiency are verified by a simple beam.

keywords: structural health monitoring; finite element model updating; dynamic condensation approach; L1 regularization approach

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基于非接触式雷达挠度测量系统的桥梁准静载影响线识别研究

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摘 要：应用非接触式雷达微波干涉 IBIS-S 遥测系统监测桥梁在车载作用下的位移影响线。建立的有限元模型，计算考虑动载效应的位移时程分析结果。依托实桥现场实测，并对比分析实测与理论计算结果以验证该发方法的可靠性与准确性。为消除动载效应的干扰，以桥梁跨中挠度为研究对象，进行基于动载效应的挠度影响线识别。针对挠度时程曲线特点，采用 dbN 算法进行基于动载挠度时程曲线的影响线识别，建立评价识别后曲线与标准静态影响线差别的误差指标，基于该指标验证了该方法的准确性与适用性。结果表明 IBIS-S 遥测系统不仅精度高，而且可以完整地获取加载整个过程的位移影响线；dbN 算法进行影响项目识别的方法具有较高的识别精度与良好的适用性。

关键词：桥梁工程；挠度；影响线；dbN 算法

Research on Bridge Quasi-Static Load Influence Line Identification Based on Non-Contact Radar Deflection Measurement System

Yang Kang , Ding Youliang
(Southeast university)

Abstract:

The non-contact radar microwave interference IBIS-S telemetry system is used to monitor the displacement influence line of the bridge under the action of vehicle. The established finite element model is used to calculate the displacement time history analysis results considering the dynamic load effect. Based on the actual measurement of the actual bridge, and comparative analysis of the measured and theoretical calculation results to verify the reliability and accuracy of the method. In order to eliminate the interference of the dynamic load effect, the deflection of the mid-span of the bridge is taken as the research object, and the deflection influence line recognition based on the dynamic load effect is performed. According to the characteristics of the deflection time-history curve, the dbN algorithm is used to identify the influence line of the dynamic-load deflection time-history curve, and the error index of the difference between the evaluation curve and the standard static influence line is established. The accuracy and application of the method are verified based on the index. Sex. The results show that the IBIS-S telemetry system not only has high precision, but also can completely acquire the displacement influence line of the whole process. The dbN algorithm has high recognition accuracy and good applicability.

keywords: Bridge engineering; deflection; influence line; dbN algorithm

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基于改进分枝——约界法的连续刚构桥失效模式研究

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摘　要：准确搜寻连续刚构桥的失效模式，是准确计算连续刚构桥可靠度的核心任务之一。针对连续刚构桥恒载占比较大，淹没了可变荷载效应，使失效模式在搜寻过程中出现遗漏，以及通过删除失效单元不考虑失效单元恒载引起的内力重分布，造成失效模式与结构实际受力性能不符的情况，提出了更全面反应连续刚构桥的失效模式的识别方法。本文对全局临界强度分枝-约界法进行改进，将构件本身恒载效应和失效单元重分布的恒载效应从结构构件有效强度中扣除，建立改进后的方法的失效模式搜寻路径；利用两跨连续桥梁有限元模型和某连续刚构桥对改进后的全局临界强度分枝-约界法进行验证。结果表明：改进后的方法得到了连续刚构桥的主要失效模式，失效路径与桥梁实际破坏情况相符，且不会遗漏桥梁结构体系的失效模式。

关键词：桥梁工程；失效模式；改进分枝——约界法；连续刚构桥；恒载效应

Study on Failure Mode of Continuous Rigid Frame Bridges Based on Improved Branch and Bound Method

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Abstract:

Accurately searching for the failure mode of continuous rigid frame bridge is one of the core tasks for accurately calculating the reliability of continuous rigid frame bridges. In view of the large load of continuous rigid frame bridge, the variable load effect is inundated and the failure mode is missed during the search process, and the failure mode and structure are eliminated by deleting the failed unit without considering the redistribution of internal forces caused by dead load of dead unit. The actual force performance does not match the situation, put forward a more comprehensive response to continuous rigid frame bridge failure mode identification method. In this paper, the global critical strength branch-and-bound method is improved, and the dead load effect of the component itself and the dead-load redistribution effect are subtracted from the effective strength of the structural component. The improved search path of the failure mode is established. The cross-continuous bridge finite element model and a continuous rigid frame bridge are used to verify the improved global critical strength branch-and-bound method. The results show that the improved method has obtained the main failure mode of continuous rigid frame bridge, and the failure path coincides with the actual failure of the bridge without omitting the failure mode of the bridge structural system.

keywords: bridge engineering; failure mode; improved branch and bound method; continuous rigid frame bridge; dead load effect

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大跨径连续刚构桥跨中下挠影响因素分析及防治措施探讨

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（吉林省交通规划设计院）

摘 要：大跨度 PC 连续刚构桥跨中下挠过大，会逐渐引起梁体开裂，梁体裂缝的存在和发展会降低了结构本身的刚度和抗变形能力，两者相互影响，相互加剧，严重影响了大跨度 PC 连续刚构桥的使用安全。本文以辉南至白山高速公路凉水特大桥（86m+160m+86m）PC 连续刚构桥为实际工程背景，对大跨度 PC 连续刚构桥长期下挠进行分析，提出防治预防措施。

关键词：大跨径；PC 连续刚构桥；跨中下挠；防治措施

Cause Analysis and Preventive Measures of Mid-Span Downward Deflection of Long-Span PC Continuous Rigid Frame Bridge

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Abstract:

Over-large midspan deflection of PC continuous rigid frame bridge will gradually cause beam cracking. The existence and development of beam cracks will reduce the stiffness and anti-deformation ability of the structure itself. The interaction and intensification of the two will seriously affect the safety of long-span PC continuous rigid frame bridge. Taking Liangshui Bridge (86m+160m+86m) PC Continuous Rigid Frame Bridge of Huinan-Baishan Expressway as an actual engineering background, this paper analyses the long-term deflection of long-span PC Continuous Rigid Frame Bridge, and puts forward preventive measures.

keywords: Long Span; PC Continuous Rigid Frame Bridge; midspan deflection; Preventive measures

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基于非线性 ARX 代理模型的车——桥系统响应预测

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摘 要：为了提高车——桥系统可靠性的计算效率，采用非线性 ARX（Auto-Regressive with eXogenous input）模型为代理模型，对车——桥系统的响应进行了预测。讨论了代理模型方法在车体竖向加速度、横向加速度和轮轴横向力预测时的准确性，并通过蒙特卡洛模拟（MCS）进行了验证。结果表明，非线性 ARX 模型对车体竖向加速度有较高的预测精度，横向加速度次之，轮轴横向力极值的预测精度稍差，相比于 MCS，ARX 模型的计算效率大幅度提升，可适用于车——桥耦合系统的可靠性分析。

关键词：车——桥系统；非线性 ARX 模型；代理模型；蒙特卡洛模拟

Response Prediction of Vehicle-Bridge Systems by Nonlinear ARX-Based Surrogate Model

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Abstract:

To improve the efficiency of reliability calculations for vehicle-bridge systems, a surrogate model based on nonlinear autoregressive with exogenous input (ARX) model is used to forecast the response of the vehicle-bridge systems. The accuracy of the surrogate model method in predicting vehicle vertical acceleration, vehicle lateral acceleration and lateral wheelset force is discussed, and the accuracy is verified by Monte-Carlo simulation (MCS). The results show that the nonlinear ARX model has great prediction accuracy for vehicle vertical acceleration and slightly worse prediction accuracy for lateral acceleration. The prediction accuracy of lateral wheelset force extreme value is slightly poor. Compared with MCS, the calculation efficiency of nonlinear ARX model is greatly improved, which is more suitable for the reliability calculations of vehicle-bridge systems.

keywords: Vehicle-bridge systems; Nonlinear ARX model; Surrogate Model; Monte-Carlo simulation

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Influence of Pier Heights on Spatial Vibration of the Train-Bridge System

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Abstract:

To investigate the spatial vibration of the train-bridge system, four multi-span simply supported beam bridge models with different pier heights are established, then the train-track-bridge coupling system is used to analyse the dynamic responses of the bridges as well as the trains. The following conclusions can be drawn: the frequency of a typical mode shape of the bridge decreases as the pier height ascends. The dynamic coefficient in the midspan is larger when the pier is higher, while this is not obvious when the train speed is below 350km/h. The lateral responses in the midspan are more sensitive to the change of pier height, and the displacements in the pier top show obvious distinction among different pier heights. The type of train, operation condition of train and train speed all have impacts on the vibration of the bridge. Compared with the bridge, responses of the vehicle show coherence among different pier heights, which illustrates that the pier height has less effect on the vibration of the train.

Key words: Spatial vibration; simply supported beam; pier height; train-track-bridge system; dynamic response; midspan; pier top

大跨度铁路斜拉桥地震易损性分析

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摘 要：为研究大跨度铁路斜拉桥的地震易损性，针对我国西部某主跨 432m 的铁路钢桁梁斜拉桥，采用 OpenSEES 软件建立桥梁的非线性有限元分析模型，分别以截面曲率、支座相对位移作为钢筋混凝土桥塔及球形支座的损伤评价指标。选取合适的地震动输入，通过拉丁超立方抽样考虑桥梁结构参数的不确定性，建立地震——桥梁样本库，并进行增量动力分析，得到桥梁关键构件的损伤指标峰值响应，继而根据概率地震需求分析，得到桥梁结构关键构件的易损性曲线。结果表明，斜拉桥在纵向地震作用下的主要易损部位为支座及塔底部位，故而在斜拉桥的抗震分析中，需重点关注这些部位。

关键词：钢桁梁斜拉桥；损伤指标；增量动力分析；易损性曲线

Seismic Vulnerability Analysis of Long-Span Railway Cable-Stayed Bridge

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Abstract:

In order to investigate the seismic vulnerability of long-span railway cable-stayed bridge, a nonlinear finite element model for the cable-stayed bridge with a span of 432m was built by OpenSEES. The sectional curvature and the relative displacement were used for the damage evaluation index of the bridge tower and the spherical bearing respectively. The appropriate earthquake records were selected as the excitation. The uncertain parameters of the bridge structure were considered by the method of Latin Hypercube Sampling (LHS), and a sample set of ground motion-bridge combination was formed. A method of incremental dynamic analysis (IDA) was utilized to obtain the peak response of the damage index of the key components of the bridge. And the seismic fragility curves of the bridge tower and the spherical bearing were developed based on the probabilistic seismic demand analysis. The results show that the main vulnerable parts of the cable-stayed bridge under longitudinal earthquake are the bearings and the bottom of the bridge tower. Consequently, it is necessary to pay attention to these components in the seismic analysis of the cable-stayed bridge.

keywords: steel truss cable-stayed bridge; damage index; IDA; fragility curve

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城市轨道交通箱梁上橡胶浮置板轨道减振特性研究及参数优化

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摘 要：以城市轨道交通 30 m 简支箱梁为研究对象，基于现场试验结果，探讨了箱梁上橡胶减振垫轨道减振特性。首先，通过动柔度法建立了车辆——轨道耦合振动频域模型，并由此得到动态轮轨作用力；接着，计算了钢轨、轨道板、桥梁各板件在 20～1000 Hz 之间的振动加速度，并利用有限元模型研究了轨道——桥梁系统振动传递特性；最后，讨论了减振垫面刚度和浮置板密度对橡胶减振垫轨道减振特性的影响。研究结果表明：仿真值与试验值吻合良好，分析方法可靠；与埋入式轨枕相比，采用橡胶浮置板轨道后，箱梁底板中心总振级可减小 25 dB，钢轨——轨道板和轨道板——底板振动加速度级传递损失分别为 23.9 dB 和 26.2 dB；综合考虑减振和其他因素，减振垫面刚度建议控制在 0.0150～0.0250 N/mm3，浮置板密度建议控制在 2600～3200 kg/m3。本文研究结果可为高架桥梁橡胶浮置板轨道的参数选择和优化提供依据。

关键词：轨道交通；橡胶浮置板轨道；箱梁；减振；参数优化

Vibration Reduction Characteristics and Parameters Optimization of Rubber Floating Slab Track on a Box-Girder in Urban Rail Transit

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Abstract:

Based on the field tests of a 30-m simple-supported box-girder in urban rail transit, vibration reduction characteristics of the rubber floating slab track on the box-girder are investigated. Firstly, a vehicle-track model is built to obtain the wheel-rail forces by the dynamic receptance method; Secondly, vibration accelerations of the rail, track slab and typical plates of the box-girder are calculated when the frequency is ranging 20~1000 Hz. Meanwhile, the vibration transmission characteristics of rail-bridge system by using the finite model. Finally, effects of the damping pad stiffness and floating slab density on the vibration reduction characteristics of the rubber floating slab track are discussed. Results show that the simulation and test values show good agreement. Compared with the embedding type sleeper track, the total vibration acceleration level at the center of the bottom plate of the box-girder can be reduced by 25 dB. In addition, the acceleration levels transmission loss from rail to track slab is 23.9 dB, as well as 26.2 dB from track slab to bottom plate. Taking the vibration reduction and other factors into consideration jointly, the damping pad stiffness and floating slab density should be in the range of 0.0150~0.0250 N/mm3 and 2600~3200 kg/m3, respectively. The research results may provide theoretical basis for the parameters selections and optimizations of the rubber floating slab track on elevated box-girders.

keywords: rail transit; rubber floating slab track; box-girder; vibration reduction; parameter optimization

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辅助墩对大跨斜拉桥地震响应影响分析

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摘 要：根据规范，得到地震波的输入方式以及输入数量，对陕西禹门口大跨组合梁斜拉桥进行地震作用下的动态时程分析，研究辅助墩对该桥在地震作用下的影响。利用有限元分析软件 CSiBridge 建立有限元模型进行仿真分析，通过改变辅助墩的数量进行地震响应分析，得出辅助墩的设置数量对该大跨组合梁斜拉桥主梁及主塔关键截面内力以及线形的影响规律，为后续开展这方面桥型的设计与研究分析提供参考。

关键词：桥梁工程；组合梁斜拉桥；地震作用；辅助墩；时程分析法

Analysis of the Influence of Auxiliary Piers on Seismic Response of Long-Span Cable-Stayed Bridges

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Abstract:

According to the code, the input mode and the number of seismic waves are obtained. The dynamic time-history analysis of the long-span composite beam cable-stayed bridge in Yumen, shan,xi province, is carried out. The influence of the auxiliary piers on the bridge under the seismic action is studied. The finite element model was established and simulation analysis carried out based on finite element software CSiBridge. Seismic response was analyzed by changing the number of auxiliary piers. The influence law of the number of auxiliary piers on the internal force and linear shape of the key sections of the main girder and main tower of the long-span composite cable-stayed bridge is obtained. It provides references for the design and research of this kind of bridge.

keywords: Bridge engineering; Composite beam cable-stayed; Earthquake action; Auxiliary pier; Time history analysis method

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高烈度山区高速公路常规桥梁抗震设计探讨

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摘 要：从桥梁分跨与分联、下部结构墩型选择、桥梁减隔震设计、延性抗震设计、防落梁技术等方面对高烈度山区高速公路常规桥梁抗震设计进行了探讨，结果表明：桥梁宜采用 4 孔～6 孔一联，一联桥的长度宜控制在 200m 以内；双柱墩抗震性能优于独柱墩；减隔震支座和阻尼器的滞回特性、耐久性和工程造价是重要因素；减隔震桥梁的抗震计算应优先采用非线性动力时程方法；连续梁的固定墩可采用延性抗震设计，但应对潜在塑性铰区的转角和墩顶位移进行控制；桥梁防落梁措施是抗震设防的重点内容之一，防落梁限位装置应安装简便、性能可靠、造价经济；横向挡块在地震中容易遭受破坏，应充分考虑梁体的撞击作用，并按照能力保护构件设计，且斜截面抗剪承载能力应高于抗弯承载能力。

关键词：高烈度；山区；高速公路；桥梁工程；减隔震设计；延性抗震设计

Discussion on Seismic Design of Conventional Highway Bridges in High Earthquake Intensity Mountain Areas

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Abstract:

The seismic design of conventional highway bridges in high earthquake intensity mountain areas is discussed from the aspects of bridge span division and connection length, substructure pier type selection, bridge isolation design, ductility seismic design and anti-falling beam technology. Some results were obtained. The seismic performance of double pier is better than that of single pier. The hysteretic characteristics durability and engineering cost of the isolation bearing and damper are important factors. The nonlinear dynamic time-history method should be preferred in seismic calculation of isolated bridges. Ductile seismic design can be adopted for the fixed pier of the continuous beam bridges, but the Angle of the potential plastic hinge area and the displacement of the pier top should be controlled. The measures to prevent falling beam of bridge is one of the important contents of seismic fortification. Transverse shear block is easy to be damaged in earthquake, the impact of beam body striking should be fully considered, and according to the design of capacity protection component, and the shear bearing capacity of inclined section should be higher than the bending bearing capacity.

keywords: high earthquake intensity; mountain area; highway; bridge engineering; seismic isolation design; seismic ductility design

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行波效应下大跨度多塔斜拉桥随机地震响应研究

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摘 要：鉴于大跨度多塔斜拉桥塔多、跨大、结构体系复杂及空间耦合效应明显等特点，论文对嘉绍跨江大桥进行多点多维随机地震响应分析。基于有限元和随机振动理论，建立空间有限元模型，并选择合适的地震动功率谱模型，重点研究嘉绍大桥考虑行波效应的平稳随机地震响应。研究结果表明，与一致激励相比较，考虑行波效应后结构的内力和位移均方根响应均明显减小，对结构抗震设计有利；同时也得到了一些嘉绍大桥特有的响应特征：纵向限位约束增加塔柱内力响应，刚性铰对多塔斜拉桥静动力特性均产生有利影响。

关键词：多塔斜拉桥；随机地震响应；多点多维激励；功率谱法；行波效应

Stochastic Seismic Response of the Long-Span Multi-Pylon Cable-Stayed Bridge Under Wave Passage Effect

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(ANHUI TRANSPORT CONSULTING & DES IGN INSTITUTE CO., LTD.)

Abstract:

Considering characteristics of long-span multi-pylon cable-stayed bridges which include multiple towers, large span, complex structural systems and obvious spatial coupling effects, the paper has studied multi-support multi-dimensional stationary stochastic seismic response of Jiashao River-Crossing Bridge. Based on the finite element theory and random vibration theory, the spatial finite element model was established and the proper power spectral density model was selected. The stationary stochastic seismic response of Jiashao Bridge under wave passage effect was analyzed. The study indicated that while considering wave passage effect, the seismic response of Jiashao bridge were obviously less than that of uniform excitations and which was advantageous to seismic design of structures. Meanwhile, the distinctive characteristics of seismic response upon Jiashao bridge were obtained: Longitudinal limit constraint increases the internal force response of the tower; rigid hinges have beneficial effects on the static and dynamic characteristics of multi-pylon cable-stayed bridge.

keywords: multi-pylon cable-stayed bridge; stationary stochastic seismic response; multi-support multi-dimensional excitation; power spectrum density method; wave passage effect

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非饱和黄土动三轴试验及参数分析

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摘 要：黄土广泛分布于我国北方地区，由于其特殊的形成方式和不同于其他土的工程性质，受到了工程界很大的关注。为了研究黄土动力作用下的力学性质，取山西某桥梁工程场地典型 Q3 黄土，进行非饱和黄土的动三轴试验。得到了不同围压下的动应力动应变曲线，动模量动应变曲线，分析了最大动模量与动剪切模量的关系。将最大动剪切量与参考应变归一化，得到不同围压下阻尼比并进行了比较分析。最后给出了阻尼比与动剪切模量关系的散点图并进行拟合，为黄土地区桥梁桩土相互作用与动力分析提供依据。

关键词：非饱和黄土；动三轴试验；动模量；阻尼比

Dynamic Triaxial Test and Parameter Analysis of Unsaturated Loess

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Abstract:

Loess is widely distributed in the northern part of China. Because of its special formation mode and different engineering properties from other soils, it has attracted great attention from the engineering community. In order to study the mechanical properties of loess under dynamic loads, the dynamic triaxial test of unsaturated loess was carried out on a typical Q3 loess of a bridge engineering site in Shanxi Province. The dynamic stress-strain curves and dynamic modulus-strain curves under different confining pressures are obtained, and the relationship between maximum dynamic modulus and dynamic shear modulus is analyzed. The maximum dynamic shear and reference strain are normalized, and the damping ratios under different confining pressures are obtained and compared. Finally, the scatter plot of the relationship between damping ratio and dynamic shear modulus is given and fitted, which provides a basis for pile-soil interaction and dynamic analysis of bridges in Loess region.

keywords: Unsaturated loess; Dynamic three axis test; Dynamic modulus; Damping ratio

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Seismic Response of Bridge Pile Foundation Based on Shaking Table Test

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Abstract: Puqian Bridge located in a quake-prone area, 8-degree seismic fortification intensity zone, the design of peak ground motion is the highest grade at home and abroad. Nevertheless, the seismic design of pile foundation is unprecedent, and the seismic issue of pile foundation is particularly prominent. This paper carried out large-scale shaking table test (STT) to study the dynamic characteristic of bridge pile foundation. Based on artificial quality model and mechanism of pile-soil interaction, peak ground acceleration varied from 0.15g~0.60g (g is gravity acceleration) were selected as the input seismic intensity. The results indicated that the peak acceleration decreases from pile top to bottom, and the acceleration amplification factor decreases gradually with the increase of seismic intensity. When the seismic intensity was 0.55g, the acceleration amplification factor of pile tip tended to a stable value of 1.32. The bedrock surface had less influence on seismic wave, and that the covering layer had marked influence on amplification of seismic wave and filtering effect. 0.50g seismic intensity was the key point that pile foundation began to damage. The seismic intensity was greater than 0.55g, the fundamental frequency of pile foundation decreased slowly and tended to stabilize at 0.87Hz. The bending moment was larger at junction of pile top and cap, soft-hard soil interface and bedrock surface, where pile cracks was easily occurred. These positions should be paid attention to during the design of the pile foundation in meizoseismal area.

Key words : geotechnical engineering; rock-socketed pile; dynamic characteristic; meizoseismal area; shaking table test

基于非光滑动力学的地震作用下桥面板—桥台碰撞——旋转现象分析及其设计原则浅析

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摘 要: 桥面板——桥台连接处在地震作用下可能发生碰撞,这可能会改变桥桁的边界条件。有时，这种变化会对桥梁造成不利的后果，如桥墩损坏、桥面破坏，甚至落梁。最近，一项大型简支梁桥振动台试验[1]显示，正交简支桥也会发生桥桁平面旋转。试验中碰撞引起桥桁旋转，造成桥墩和桥台显著的残余变形和破坏。本文利用该试验的实测数据，验证了非光滑动力学法的有效性，较好地反映桥面板与桥台接触的平面刚体动力学特征，同时提出了摩擦对简支桥转动作用的物理机理,阐明了在分析桥面板——桥台相互作用过程中考虑摩擦接触力的重要性，尤其是对于通常忽略旋转问题的正交简支桥。本文还比较了非光滑动力学法和柔度法（间隙单元法）在模拟桥桁碰撞现象的差别。最后，本文建议，对于简支桥梁抗震设计，除了必要的构造措施以外，应综合考虑桥梁的平面几何选型来判断其平面回转的可能性。

关键词: 桥面板—桥台碰撞；非光滑动力学；摩擦；抗震设计

Nonsmooth Seismic Response Analysis of Bridges with Deck-Abutment Impact-Induced Rotation and Preliminary Discussion on the Seismic Design Consideration

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Abstract:

Deck-abutment contact, during earthquake excitation, might alter the boundary conditions at the deck level and activate a mechanical behavior unforeseen during the design of the bridge. Occasionally, this discrepancy between the assumed and the actual seismic behavior has detrimental consequences for the bridge e.g. pier damage, deck unseating or even col-lapse. A recent insightful shake-table test of a scaled deck-abutment bridge model [1], showed unexpected in-plane rotations even though the deck was straight. These contact-induced rotations produced significant residual displacements and damage to the piers and the bents. The present paper utilizes the measured response of the deck-abutment system to examine the validity of a proposed nonsmooth dynamic analysis framework. The results show that the proposed approach satisfactorily captures the planar rigid-body dynamics of the deck which is characterized by deck-abutment contact. Further, the study brings forward the role of friction on the physical mechanism behind the rotation of straight bridges. It underlines the importance of considering the frictional contact forces during deck-abutment interaction even for straight bridges, which are typically neglected. The paper also comparatively

assesses the nonsmooth approach vs. the compliance (or gap element) approach with respect to their ability to predict the measured response. Finally, it is suggested that engineers should comprehensively consider the geometry of a simply supported bridge during seismic design, except the required construction details.

keywords: deck-abutment ponding; nonsmooth dynamics; friction; seismic design

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基于横系梁数量变化的横坡地形双柱式墩地震易损性分析

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摘 要：双柱式墩在西部山区应用广泛，当双柱墩的墩柱超过一定的高度时，一般会在墩柱中设置横系梁，本文探索横系梁的设置数量对双柱墩的抗震性能影响程度，运用基于传统可靠度的直接回归概率需求模型的方法分析了横坡地形双柱式墩的地震易损性。结果表明：在横桥向地震动输入的激励下，相同损伤状态下，易损性曲线会在某一地震动强度指标 PGA 下发生交叉；当地面峰值加速度小于交叉点加速度 PGA 时，双柱式墩所对应的超越概率随着墩柱间横系梁的设置数量的增加而减小；当地面峰值加速度大于交叉点加速度 PGA 时，超越概率随着墩柱间横系梁的设置数量增加而增大。

关键词：地震；双柱式墩；横系梁；易损性

Seismic Vulnerability Analysis of Steep Slope Double-Column Piers Based on the Variation of the Number of Transverse Beams

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(Chang'an University)

Abstract:

Double column pier is applied widely in the western mountains, while the double column pier pier exceeds a certain height, usually set in the pier transverse beam, this article explores cross collar beam set the number of degree of influence on the seismic performance of the double column pier, probability of using directly regression based on traditional reliability requirements model method to analysis the transverse slope topography and double column pier seismic vulnerability. The results show that under the excitation of the transverse seismic input, the vulnerability curves will cross under a certain seismic intensity index PGA under the same damage state. When the peak acceleration on the local surface is less than the PGA at the intersection, the transcendency probability corresponding to the double-pillar pier decreases with the increase of the number of transverse girders between the piers. When the local peak acceleration is greater than the PGA at the intersection, the transcendence probability increases with the increase of the number of transverse beams between piers.

keywords: the earthquake; double column pier; cross collar beam; vulnerability

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山区横坡地形坡度变化对双柱式墩地震易损性的影响分析

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（长安大学）

摘 要：为满足西部山区道路设计线形及跨越地形条件的需要，桥梁多建设在不同形式的边坡上。针对西部山区桥梁抗震设防目标的要求，本文以双柱式墩为例，以地震动峰值加速度 PGA 为强度指标、墩顶位移延性比为损伤指标，通过确定性的分析方法运用直接回归概率需求模型建立陡横坡地形双柱式墩理论易损性曲线。结果表明:相同破坏状态下，易损性曲线会在某一地震动强度指标 PGA 下发生交叉；当地面峰值加速度小于交叉点加速度 PGA 时，双柱式墩所对应的超越概率随着横坡度的增大而减小；当地面峰值加速度大于交叉点加速度 PGA 时，超越概率随着横坡度的增大而增大。

关键词：陡横坡；双柱式墩；易损性分析；损伤指标；增量动力时程分析法

Analysis of the Influence of Mountain Cross Slope Topographic Slope Change on Seismic Vulnerability of Double-Column Piers

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Abstract:

In order to meet the needs of road alignment design and terrain crossing conditions in western mountainous areas, bridges are mostly built on slopes of different forms. According to the requirements of seismic fortification targets of bridges in western mountainous areas,this paper, taking the double column type as an example, mainly takes the PGA as the strength index and the displacement ductility ratio of the top of the pier as the damage index. Through the deterministic analysis method, the theoretical vulnerability curve of the double-column pier on the steep slope terrain is established by using the direct regression probability demand model. The results show that under the same failure state, the vulnerability curves will cross under a certain ground motion intensity index PGA. When the peak ground acceleration is less than the cross-point acceleration PGA, the exceeding probability corresponding to the double-column pier decreases with the increase of the cross slope. When the peak ground acceleration is greater than the cross-point acceleration PGA, the exceeding probability increases with the increase of the cross slope.

keywords: steep cross slope; double column pier; vulnerability analysis; damage index; incremental dynamic time history analysis

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连续刚构桥抗震性能影响因素分析

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摘 要：以某（95+180+95）m 连续刚构桥作为研究的对象，基于 Midas-civil 建立了考虑边跨支座处的弹性约束作用以及基础和地基的影响的数值模拟有限元模型，并基于此模型进行了结构地震相应分析，分析了桥墩形式对桥梁抗震性能的影响。结果表明：采用双肢结构的桥墩可以有效的提高结构的柔性，减小地震作用引起的墩顶内力和墩底内力，而双肢实心墩和双肢薄壁墩在地震波作用下产生的墩底内力和墩顶内力差距并大，所以采用双肢薄壁墩截面可以在保证受力的基础上节约材料。

关键词：连续刚构桥；抗震；桥墩；有限元法；桥梁工程

Analysis of Factors Influencing Seismic Performance of Continuous Rigid Frame Bridge

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Abstract:

Taking a (95+180+95)m continuous rigid frame bridge as the research object, used the finite element program Midas, considered side span bearing of elastic restraint function and the influence of pile and soil, established the dynamic computational finite element model of long span continuous rigid frame, analyzed the form of pier's influence on the seismic performance of Bridges. Results show that the double limb structure can effectively improve the structure of flexible piers, reduce the earthquake effect caused by the internal force, internal force and pier pillar top bottom and double limb solid pier and double limb thin-wall piers under the action of seismic wave produced by end of the pier and big gap between the internal force and internal force loaded on top, can use the material saving both limbs thin wall pier.

keywords: continuous rigid frame bridge; earthquake; pier; finite element method; Bridge engineering

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Performance of Steel-UHPC Lightweight Composite Bridge Deck Structures Subjected to Blast Loading

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Abstract: Numerous terrorist attacks (e.g., the 2001 attack on the World Trade Center) happened in recent years. The safety of civilian structures subjected to blast loading has been widely concerned throughout the world. Most of studies placed emphasis on the buildings subjected to blast. Research on the blast resistance of other infrastructure system such as bridges is very rare. More importantly, the current codes have almost no specific provisions or guidelines for blast protection of bridges. As a key element of the long-span bridge structure, the bridge deck (e.g., orthotropic steel deck) has been considered attractive targets because of their accessibility and potential impacts on human lives and structural safety. On the other hand, to overcome the limitations (e.g., fatigue damage) of the conventional orthotropic steel bridge decks under vehicle loads, the second author has proposed an innovative composite deck system that consists of an orthotropic steel deck and an ultra-high performance concrete (UHPC) layer. Physical experiments demonstrated the excellent performance of the new composite deck system under vehicle loads. In addition to the basic behavior of the proposed deck system, this investigation aims to further study its blast-resistant performance. Typical composite decks used in long-span bridges were modeled using explicit finite-element (FE) analysis software LS-DYNA. For comparisons, the FE models of the conventional orthotropic decks were also generated. In the FE models, the parameters that varied in the analyses were the explosive size in terms of equivalent TNT. The behaviors and failure modes of the conventional and composite decks under blast loading were compared. It was demonstrated that the blast resistance of the composite deck system was superior to the traditional orthotropic deck.

Key words: Orthotropic steel deck; ultra-high performance concrete (UHPC); Blast resistance; finite element analysis (FEA)

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扁平箱梁气动特性与颤振性能的阻塞效应

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摘 要：风洞试验是桥梁颤振研究最为重要的手段之一。由于风洞尺寸的限制，颤振试验中存在一定的阻塞效应，然而已有关于颤振阻塞率效应的研究较为少见。数值风洞模拟方法可以自定义尺寸大小，从而避免实际风洞尺寸的限制。本文采用 CFD 数值模拟方法，针对大跨度桥梁扁平箱梁桥，在阻塞率为 1%～10%下进行了颤振分析，主要研究阻塞效应对扁平箱梁的静力三分力系数、压力分布、颤振导数和颤振临界风速的影响。结果表明：随着阻塞率的增大，扁平箱梁的静力三分力系数逐渐增大，平均压力系数的绝对值逐渐增大，颤振临界风速逐渐减小。最后，基于数值分析结果，提出了 0° 攻角下扁平箱梁颤振临界风速的阻塞效应修正公式，为阻塞率的合理取值范围提供了建议，可为实际工程中的抗风设计提供参考。

关键词：桥梁工程；颤振性能；阻塞效应；数值模拟；扁平箱梁

Blockage Effects on Aerodynamic Characteristics and Flutter Performance of a Flat Box Girder

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Abstract:

Wind tunnel test is one of the most important means for bridge flutter performance research, but there are blockage effects in flutter test due to the size limitation of the wind tunnel and studies in this field is still scarce. On the other hand, the size can be defined by users to get rid of the size limitation in the numerical wind tunnel simulation. This paper presents a study on blockage effects of a simplified box girder by computation fluid dynamics (CFD) simulation, taking common and large angles of attack into consideration, and the blockage effects on the aerodynamic characteristics and flutter performance of a long-span suspension bridge are studied. The results show that with the increase of the blockage ratio, the aerodynamic coefficients and the absolute value of mean pressure coefficient of the streamlined box girder increase, the critical flutter wind speed decreases and the flutter frequency approaches the torsional frequency gradually. Finally, the correction formula of critical flutter wind speed of streamlined box girders with different blockage ratios are given, based on the numerical simulation results, which can provide reference for wind resistance design of streamlined box girders in practical engineering.

keywords: bridge engineering; flutter performance; blockage effects; numerical simulation; flat box girder

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安装亮化灯具后斜拉索驰振性能研究

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摘 要：在既有斜拉桥的斜拉索上安装光彩亮化灯具是一种装点城市夜景的有效手段，但灯具的存在使斜拉索由圆形断面变为异形断面，极大地改变了斜拉索的气动特性。为了研究安装灯具斜拉索的驰振稳定性，首先通过数值模拟研究 200mm 斜拉索在安装灯具后断面的气动性能，并从表面压力分布及流场变化的角度解释了升力系数出现负斜率的原因。然后通过节段模型风洞试验测试了 180mm、200mm 和 235mm 三种斜拉索在安装灯具后断面的三分力系数，进一步计算斜拉索——灯具组合结构发生驰振的可能性和临界风速。研究结果表明：(1)安装灯具后 200mm 斜拉索的气动特性发生显著变化，来流在截面表面形成不对称的静压力区，导致截面升力系数曲线出现波动；(2)灯具的安装使三种斜拉索升力系数曲线出现显著负斜率，说明三种斜拉索具备在较低风速下发生驰振可能；(3）随着灯具与斜拉索外径的比值减小，最小驰振力系数而趋近于零，驰振临界风速提高。

关键词：斜拉索

Study on the Galloping Performance of Stay Cables with Lighting Fixtures

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Abstract:

In order to decorate the city's night scenes, the installation of lighting fixtures on stay cables of existing cable-stayed bridges is an effective choice. However, the presence of lighting fixtures changes the cable from a circular section to a profiled section, which greatly changes its aerodynamic characteristics. In order to research the galloping stability of the section, firstly the study was carried out on the aerodynamic performance of the 200mm stay cable after installing lighting fixtures by numerical simulation. And the reason for the negative slope of the lift coefficient is explained from surface pressure distribution and flow field variation. Then, through the segmental model wind tunnel test, the mean aerodynamic force coefficient was testes of three stay cables of 180mm, 200mm and 235mm after installing lighting fixtures. Furthermore, the possibility of galloping and the critical wind speed of the stay cables with lighting fixture were calculated. The experimental results show that: (1) It is found that the aerodynamic shape of the 200mm stay cable changed significantly after installing lighting fixtures, and the flow forms an asymmetrical static pressure zone on the cross-section surface, which causes the lift coefficient curve to fluctuate. (2) It is found that the installation of lighting fixtures caused a significant negative slope of lift coefficient curves of three stay cables, indicating that the three stay cables have the possibility of galloping at a lower wind speed. (3) As the ratio of the height of luminaire to the outer diameter of stay cable

decreases, the minimum galloping force coefficient approaches zero, and the critical wind speed of the galloping increases.

keywords: stay cable

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桥梁主梁断面振动模态对自激力的影响研究

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摘　要：基于 CFD 技术，采用任意拉格朗日——欧拉（ALE）方法和动网格技术搭建了模拟主梁断面自激力的数值计算模型，进而采用单自由度分状态和 3 自由度耦合强迫振动法模拟了两种典型主梁断面的气动自激力，并同时识别出了相应的颤振导数。将数值模拟识别的颤振导数与风洞实验结果进行了对比分析，验证了本文方法模拟桥梁断面气动自激力的可靠性。然后进一步分析了振动模态对桥梁断面气动自激力的影响。结果表明：对于流线型主梁断面，自激升力和自激扭矩基本满足模态叠加假定，自激阻力不满足模态叠加假定；对于钝体主梁断面，绕流场出现了明显的流动分离和再附现象，且模型的振动形态对流动分离特点有很大的影响，导致自激力不严格满足模态叠加假定。

关键词：主梁断面；自激力；颤振导数；振动模态；计算流体力学

Study on the Effect of Vibration Mode on Self-Excited Forces of Bridge Deck Sections

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Abstract:

Based on CFD technology, the numerical calculation model for simulating the self-excited forces of deck section is presented by using Arbitrary Lagrange-Euler (ALE) method and dynamic mesh technology. And then, the self-excited forces of two typical deck sections are simulated by means of SDOF and 3-DOF coupled forced-vibration method. The corresponding flutter derivatives are also identified. Reasonable agreements between results from the numerical calculation and those from wind tunnel tests demonstrate the reliability of present numerical method. The effect of vibration mode on aerodynamic self-excited forces of deck section is analyzed. The result illustrates that the self-excited lift and self-excited torque of streamlined deck section satisfy the modal superposition assumption, while the self-excited drag fail to satisfy the modal superposition assumption. As for bluff deck section, large separation occurs in the flow field around the deck section and the vibration mode has great influence on the characteristics of flow separation, leading to the failure of modal superposition assumption for self-excited forces.

keywords: deck section; self-excited force; aerodynamic derivative; vibration mode; CFD

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Analysis on Wind Stability of 4000m-Span Suspension Bridge with Carbon Fiber Space Cable System

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Abstract: In order to solve the problem of the utilization of the main cable material and wind stability of the suspension bridge with super-large span steel main cable, this paper use ANSYS to establish two kind of models of spatial suspension bridge and parallel cable system suspension bridge. The software compares the two models of the dynamic mode, static wind stability and flutter stability. The results show that tensional vibration of the space suspension bridge is much later than the parallel suspension bridge, and the frequency of the cable system is higher than that of the parallel cable suspension bridge, and the critical wind speed and the critical wind speed of the flutter are higher than that of the parallel cable suspension bridge. Therefore, the space suspension bridge has better resistance wind stability.

Key words: super-large span suspension bridge; space cable network; carbon fiber cable; wind stability

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考虑桥塔遮蔽效应的桁架桥面风环境风洞试验研究

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摘 要：桥面的风环境影响车辆的气动性能，关乎桥上行车安全。本文以大比例（缩尺比1:20.4）的桁架梁为研究对象，进行了桥面风环境节段风洞试验。结果表明：桥塔遮蔽效应会引起风场突变；在桥塔区域，桥面风环境受桥面附属结构和桥塔的共同影响；由于附属设施会引起桥面风环境的突变，在进行桥面附属设施的设计时，应该考虑其对于桥面风环境的影响。

关键词：桁架桥；风洞试验；桥面风环境；风屏障；桥塔遮挡效果

Study on the Shadowing Effect of Bridge Tower on Wind Environment of Truss by Wind Tunnel Test

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Abstract:

Vehicle aerodynamic performance and driving safety is related to wind environment on bridge deck. In this paper, taking a large scaled (1: 20.4) truss girder as objects, the wind environment tests were carried out in wind tunnel. The results show that the shadowing effect of bridge tower can abrupt change the wind field. For the effects of bridge tower, the wind environment is affected by affiliated facilities and bridge towers. Finally, when designing affiliated facilities on the deck, consideration should be given to their effects on wind environment, which can cause sudden change of wind environment.

keywords: truss; wind tunnel tests; wind environment on bridge deck; wind barriers; sheltering effect of bridge tower

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Analysis of the Rainfall Influence on Critical Wind Speed of Flutter of Long-Span Suspension Bridge Based on Mumerical Method

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Abstract: In order to study the influence of rainfall on the critical wind speed of flutter of long-span suspension bridges in mountainous area, the impact of rainfall on stiffening girder is analyzed based on the main characteristics of rainfall and the movement speed in all directions. The mechanical equation under the joint action of wind and rain is established and the impact force is transferred, the damping effect of rainfall is then derived, and the element damping matrix form of rainfall is obtained by combining the integration of shape function. Furthermore, the flutter motion equation of wind-rain-bridge coupling system is derived, and the finite element analysis method for critical wind speed of structural flutter considering the influence of rainfall is established. Finally, taking a large-span suspension bridge in mountainous area as the research object, the influence of rainfall on the critical wind speed of flutter is analyzed, the results indicate that the critical wind speed of flutter will be accordingly increased due to the existence of rainfall damping, whereas the mass of raindrops is too light and the final velocity of raindrops in the falling process is low, the critical wind speed of flutter increased by only 5.54% in the case of heavy rainstorm. Therefore, when the rainfall intensity is general, the influence of rainfall on the critical wind speed of flutter can be ignored.

Key words: suspension bridges; rainfall damping; wind-rain action; flutter critical wind speed; eigenvalue analysis

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悬索桥主缆施工期风致振动风洞试验研究

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摘 要：选取某大跨悬索桥主缆施工期D形断面工况进行节段模型风洞试验，测试了主缆在不同风攻角下的气动性能。结果表明：主缆模型在0°及+3°风攻角时发生较大振幅的驰振，且振幅随风速增大近似呈线性增大趋势；在施工期遭遇强风时采取适当的气动措施可有效抑制驰振的发生。

关键词：主缆；施工期；风致振动

Wind Tunnel Tests of Wind-Induced Vibration for Main Cables of Suspension Bridges During Construction

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Abstract:

Wind tunnel tests of a D-shaped main cable for a suspension bridge during construction period were performed, and the aerodynamic performance of the main cable with different wind incidence angles was studied. According to results of the tests, the main cable performed large-amplitude vibrations at wind incidence angles of 0° and +3°, and the vibration amplitude linearly increased with the wind speed. Appropriate aerodynamic measures could efficiently suppress the galloping of main cables during construction.

keywords: main cable; construction period; wind-induced vibration

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多塔斜拉桥动力特性和颤振稳定性的参数敏感性分析

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摘 要：为了研究多塔斜拉桥动力特性和颤振稳定性的参数敏感性，因此，本文以一座三塔多跨的大跨斜拉桥为研究对象，建立结构的有限元模型。计算了不同拉索拉力、拉索面积、索塔刚度、主梁刚度下斜拉桥的竖弯、扭转基频及结构的颤振临界风速。计算结果表明，拉索拉力和索塔刚度对竖弯、扭转基频及颤振稳定性的大小没有影响，而主梁刚度和拉索面积对上述桥梁动力参数的影响较大。

关键词：斜拉桥；参数敏感性；动力特性；颤振临界风速

Parameter Sensitivity Analysis of Dynamic Characteristics and Flutter Stability of Multi-Tower Cable-Stayed Bridge

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Abstract:
In order to study the parameter sensitivity of dynamic characteristics and flutter stability of multi-tower cable-stayed bridge, this paper took a three-story multi-span long-span cable-stayed bridge as the research object and the finite element model of the structure was established. The vertical bending, torsional fundamental frequency and flutter critical wind speed of cable-stayed bridge under different cable tension, cable area, tower stiffness and girder stiffness were calculated. The results show that the cable tension and cable stiffness have no effect on the vertical bending, torsional fundamental frequency and flutter stability, while the main beam stiffness and cable area have a great influence on the above bridge dynamic parameters.
keywords: cable-stayed bridge; parameter sensitivity; dynamic characteristics; flutter critical wind speed

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Modal Characteristics Analysis of Suspension Bridge with Large-Span and Ruled Surface Space Cable

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Abstract: In this paper, new concepts of single-leaf hyperboloid space cable suspension bridge and hyperbolic parabolic space cable suspension bridge are proposed. Combined with 4000m-type Messina Strait of large span suspension bridge, a dynamic modal analysis of space cable suspension bridge is carried out. The results show that the torsional vibration mode of the space suspension bridge is much higher than that of the parallel suspension bridge, the torsional frequency and the bending frequency ratio are greatly improved, and the critical wind speed of the dune is greatly improved. The space cable suspension bridge has good wind stability.

Key words: suspension bridge with space cable; ruled surface; torsional bending frequency ratio; wind stability

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大跨度斜拉桥运营期拉索振动响应实测与控制

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摘 要：针对大跨度斜拉桥拉索高阶振动问题，以苏通长江公路大桥为依托，进行了大跨度斜拉桥拉索风致振动现场实测研究，在此基础上分别进行了表面凹坑和缠绕控制风雨振螺旋线的拉索节段模型涡振试验研究，并对拉索的阻尼比、气动控制措施分别进行了试验研究。结果表明，斜拉索在某些风速条件下存在高阶振动现象，部分表面凹坑斜拉索发生了大幅的风雨振现象；表面凹坑和缠绕控制风雨振螺旋线的拉索在低阻尼比条件下出现了明显的涡激共振现象；增加阻尼比或缠绕合适参数的较粗螺旋线可有效控制拉索的涡激共振现象。

关键词：斜拉索；涡激共振；高阶振动；现场实测；风洞试验

Field Measurement and Control of Vibration Responses of Stay-Cables of Large Span Cable-Stayed Bridge in Service

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Abstract:

Aiming at the high-order vibration problem of cable-stayed bridges of long-span cable-stayed bridges, based on the Sutong Bridge, the field measurement study of wind-induced vibration of cable-stayed bridges with long-span cable-stayed bridges was carried out. On this basis, the vortex vibration test of the stay-cable segment model with indent surface and smooth surface with 2.0mm spiral wires were carried out respectively, and the damping ratio and aerodynamic control measures for the wind-induced vibration of the stay-cable were investigated respectively. The research results show that the stay-cable exhibited high-order vibration under certain wind speed conditions, and some indent stay-cables have large amplitudes wind-rain induced vibration phenomenon. The vortex-induced vibration of indent stay-cable and the smooth surface stay-cable with 2.0mm helical wires, which usually effective for suppress rain-wind induced vibration of stay-cable, were observed at low damping ratio conditions. Increasing the damping ratio of stay-cable or wrapping the thick helical fillets with suitable parameters can effectively suppress the vortex-induced resonance phenomenon of the stay-cable.

keywords: stay-cable; vortex-induced resonance; high-order vibration; field measurement; wind-tunnel tests

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大跨悬带桥的颤振特性及其节段模型试验适用性研究

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摘 要：在绿色道路建设事业蓬勃发展的大趋势下，悬带桥作为一种新型人行桥被广泛应用于山区之中。受短吊杆影响，导致悬带桥的动力特性和颤振性能与常规悬索桥不同，进而会影响悬带桥节段模型试验的适用性。本文将二维与三维颤振分析方法相结合，对悬带桥的颤振性能和节段模型试验的适用性加以研究，并针对悬带桥节段模型试验的模态选取方法给出合理建议。

关键词：颤振；悬带桥；节段模型试验

Research on Flutter Characteristics of the Long-Span Stress-Ribbon Bridge and Applicability of Segmental Model Test

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Abstract:

With the vigorous development of green road construction, suspension bridge is widely used in mountainous areas as a new type of pedestrian bridge. Due to the influence of the short suspenders, the dynamic characteristics and flutter performance of suspension bridges are different from those of conventional suspension bridges, which will affect the applicability of suspension bridge segmental model test. In this paper, two-dimensional and three-dimensional flutter analysis methods are combined to study the flutter performance of suspension bridges and the applicability of segment model test, and reasonable suggestions are given for the modal selection method of segment model test of suspension bridges.

keywords: Flutter; The Stress-ribbon Bridge; Segmental model test

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横风作用下高速移动列车——桥梁系统气动特性风洞试验研究

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摘 要：基于惯性驱动原理，以高速伺服电机为驱动动力，高强度旋转传送带传动，提出了一种缩尺比为 1:16.8 的移动车辆桥上运行气动特性试验装置和试验方案。该方法提供了一种适用于加速距离短，可使试验模型瞬时加速达到上百公里每小时、且不受车辆外形限制、可降低设计成本以及能够提高试验的安全与稳定性。并开发了一套无线风压测试系统，通过风洞试验的测试，结果表明：采用该方法测试的车辆气动特性有较好的平稳性和可重复性以及能够满足高速移动列车表面压力气动特性采集的需求，能够更精准得到列车的气动特性。

关键词：高速列车；车桥系统；风洞试验；横风；气动特性；表面风压

Study on Aerodynamic Characteristics of High-Speed Vehicle on the Bridge in Crosswind

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Abstract:

Based on the principle of inertial drive and driven by high speed servo motor and high strength rotary conveyor belt, a pneumatic test device and test scheme for running on the moving vehicle bridge with a scale ratio of 1:16.8 is proposed. This method provides a suitable method for short distance, which can make the instantaneous acceleration of the test model reach hundreds of kilometers per hour, and is not limited by the vehicle shape, which can reduce the design cost and improve the safety and stability of the test. And a set of wireless wind pressure test system is developed. The test results of wind tunnel test show that the vehicle aerodynamic characteristics tested by this method have better stability and repeatability, and can meet the requirements of high-speed mobile train surface pressure aerodynamic characteristics acquisition, and can more accurately obtain the aerodynamic characteristics of the train.

keywords: High speed train; vehicle-bridge system; wind tunnel test; crosswind; aerodynamics; wind pressure

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钝体结构非定常自激力模型

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摘 要：针对作用在结构上非定常自激力（USEF），本文建立了非线性数学模型，解决了准静态理论不能准确结构驰振响应的问题，USEF 和结构的驰振响应均从气弹——测压（HAPB）风洞试验中测得。根据能量等效原则，USEF 可分为气动阻尼力，气动刚度力和剩余力三部分。由于仅气动阻尼和气动刚度部分为振动系统提供能量，可建立关于两者的非线性数学模型。经验证，对于具有不同质量阻尼比的结构，本文建立的数学模型可以准确预测结构的驰振响应。

关键词：钝体结构，非定常自激力，气弹——测压，准静态理论

Unsteady Self-Excited Forces on a Slender Prism

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Abstract:

A mathematical model to quantify the unsteady self-excited forces (USEFs) acting on a slender prism was developed, to address the shortcomings of the classical quasi-steady theory employed to predict galloping instabilities of slender prisms. The unsteady aerodynamic force and galloping response of a prism were obtained from a hybrid aeroelastic-pressure balance (HAPB) that can synchronously observe unsteady pressure and aeroelastic response. According to an energy equivalent method, the unsteady aerodynamic force was quantitatively decomposed into three components: an aerodynamic damping force component, an aerodynamic stiffness force component and a residual force (buffeting force) component. It was confirmed that only the aerodynamic damping and aerodynamic stiffness components contribute energy to an oscillation prism. Accordingly, a nonlinear mathematical model for the USEF which is based on a 1st-order polynomial function representing the aerodynamic damping and stiffness force components, was established. The results indicated that the 1st-order model was accurate in predicting the galloping response of the prism. It was also demonstrated that the model can be used to predict galloping instabilities of prisms with different mass-damping ratios.

keywords: Bluff body; unsteady self-excited force; aeroelastic-pressure; quasi-steady theory

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波形腹板钢箱——混凝土组合梁桥动力特性分析与试验研究

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摘 要：为精确分析波形钢腹板剪切变形和箱梁的剪力滞效应对波形腹板钢箱——混凝土组合梁桥自振特性的影响，首先，基于势能驻值原理以波形腹板钢箱——混凝土组合梁桥的竖向位移 、自由振动弯曲变形引起的转角位移 以及剪切转角的最大差值位移 为未知位移函数，推导出波形腹板钢箱——混凝土组合梁桥在考虑波形钢腹板剪切变形和箱梁的剪力滞效应下的单元刚度矩阵；其次，根据所推导的单元刚度矩阵，采用 MATLAB 软件编制了考虑波形钢腹板剪切变形和箱梁的剪力滞效应的波形腹板钢箱——混凝土组合梁桥自振频率计算的求解程序。MATLAB 求解程序计算所得的自振频率的正确性，得到了在建实桥自振频率实测值和 ANSYS 三维有限元值的验证；最后，对波形腹板钢箱——混凝土组合梁桥的自振频率的影响参数进行了分析。研究成果可将考虑波形钢腹板剪切变形和箱梁的剪力滞效应下波形腹板钢箱——混凝土组合梁桥的动力分析问题，简便地纳入到普通杆系结构矩阵位移结构体系中，避免了 ANSYS 有限元模型建立和求解程序的复杂性，可为该类桥型的自振特性的分析和计算提供参考。

关键词：波形腹板钢箱——混凝土组合梁桥；动力特性试验；单元刚度矩阵；自振频率；参数分析

Dynamic Characteristics Analysis and Experimental Study of Corrugated Web Steel Box-Concrete Composite Girder Bridge

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Abstract:

In order to accurately analyze the influence of the shear deformation of corrugated steel web and the shear force lag effect of the box girder on the natural vibration characteristy of the corrugated web steel box-concrete composite girder bridge, firstly, vertical displacement ω(x) of the corrugated web steel box-concrete composite girder bridge, angular displacement θ(x) caused by the bending deflection of the free vibration and maximum differential displacement β(x) of the shear intersection angle were taken as the unknown displacement function on the basis of the potential energy variation principle to derive the element stiffness matrix of the corrugated web steel box-concrete composite girder bridge under the shear deformation of the corrugated steel web and the shear force lag effect of the box girder; then, according to the element stiffness matrix derived thereby, MATLAB software was adopted to prepare the solving program for the natural vibration frequency calculation of the corrugated web steel box-concrete composite girder bridge under the shear deformation of the corrugated steel web and the shear force lag effect of the box girder; then, the validity of the natural vibration frequency calculated according to MATLAB solving program was verified by the

measured value of the natural vibration frequency of the bridge under construction and ANSYS three-dimensional finite element value. Finally, the influence parameters of the natural vibration frequency of the corrugated web steel box-concrete composite girder bridge were analyzed. According to the research result, the dynamic analysis problem of the corrugated web steel box-concrete composite girder bridge under the shear deformation of the corrugated steel web and the shear force lag effect of the box girder can be simply included into the displacement structure system of common bar system structure matrix, thus avoiding the complexity of the establishment and the solving program of ANSYS finite element model and providing reference for analyzing and calculating the natural vibration characteristics of such bridge.

keywords: Corrugated web steel box-concrete composite girder bridge; Dynamic characteristic test; Element stiffness matrix; Natural frequency vibration; Parameter analysis

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多梁式钢—混组合梁桥横向分布系数计算方法对比研究

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摘 要：为科学合理的评价多梁式钢—混组合梁桥横向分布规律，选取相同桥面宽度、不同跨径、不同主梁数以及不同主梁高度的 6 种钢—混组合梁桥为研究对象。分别采用杠杆原理法、刚性横梁法、修正的刚性横梁法、铰接梁法、刚接梁法、G-M 法以及 ANSYS 三维有限元法对其横向分布系数进行计算分析。研究表明，杠杆原理法和铰接梁法计算误差较大，横向分布系数变化规律不同于其他计算方法；刚性横梁法计算的边梁横向分布系数值偏大（约 30%）；当宽跨比大于 0.5 且主梁间距和桥面宽度的比值在 0.125～0.25 之间时，横向分布系数采用刚接梁法计算较为精确；当宽跨比小于 0.5 或宽跨比大于 0.5 且主梁间距和桥面宽度的比值小于 0.125 时，横向分布系数采用 G-M 法计算较为精确；当宽跨比大于 0.5 且主梁间距和桥面宽度的比值大于 0.25 时，横向分布系数采用修正的刚性横梁法计算较为准确。

关键词：桥梁工程；横向分布系数；钢—混组合梁；多梁式；有限元模型

Comparative Study on Calculation Methods of Transverse Distribution Coefficients of Multi-Beam Steel-Concrete Composite Beam Bridges

Ji Wei , Zhang Jingwei
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Abstract:

In order to in order to scientifically and reasonably evaluate the transverse distribution law of multi-beam steel-concrete composite girder bridges, six kinds of steel-concrete composite girder bridges with the same bridge deck width, different spans, different girder numbers and different girder heights are selected as research objects.Lever principle method, rigid beam method, modified rigid beam method, hinged beam method, rigid beam method, G-M method and ANSYS three-dimensional finite element method are used to calculate and analyze the transverse distribution coefficient. The research shows that the lever principle method and the hinged beam method have large calculation errors, and the variation law of transverse distribution coefficient is different from other calculation methods. The lateral distribution coefficient calculated by the rigid beam method is relatively large (about 30%); When the ratio of width to span is greater than 0.5 and the ratio of main girder spacing to bridge deck width is between 0.125 and 0.25, the transverse distribution coefficient is calculated more accurately by rigid beam connection method.When the width-to-span ratio is less than 0.5 or the width-to-span ratio is greater than 0.5 and the ratio of the main girder spacing to the bridge deck width is less than 0.125, the transverse distribution coefficient is calculated more accurately by the G-M method.When the ratio of width to span is greater than 0.5 and the ratio of main girder spacing to bridge deck width is greater than 0.25, the transverse

distribution coefficient is more accurately calculated by the modified rigid beam method..

keywords: Bridge engineering; lateral distribution coefficient; steel-concrete composite beam; multi-beam type; finite element model

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计算机编程技术在沉井施工中的应用

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摘 要：沉井是个无底无盖的井筒，用作桥梁基础、水泵房、码头等工程的施工围护和承重结构，使用范围十分广泛。沉井施工要求高，方案验算项多，多数参数试算工作十分繁琐且容易出错。作者结合东方水城污水泵房沉井基础，在visual basic开发平台上提出常用的圆形、矩形、方形等三种沉井验算的电算理论和方法，编写了计算程序，适用于大型桥梁沉井基础、城市污水泵房集水井、地下室、设备深基础、顶管施工工作井、高层建筑大型箱基等各种沉井的施工计算。

关键词：工程施工；沉井；电算技术

Application of Computer Programming Technology in Open Caisson Construction

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Abstract:

The open caisson is a bottomless and uncovered shaft, which is widely used as a construction enclosure and bearing structure for bridge foundation, water pump house, wharf and other projects. The open caisson construction requires high requirements and many items of scheme checking calculation, and most of the parameter calculation work is tedious and prone to errors. Based on the caisson foundation of the sewage pump room in Dongfang Shuicheng, the author puts forward three kinds of commonly used computer theories and methods of caisson checking on the visual basic development platform, and compiles the calculation program, which is suitable for the construction calculation of various caissons such as large bridge caisson foundation, urban sewage pump room sump, basement, equipment deep foundation, pipe jacking construction work well and large box foundation of high-rise buildings.

keywords: engineering construction; Open caisson; Computer technology

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杨梅洲特大桥主墩承台大体积混凝土施工技术

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摘 要：杨梅洲特大桥主墩承台高 8m，最大直径 36m，设计方量 7513m3，大体积混凝土构件极易产生温度和收缩裂缝。论文从原材料选择、配合比设计、冷却水管布设、混凝土浇筑工艺、施工信息化监控等方面系统论述特大桥主墩承台大体积混凝土施工技术要点。结果显示，混凝土温度控制符合规范要求，降温速率约为 1.8℃/d，混凝土表面密实光滑无任何可见裂缝。

关键词：桥梁工程；主墩承台；大体积混凝土；施工工艺；裂缝控制

Construction Techniques of Mass Concrete for the Pile Cap of Main Piers of Yangmeizhou Bridge

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Abstract:

The height for the pile cap of main piers of Yangmeizhou Bridge is 8 meters, and its maximum diameter is 36 meters, with total volume of 7513m3. Mass concrete structure is very easy to produce temperature cracks and shrinkage cracks. This paper systematically discusses the key points of mass concrete for pile cap during the period of long bridge construction in the aspect of material selection, mixing proportion design, cooling pipe layout, concrete casting method and construction information monitoring. The results show that the control of concrete temperature satisfies the requirements of the specification, the cooling rate is about 1.8℃/d, and the concrete surface is dense and smooth without any visible cracks.

keywords: bridge engineering; main pier pile cap; mass concrete; construction method; crack control

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钢管混凝土系杆拱桥在抚河类浅水水域的施工方案比选

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摘　要：本文以正在施工中的中承式钢管混凝土系杆拱桥——王安石抚河大桥（主跨168m）为研究对象，讨论钢管拱桥先拱后梁与先梁后拱两种工序的优缺点；比较钢管拱桥的各种施工方法，考虑施工难度、对环境的影响、工期、经济性等方面的影响，对包括塔吊法、龙门吊法、筑岛、转体施工等技术工法进行比选，论证各工法的优劣，从而提出在浅水航道中钢管混凝土系杆拱桥的最优施工工法以及主要施控制点。

关键词：钢管混凝土系杆拱桥；浅水航道；施工方案比选

Comparison of Construction Schemes and Key Control Points of Constructing Concrete-Filled Steel Tube Tied Arch Bridge in Shallow Water Channel

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Abstract:

To support this paper, the under-construction Wang'anshi Fuhe Bridge (main span 168m), a mid-through tied arch bridge with concrete-filled steel tube(CFST), is taken as the research object, to discuss the advantages and disadvantages of the two construction procedures of the first-arch-then-girder, and the first-girder-then-arch. In account of construction difficulty, environmental influence, construction period and economy, the advantages and disadvantages of each construction method is revealed from construction methods including tower crane, gantry crane, island building and swiveling construction, which puts forward the optimal construction method and main control points of CFST tied arch bridge in shallow water channel.

keywords: CFST tied arch bridge; shallow water channel; construction scheme comparison

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干寒戈壁地区高墩混凝土智能带模养生技术研究

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摘　要：我国西北戈壁地区气候环境恶劣，常年干燥、大风、大温差。 在这种环境特殊气候条件下，施工控制不到位及养护措施不当会造成桥墩的开裂。本文作者以敦当高速公路大巴特沟特大桥为背景，结合施工经验对干寒戈壁地区桥梁薄壁空心墩混凝土养生技术进行研究。项目施工通过对高墩混凝土采用智能带模养生技术，有效解决了干寒、大风沙地区高墩混凝土养生技术难题，有效提高了混凝土的早期强度及结构耐久性，节约养生成本，保证了工程实体质量，对今后干寒戈壁地区高墩混凝土施工养生技术提供重要的参考价值。

关键词：混凝土养生

Research on Intelligent Formwork Curing Technology for High Pier Concrete in Dry and Cold Gobi Region

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Abstract:

The Gobi region in northwest China has a harsh climate environment with perennial dryness, strong winds and large temperature differences. Under this kind of environment and special climate condition, the bridge pier will crack if the construction control is not in place and the maintenance measures are improper. In this paper, the author takes the Grand Bategou Bridge on Dundang Expressway as the background and combines the construction experience to study the concrete curing technology of thin-walled hollow piers of bridges in dry and cold Gobi region. The construction of the project adopts intelligent curing technology with formwork for high pier concrete, which effectively solves the technical problem of curing high pier concrete in dry and cold regions and windy and sandy regions, effectively improves the early strength and structural durability of concrete, saves curing cost, ensures the quality of engineering entities, and provides important reference value for curing technology of high pier concrete construction in dry and cold Gobi regions in the future.

keywords: Concrete curing

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深水条件下钢围堰基槽淤积层及大型孤石处治技术

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摘 要：受三峡库区蓄水的影响，长江两岸大型基础工程面临深水位施工的困难。因水下钻爆方案未获得批复，万州长江公路大桥防撞设施工程 1 号导向井钢围堰基槽只能采用水下开挖方案。本文通过对 1 号导向井钢围堰位置厚层堆积体清除技术、大型孤石深水位条件下锚固与清除技术、钢围堰基槽深水位条件下取芯成槽和淤积层清除等关键技术的研究，形成了一套适用于深水位条件的钢管桩联合工程钻机取芯掏槽实现水下围堰基槽和岩体的开挖技术。该技术经过了万州长江公路大桥防撞设施工程 1 号导向井钢围堰基槽堆积体和大型孤石的处治实践验证，可为今后类似工程提供借鉴和参考。

关键词：深水；围堰基槽；堆积体；淤积层；大型孤石；处治技术

Treatment Technology of Silt Layer and Large Orphan Stone in Steel Cofferdam Foundation Channel Under Deep Water Conditions

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Abstract:

Influenced by the impoundment of the Three Gorges Reservoir Area, large-scale foundation projects on both sides of the Yangtze River are facing difficulties in deep water level construction. Because the underwater drilling and blasting scheme has not been approved, the foundation trench of No. 1 steering well steel cofferdam of Wanzhou Yangtze River Highway Bridge anti-collision facility project can only be excavated underwater. In this paper, through the research on the key technologies of the steel cofferdam of No. 1 steering well, such as the removal technology of thick deposit, anchorage and removal technology under the condition of large-scale solitary stone deep water level, core grooving and silt layer removal under the condition of deep water level of the steel cofferdam foundation groove, a set of core cutting technology of the steel pipe pile combined engineering drilling rig is formed to realize the excavation of the foundation groove and rock mass of the underwater cofferdam This technology has been verified by the treatment practice of the foundation trench accumulations and large orphans of No. 1 steering well steel cofferdam of Wanzhou Yangtze River Highway Bridge Anti-collision Facility Project, which can provide reference for similar projects in the future.

keywords: Deep water; cofferdam foundation channel; accumulation; siltation layer; large solitary stone; treatment technology

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岩质河床条件下双排钢板桩围堰施工关键技术

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摘 要：钢板桩以其结构形式灵活、施工便捷、重复利用率高等特点，在水下基础施工中被广泛运用。双排钢板桩结构充分利用钢板桩上述优点，在岩质河床条件下能够更有效的解决钢板桩贯入度小的难题，提高围堰稳定性、安全性。以渠江四桥围堰施工为例，通过理论验算和实际施工，证明双排钢板桩在岩质河床条件下施工是合理可行的，为同类工程提供了经验。

关键词：岩质河床；双排钢板桩；围堰

The Key Technologies for Construction of Double Row Steel Sheet Piles Cofferdam Under Rocky Riverbed Conditions

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Abstract:

Steel sheet piles are widely used in underwater foundation construction because of their flexible structure, convenient construction and high reuse efficiency. The structure of double row steel plate pile makes full use of the above advantages of steel plate pile, which can effectively solve the problem of small penetration degree of steel plate pile under the condition of rock riverbed and improve the stability and safety of cofferdam. Based on the construction of Qujiang No.4 Bridge cofferdam, Through theoretical calculation and actual construction, it is proved that double row steel sheet pile construction is reasonable and feasible under the condition of rock riverbed，It offers experience for similar projects.

keywords: rocky riverbed; double row steel sheet piles; cofferdam

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短线法节段梁匹配预制及悬臂拼装线形控制技术研究

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摘 要：针对短线法节段梁匹配预制及悬臂拼装过程的线形控制问题，本文重点研究了节段梁的施工理论线形、坐标转换和误差调整，考虑具体的施工工艺、施工荷载及构件拼接胶材料特性，提出了拼装线形偏差预测直接法、斜率法及其可视化方法，以及多种指导施工的纠偏措施，并将这些技术应用于某实际跨海大桥引桥工程，对其节段梁匹配预制及悬臂拼装全过程进行了精细的仿真模拟，实现了高精度的线形控制，取得了很好的应用效果。

关键词：短线法，匹配预制，悬臂拼装，误差调整，线形控制

Research on Geometric Control Technology of Matching Prefabrication and Cantilever Assembly of Segment Beam with Short-Line Method

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Abstract:

In view of the geometric control in the process of matching precast and assembly of segment beam with short-line method, the principles of theoretical shape in construction, and coordinate transformation, and error adjustment of the segment beams are studied. And a direct method, a slope method and a visualization method to predict the deviation of assembling line as well as several rectifying measures to guide erection are proposed, considering the actual construction technology, construction loads and the characteristics of material component splicing adhesive. Based on the actual engineering project of the approach bridge of a cross-sea bridge, the whole process of segment beam matching prefabrication and cantilever assembly is simulated in detail, and the high-accuracy geometric control is carried out. Eventually, a better application effect has been achieved, this article says.

keywords: short-line method; matching prefabrication; cantilever assembly; error adjustment; geomotric control

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论辐射降温在桥梁中的发展应用研究

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摘 要：简要概述了辐射降温材料的机理、发展历程及研究现状，总结了对影响辐射降温效果的两大因素——基底和颜填料。提出辐射降温材料在桥梁行业上大规模应用的必要性，将解决由于照和四季变换产生的温度应力不均问题，同时优化了桥梁结构生命周期的经济性。

关键词：辐射降温

Study on the Development and Application of Radiation Cooling in Bridges

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Abstract:

The mechanism, development history and research status of the radiation cooling materials are briefly summarized, and the two factors affecting the radiation cooling effect, the substrate and pigment storage, are summarized. The necessity of large-scale application of radiation cooling materials in the bridge industry is proposed, which will solve the problem of uneven temperature stress caused by illumination and four seasons, and optimize the economics of the bridge structure life cycle.

keywords: radiation cooling

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聚乙二醇/硅溶胶相变混凝土的制备与性能研究

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摘 要：以聚乙二醇为相变原材料，硅溶胶为定形载体，采用溶胶——凝胶法得到了聚乙二醇/硅溶胶复合定形相变材料（PEG/SiO2-CPCMs），并按绝对体积法将其掺入混凝土中制备得到相变混凝土。分析测试了 PEG/SiO2-CPCMs 的微观结构、相容性及储能特性，探究了相变混凝土的抗压强度及导热系数变化规律，最后对 15%体积掺量的相变砼进行了室内降温试验。结果表明：硅溶胶能对聚乙二醇起到很好的定形效果，最佳比例为 3:7，二者相容性良好，经 200 次热循环后，几乎无质量损失，PEG/SiO2-CPCMs 相变起始温度为 42.4℃，熔融焓值为 82.1 J/g，掺量为 5%的相变混凝土常温强度降幅为 4.96%左右，相变材料的掺加对混凝土导热性能无明显影响，室内降温试验表明相变混凝土具有显著的降温效果，最高降温幅度 4.5℃。

关键词：相变材料；聚乙二醇；硅溶胶；相变混凝土

Study on Preparation and Properties of Polyethylene Glycol/Silica Sol Phase Change Concrete

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Abstract:

Using polyethylene glycol as phase change material and silica sol as carrier, sol-gel method was used to prepare polyethylene glycol / silica sol composite phase change material (PEG/SiO2-CPCMs). The microcosmic structure, compatibility and energy storage characteristics of PEG/SiO 2-CPCMs were analyzed and tested. The variation rules of compressive strength and thermal conductivity of phase change concrete were explored. Finally, the indoor cooling test of phase change concrete with 15% volume content was carried out. The results show that silica sol has a good setting effect on polyethylene glycol (PEG). The optimum ratio is 3:7. The compatibility between them is good. After 200 thermal cycles, there is almost no mass loss. The initial temperature of phase transformation of PEG/SiO 2-CPCMs is 42.4 C, the melting enthalpy is 82.1 J/g, the normal temperature strength of phase change concrete with 5% content decreases by 4.96%, and the thermal conductivity of phase change concrete with 5% content decreases by about 4.96%. The indoor cooling test shows that the phase change concrete has remarkable cooling effect, the maximum cooling range is 4.5 ℃.

keywords: Phase Change Materials; Polyethylene Glycol; Silica Sol; hase Change Concrete

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景中高速机场连接线波形钢腹板钢——混组合箱梁制作技术

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摘 要：景中高速机场连接线高架桥为甘肃省钢结构桥梁的试点工程，同时被交通运输部列为全国首批9座钢结构桥梁典型示范项目之一。本工程采用波纹钢腹板降低附加应力和提高预应力导入率，使桥面板拉应力满足预应力A类构件的要求，达到材料的优质组合，解决了普通钢混组合结构桥面板易开裂通病和传统混凝土梁腹板开裂问题；使用压型钢板实现无模板施工，工序便利，现场工作量少；材料综合利用率高，发挥钢——混组合结构性能，适用于省内地形桥梁架设，后续工艺与普通钢筋混凝土桥基本相同，可以直接采用目前比较成熟的架桥工艺工法等为本工程波形钢腹板钢——混组合箱梁桥的设计亮点。对波形钢腹板钢——混组合箱梁结构特点进行探索和分析，通过工艺过程优化、改进生产技术，详细阐述波形钢腹板钢——混组合箱梁制作从单元划分、单元件制作、整体组装焊接到预拼装等，采用全过程的质量控制措施，保证波形钢腹板钢——混组合箱梁的制造精度，完整形成了本类组合箱梁的成套制造技术，并在本工程实际中成功运用。

关键词：波形钢腹板钢——混组合箱梁；制作技术；工艺优化；质量控制

Fabrication Technology of Corrugated Steel Web Steel-Composite Box Girder for Jingzhong Expressway Airport Connection Line

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Abstract:

The viaduct connecting jingzhong expressway with airport is a pilot project of steel structure bridge in gansu province. In this project, corrugated steel webs are adopted to reduce the additional stress and improve the prestress lead-in rate, so that the tensile stress of the bridge deck can meet the requirements of the prestressed class A members and reach the high-quality combination of materials, which solves the common problem of cracking of the bridge deck of ordinary steel-concrete composite structure and the cracking problem of the traditional concrete girder webs. Using pressed steel plate to achieve formwork free construction, convenient process, less work on site; The high comprehensive utilization rate of materials, the performance of steel-concrete composite structure, suitable for the provincial topographic bridge erection, the follow-up process and the ordinary reinforced concrete bridge are basically the same, can directly use the current relatively mature bridging process method for this project corrugated steel webs steel-concrete composite box girder bridge design highlights. Of corrugated steel web plate steel box girder and mixed exploration and analysis on the structure characteristics, through process optimization, improvement of production technology, corrugated steel web plate are introduced in detail, steel box girder and mixed production from the unit, unit parts production, the whole assembly welding to assemble, etc,

adopt the whole process of quality control measures, ensure the corrugated steel web of steel box girder and mixed manufacturing accuracy, complete formed this kind of composite box girder of complete sets of manufacturing technology, and successful application in the engineering practice.
keywords: Corrugated steel web steel-composite box girder; Production techniques; Process optimization; Quality control

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大跨悬浇钢筋混凝土拱桥施工扣索力优化计算分析

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摘 要：钢筋混凝土拱桥拱圈中由于未布设预应力钢筋，其内力对扣索力十分敏感，索力取值稍有不妥将导致主拱圈拉应力超限而引起开裂。而现行钢筋混凝土拱桥扣索力计算方法过程繁琐、计算效率较低，扣索拆除缺乏理论依据。本文以某大跨悬浇钢筋混凝土拱桥为计算示例，提出一种新的扣索力优化计算方法。首先，基于“未知荷载系数法”，获取拱圈最大悬臂状态扣索力初值。接着，开展正装分析，提取施工过程索力、应力、位移影响矩阵，结合优化原理，利用 MATLAB 软件对扣索力开展进一步优化。最后，分别基于影响线原理和无应力状态法原理确定拱圈合龙前扣索力最优拆除顺序和扣索补张拉值，确保拱圈受力合理、松索成拱后拱圈线形光滑圆顺。算例结果表明：采用此优化计算方法，算例扣索初拉力值较为均匀，所有索力值安全系数均大于 2.5；拱圈松索成拱线形合理，未出现“马鞍形”；拱圈施工过程中截面拉应力均小于 1.8MPa，满足设计要求。

关键词：优化原理

Optimum Algorithm for Construction Buckling Force of Long-Span Cantilevered Reinforced Concrete Arch Bridge

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Abstract:

The internal force of the arch ring of reinforced concrete arch bridge is very sensitive to the buckling force due to the absence of prestressing steel bars. A slight improper value of the cable force will lead to the cracking of the main arch ring due to the excessive tension stress. However, the current calculation method of the anchorage forces of reinforced concrete arch bridges is cumbersome and inefficient, and there is no theoretical basis for the removal of the anchorage cables. Based on a long-span cantilevered reinforced concrete arch bridge, this paper presents a new method for optimizing the buckling force. Firstly, based on the unknown load coefficient method, the initial value of the maximum cantilever buckling force of the arch ring is obtained. Then, carry out the forward analysis, extract the influence matrix of cable force, stress and displacement in the construction process, combined with the optimization principle, further optimize the cable force by using MATLAB software. Finally, based on the principle of influence line and stress-free state method, the optimal dismantling order of the cable force before closure of arch ring and the additional tension value of the cable are determined to ensure that the stress of the arch ring is reasonable and the line shape of the arch ring is smooth and smooth after loosening of the cable. The results show that: With this optimization calculation method, the initial tension value of the cable is more uniform, and the safety factor of all the cable tension values in construction is greater

than 2.5; the arch ring cable is reasonable in arch alignment, and there is no saddle shape; the cross-section tension stress of the arch ring during construction is less than 1.8 MPa, which meets the design requirements.

keywords: concrete arch bridge

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高寒大温差地区低温早强耐久性混凝土施工的质量控制

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摘 要：近几年我国基建行业的发展不断提速，对混凝土工程的质量要求也日益严格，混凝土是混凝土工程最重要的一项内容，因而对其质量控制就成为工程人关注的焦点。在高寒地区，寒冷、干燥、平均气温低、昼夜温差大的气候下混凝土很容易受到冻害，对耐久性有很大影响，进而给整体工程建设质量带来危害，因此对高寒地区混凝土施工质量的控制进行研究极为重要。本文深入分析影响高寒地区混凝土耐久性的主要因素，然后提出在高寒地区提高混凝土的主要措施，以此保证工程的整体质量。

关键词：高寒地区；低温早强；混凝土施工；质量控制

Quality Control of Low Temperature Early Strength Durable Concrete Construction in High Temperature and Great Temperature Difference Area

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Abstract:

In recent years, the development of China's infrastructure industry has been accelerating, and the quality requirements for concrete engineering have become increasingly strict. Concrete is the most important content of concrete engineering. So its quality control has become the focus of engineering people. In the alpine region, the concrete is vulnerable to freezing damage in cold, dry, low average temperature and a high temperature difference between day and night, which has a great impact on durability and thus brings harm to the overall construction quality. Therefore, the quality of concrete construction in alpine regions is high. Controlling research is extremely important. This paper deeply analyzes the main factors affecting the durability of concrete in alpine regions, and then proposes the principal measures to improve concrete in alpine regions to ensure the overall quality of the project.

keywords: alpine region; low temperature early strength; concrete construction; quality control

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绿色养护——不同纤维增强碱矿渣胶凝材料的配合比试验研究

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摘 要：为节约资源，变废为宝，本文研发了一种新型绿色环保材料——植物纤维增强碱矿渣胶凝材料，并横向对比了高弹性模量纤维（聚丙烯纤维、微细钢纤维、较粗钢纤维）增强碱矿渣胶凝材料的增韧效果。综合考察了碱激发剂种类、水玻璃模数、碱含量、水用量、纤维种类、纤维处理方式对碱矿渣胶凝材料力学性能的影响。分析表明：加入钾水玻璃的试件抗折强度、抗压强度均比加入钠水玻璃的试件高。M=1.0 的胶砂件抗折强度与抗压强度最高分别可以达到 15.4MPa 和 130MPa，均大于相同条件下 M=2.0 的试件。获得了碱矿渣胶凝材料的两种较优配比，此外，可知麦秆相比稻杆和玉米杆，增强效果更佳，微细钢纤维相比麦秆、聚丙烯纤维和较粗钢纤维，增强效果最好。研究成果在减少环境污染、提高材料延性、实现资源循环利用等方面将发挥巨大作用。

关键词：碱矿渣胶凝材料；配合比；力学性能；微观；纤维

Green Maintenance-Experimental Research on Mixture Ratio of Different Fibers Reinforced Alkali-Activated Slag Cementitious Material

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Abstract:

In order to save resources and turn waste into wealth, this paper developed a kind of new green material-plant fiber reinforced alkali-activated slag cementitious material, and compared with the enhancement effect of high elastic modulus fiber (polypropylene fiber, fine steel fiber and coarse steel fiber) reinforced alkali-activated slag cementitious material. The effects of alkali activator, sodium silicate modulus, alkali content, water content, fiber type and fiber treatment on the mechanical properties of alkali-activated slag cementitious material were investigated. The analysis shows that bending strength, compressive strength of specimens added with potassium silicate are higher than that of specimens added sodium silicate. The flexural strength and compressive strength of specimens with alkali content M = 1.0 can reach 15.4MPa and 130MPa, respectively, and higher than that of specimens with alkali content M = 2.0 in the same condition. Two kinds of the optimal mixture ratio of the alkali-activated slag cementitious material were obtained. In addition, the enhancement effect of the wheat straw is better than rice straw and corn stalk. Compared with wheat straw, polypropylene fiber and coarse steel fiber, the enhancement effect of fine steel fiber is the best. The research results will play an important role in reducing environmental pollution, improving the material ductility and realizing resource recycling.

keywords: alkali-activated slag cementitious material; mixture ratio; mechanical property; micro; fiber; alkali-activated slag cementitious material; mixture ratio; mechanical property; micro; fiber

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绿色养护——碱矿渣胶凝材料研究现状与展望

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摘 要：总结了近年来碱矿渣胶凝材料（AASCM）的研究现状，包括AASCM的配合比设计，受压应力——应变关系全曲线方程，常温下、高温下和高温后的力学性能，粘结锚固性能，以及用AASCM粘贴碳纤维布加固混凝土梁板抗火设计方法等，揭示AASCM具有强度高、成本低、耐高温性好的优点，分析了AASCM成为新型建筑材料的存在的问题和可行性。在此基础上，提出将AASCM运用到砌体结构中，并用AASCM替代砌筑砂浆，用于砌筑AASCM砌块墙，既节能环保，又耐高温，可提高砌体结构的抗火能力，并可丰富现代砌体结构的内涵。

关键词：碱矿渣胶凝材料；高温；力学性能；受压应力——应变关系；砌体

Green Maintenance-Research Status and Prospects of Alkali-Activated Slag Cementitious Material

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Abstract:

This paper presents research status of alkali-activated slag cementitious material (AASCM) in recent years, including the mix design of AASCM, and compressive stress-strain full curve equation, and the mechanical properties of AASCM at room temperature, at high temperature and after high temperature, and bond anchorage properties, as well as fire resistance of concrete beams and slabs strengthened with carbon fiber sheets using AASCM and so on. The advantages of AASCM with high strength, low cost, high temperature resistance are revealed, and the questions and feasibility of AASCM as new building materials are analyzed. On the basis of experimental and analytical results, AASCM is proposed to apply to the masonry structures, and AASCM may be used to substitute mortar for AASCM masonry block walls, not only energy saving and environmental protection, but also high temperature resistance. AASCM masonry block walls may improve the fire resistance of the masonry structures and enrich the connotation of modern masonry structures.

keywords: alkali-activated slag cementitious material; high temperature; mechanical property; compressive stress-strain relationship; masonry; alkali-activated slag cementitious material; high temperature; mechanical property; compressive stress-strain relationship; masonry

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新型钢混组合式吊杆——主梁锚固结构研究

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摘 要：本文依托温州龙港大桥改建工程，提出了一种新型钢——混凝土组合吊杆——主梁锚固结构，该锚固结构由耳板，设置开孔板连接件的锚拉板和加劲板，以及承压板组成。开展了现场荷载试验，实测耳板主应力大小。进行了 1:2 缩尺模型静力与疲劳试验，研究了试件的荷载——滑移曲线，结合部钢板的主应力大小及方向，和混凝土竖向应力分布。研究结果表明新型组合锚固结构连接刚度大，锚固区疲劳性能良好，耳板传力均匀可靠。该新型锚固结构具有易于更换吊杆，构件预制施工方便，锚固区空间开阔易于检测维护等优点，已在多座桥梁中应用。

关键词：拱桥；组合结构；吊杆锚固；受力机理；拱桥；组合结构；吊杆锚固；受力机理；拱桥；组合结构；吊杆锚固；受力机理

Study of New Steel-Concrete Composite Suspender-Beam Anchor Structure

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Abstract:

Based on Wenzhou Longgang bridge rebuileding engineering, a new style steel-concrete composite suspender-beam anchor structure is proposed. This anchor structure include ear-plate, rib plate that with perfobond connector, bearing plate. Field loading test is conducted to measure principal stress. Though static and fatigue performance 1:2 scale model tests, researched load-slip curves of specimen, principal stress of plate in joint,vertical stress of concrete. Study result shows this new style composite anchor structure has high rigidity, good anti-fatigue performance in anchor zone, load transmitting is uniform and reliable. This new style anchor structure has many advantages such as easy to change suspender, easy to prefabricate component, easy to inspection and maintenance anchore zone. And already used in several bridge.

keywords: Arch Bridge; composite structure; suspender anchor; mechanical performance

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超高性能混凝土梁抗弯承载力简化计算方法

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摘 要：通过细观力学手段，揭示了纤维对残余抗拉强度贡献机理，提出了考虑纤维分布、取向和埋深的 UHPC 细观本构模型，为预测 UHPC 残余抗拉强度提供新思路。基于 UHPC 细观本构，通过受力平衡方程和变形协调条件，建立了 UHPC 梁抗弯承载力简化计算方法。经与 9 片 UHPC 梁试验结果对比发现，本文提出的模型可以很好地预测 UHPC 梁受弯承载力。

关键词：超高性能混凝土；受弯承载力；本构模型

Simplified Calculating Method on Flexural Strength of Ultra High Performance Concrete Beams

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Abstract:

The resistance mechanism of fiber on the residual tensile strength is investigated by mesomechanics analysis, and a mesoscale constitutive model which takes into account the distribution, orientation and embedment length of fibers is proposed, providing an alternative way to predict the residual tensile strength of UHPC. Based on the proposed constitutive model, the flexural analysis model is established via force equilibrium and deformation compatibility equations. The proposed flexural model is verified by the result of 9 UHPC beams. It is found that the proposed model could accurately predict flexural strength of the test beams.

keywords: Ultra-high performance concrete; flexural strength; constitutive model

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Tension Stiffening in Strain-Hardening Cement-Based Composites (SHCC) Under Impact Loads

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Abstract: Damage mechanism in various strain hardening cement composites (SHCC) under high speed tensile loading and flexural impact was investigated. The impact test setup was based on a free-fall drop weight on a three-point bending specimen. A servo-hydraulic high-speed tensile machine was used for tension tests. As the input impact energy increased from 6.7J to 67J, absorbed energy increased from 0.7 J to 3.6 J and remained constant at that level. Ultimate load and maximum deflection also increased with increasing input energy. Uniaxial tension tests on SHCC specimens were conducted at strain rates of 25 s-1, 50 s-1, and 100 s-1. Increases in tensile strength and strain capacity were observed with increasing strain rate. Image analysis by means of digital image correlation (DIC) method was used to obtain the evolution of crack width which was subsequently correlated with stress response. The non-uniform strain distribution was characterized as three distinct response zones of localization, shear lag, and uniform strain and quantitatively measured in each zone. Mechanism corresponding to the basic aspects of tension stiffening modelling were identified by computing the average stress in the matrix phase between two cracks. The width of crack localization zone as well as crack spacing were also obtained using DIC as indications of bonding properties. A finite difference method simulating tension stiffening behaviour was developed to predict crack spacing and stress-strain responses of TRC systems. Improvements in bond properties and mitigation of cracking with the addition of short fibres were verified using multiple methods.

Key words: high speed tension testing; impact behaviour; digital image correlation (DIC); crack width and spacing; localization; strain rate; SHCC

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高强钢筋与 UHPC 界面粘结性能试验研究

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摘 要：超高性能混凝土（UHPC）由于具有优异的材料性能，其与钢筋的粘结性能备受关注。本文对 8 组高强钢筋与 UHPC 中心拉拔试件进行了加载测试，研究了钢筋直径、钢筋埋深和保护层厚度对粘结性能的影响，并对粘结破坏机理进行分析。试验结果表明，高强钢筋与 UHPC 中心拉拔试件均发生了劈裂拔出破坏；平均极限粘结强度随着钢筋直径和钢筋埋深的增加而减小，随着保护层厚度的增加而增加；相比于钢筋直径和钢筋埋深，保护层厚度对平均极限粘结强度影响更加显著；粘结滑移曲线可划分为微滑移段、滑移段、劈裂段、下降段和残余段。

关键词：超高性能混凝土；粘结性能；破坏模式

Experimental Study on the Bonding Performance Between High Strength Rebar and Ultra-High Performance Concrete

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Abstract:

Ultra-high performance concrete (UHPC) has attracted much attention because of its excellent material properties. In this paper, eight sets of pulling out specimens were tested. The effect of reinforcement diameter, anchorage length and the cover layer thickness on the bond performance was studied and the bond failure mechanism was analyzed. The test results show that the bonding failure occurs in the form of splitting and pulling out for all specimens. The average ultimate bond strength decreases with the increase of the diameter and anchorage length and increases with the increase of the cover layer thickness. Compared with the diameter and anchorage length, the influence of the cover layer thickness on the average ultimate bond strength is more significant. The bond-slip curve can be divided into five stages, including micro slip stage, slip stage, splitting stage, descent stage and residual stage.

keywords: UHPC; bond property; failure mode

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玄武岩纤维板在桥梁加固中的应用研究

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摘 要：本文将着重介绍运用玄武岩纤维板在桥梁建筑物进行加固的方法，介绍了玄武岩纤维板的基本性能，对玄武岩纤维板的加固原理进行了分析和总结,探讨了玄武岩纤维板在桥梁加固工程中应用的广阔前景。

关键词：玄武岩纤维板；桥梁加固；应用研究

Application of Basalt Fiber Reinforced Slab in Bridge Reinforcement

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Abstract:

This paper will focus on the using basalt fiber sheet reinforcement method in bridge building, introduces the basic properties of basalt fiber board, the basalt fiber in reinforcement principle to carry on the analysis and the summary and explore the basalt fiber sheet in bridge reinforcement engineering application prospects.

keywords: Basalt fiber board; Building reinforcement; Application research

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高性能树脂混凝土钢丝网薄层加固 RC 偏压柱理论分析

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摘 要：配有钢丝网的高性能树脂混凝土薄层（HTRCS）复合材料是一种新型的加固材料，该材料能利用树脂混凝土的强度发展快的特点来减少养护时间，以便加固后的 HTRCS 材料能尽快承受荷载，进而实现交通的快速恢复。目前,对该加固方式的研究较少，且主要集中在加固效果及其影响因素的试验研究中，而对加固机理的分析很少。本文基于已完成的高性能树脂混凝土钢丝网薄层加固 RC 偏压柱的试验，对加固试件破坏机理、加固试件的承载力进行了理论分析。建立了裂缝平均间距与钢丝网周长关系式，可对钢丝网层数与平均裂缝间距进行定量分析；利用半波曲线较好地拟合了不同钢丝网层数下试件横向挠度曲线方程；分析验证了加固试件对于不同荷载等级，变形过程中均满足平截面假定；基于条带法运用 MATLAB 程序对 HTRCS 加固 RC 偏压柱的承载力进行理论值计算，与试验值比较误差在 5%以内，因此用条带法进行承载力计算是合理可行的。

关键词：桥梁工程；树脂混凝土钢丝网薄层（HTRCS）；钢筋混凝土（RC）偏压柱；加固机理； 理论分析

Theoretical Analysis of Bearing Capacity of Concrete Eccentric Compressive Column Reinforced by HTRCS

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Abstract:

High toughness resin concrete with steel wire mesh (HTRCS) is a new type of reinforcement material. This material can utilize the characteristics of rapid development of the strength of the resin concrete to reduce the curing time, so that the reinforced HTRCS can bear the load as soon as possible, thereby achieving rapid recovery of traffic. At present, there are few studied on this reinforcement method, and it is mainly focused on experimental research of reinforcement effect and its influencing factors. However, the analysis of reinforcement mechanism is rare. In this paper, based on the experiment conducted previously, failure mechanism and bearing capacity of strengthened specimens were analyzed theoretically. The relationship between the average crack spacing and the circumference of steel wire mesh was established, which can be used for quantitative analysis of the layers of steel wire mesh and the average crack spacing; The equation of transverse deflection curve of specimens with different layers of wire mesh was well fitted by half-wave curve; It was analyzed and verified that the reinforced specimens meet the plane section assumption during the deformation process for different load levels; Based on the strip method, the MATLAB program

was used to calculate the bearing capacity of the HTRCS-reinforced RC biased column. The error was less than 5% compared with the experimental value. Therefore, it is reasonable and feasible to calculate the bearing capacity by the strip method.

keywords: bridge engineering; HTRCS; RC eccentric column; reinforcement mechanism; theoretical analysis

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Deformation Control of Bridge Piles of the High-Speed Railway Under Crossed by Shield Tunnel

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Abstract: Hangzhou metro line 1 is designed to cross under the Hu-Hang high-speed railway. According to the design, the shield tunnel is very close (minimum distance 5.19m) to the bridge piles of the Hu-Hang high-speed railway. Therefore, how to control the deformation of the bridge piles is a big problem in the shield tunnel excavation. Before construction, the method of the bored piles coupled with the jet grouting piles was proposed. The 3D numerical model was built to study the deformation of the bridge piles with the cases of the shield tunnel excavation without soil consolidation, the construction of the bored piles coupled with the jet grouting piles and the shield tunnel excavation with soil consolidation. The results show that the method of the bored piles coupled with the jet grouting piles can control the deformation of the bridge piles in the shield tunnel excavation effectively. Then, the deformation monitoring of the bridge piles was performed in the process of construction. The monitored data were close to the calculated results, which implies that the method of the bored piles coupled with the jet grouting piles is effective.

Key words: High-speed railway, Shield tunnel, Bored piles, Jet grouting piles, Under cross

聚氨酯水泥钢丝绳加固 T 梁桥抗弯承载能力试验研究

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摘 要：本文介绍了聚氨酯水泥钢丝绳加固桥梁的新型桥梁主动加固方法。为验证该加固方法的可行性，本文通过室内试验，对聚氨酯水泥的抗拉、抗压进行了测试，对未加固和不同聚氨酯钢丝绳加固方案的 3m 普通钢筋混凝土 T 梁进行抗弯承载力破坏试验，通过对比各试验梁的试验数据，分析了聚氨酯水泥钢丝绳的加固效果。室外试验依托某实桥加固工程，分别对加固前后的该桥进行荷载试验，通过对比加固前后荷载试验数据，验证聚氨酯水泥钢丝绳对试验梁刚度、强度以及承载能力的提升效果，结果表明，聚氨酯钢丝绳抗弯加固可有效提高试验梁的抗弯承载能力，加固效果良好，进一步验证了该加固方法的实际工程价值，可用于实际桥梁的抗弯承载能力的提升。

关键词：聚氨酯水泥；加固；T 梁；抗弯承载能力

Experimental Study on Flexural Bearing Capacity of T-Beam Bridge Strengthened with Polyurethane Cement Steel Wire Rope

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Abstract:

This paper introduced a new active reinforcement method for bridges strengthened by polyurethane cement wire rope. In order to verify the feasibility of this reinforcement method, the tensile and compressive properties of polyurethane cement were tested through laboratory tests and the bending failure tests of 3m ordinary reinforced concrete T-beams without reinforcement and with different reinforcement schemes of polyurethane wire rope were carried out in this study. The reinforcement effect of polyurethane cement wire rope was analyzed by comparing the test data of each test beam. The results show that polyurethane wire rope reinforcement can effectively improve the flexural bearing capacity of test beams. The outdoor test relies on a bridge reinforcement project, the load tests of the bridge before and after reinforcement were carried out respectively. By comparing the load test data, the reinforcement effect of polyurethane cement wire rope on stiffness, strength and bearing capacity of test beams is verified, and the practical engineering value of the reinforcement method is further verified. It can be used to improve the bending capacity of actual bridges.

keywords: polyurethane cement; reinforcement; T-beam; flexural bearing capacity

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南京长江大桥双曲拱桥加固改造设计

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摘 要：南京长江大桥是长江上第一座由中国自行设计和建造的双层式公铁两用特大桥梁，具有划时代的里程碑意义。其公路引桥靠两侧桥台部分采用双曲拱桥，富有民族特色，极具时代特征。经过近 50 年的运营，双曲拱桥的耐久性病害非常严重。加固改造工程遵循“修旧如故”的总原则，在不改变其结构体系、基本不改变其外观的前提下，适当恢复并提高其承载力，着重提升其耐久性。针对双曲拱桥的固有缺陷和本工程的病害特点，主拱圈加固采用了以主拱肋外包薄层混凝土为主要措施的增大截面加固法，并适当增强了横向联系。将拱上填料由原来的石灰煤渣土全部更换为泡沫混凝土，并在填料顶面增设连续配筋混凝土板，最后铺设沥青混凝土成为复合路面，大大增强桥面的耐久性及舒适性。本工程主要采用了补偿收缩的自密实混凝土、阴极保护对新老钢筋的额外保护、全桥混凝土涂装等措施来提升结构的耐久性。现工程已按设计方案顺利实施完毕，取得良好效果。

关键词：南京长江大桥；双曲拱桥；加固改造；耐久性

Strengthen & Rehabilitation Design of Two-Way Curved Arches of Nanjing Yangtze River Bridge

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Abstract:

Nanjing Yangtze River Bridge is an extra large size bridge with double decks. It is the first bridge crossing Yangtze River which designed and constructed by Chinese. This bridge is an important milestone with epoch-making significance in China. The approach bridges near the abutments of highway bridge of Nanjing Yangtze River Bridge are two-way curved arch bridge with typical Chinese style. After near 50 years' service, this bridge is found to be suffering critical durability problems. The rehabilitation design follows the principle of keeping its original style, without changing its structure type and its appearance, however, the capacity of the bridges shall be recovered and strengthened, and the durability of the bridges will be improved. According to the inherent defects of this type of bridges and the deterioration characters of this project, an increasing section area method via enwrapping the arch ribs with thin reinforced concrete, is adopted to strengthen the arch ribs. At the same time, the transverse beams are strengthened too. The original filler above the arches of the bridge was mixture of soil, lime and coal cinder. In the rehabilitation design, it is replaced by foamed concrete thoroughly. Continued reinforced concrete plates are cast above the filler, then followed by asphalt pavement. To increase the durability of the structure, some

measures are taken, such as increasing the section of arch ribs with shrinkage-compensating self-compacting concrete, extra protection of the new and old reinforced bars with cathodic protection systems, coating the whole bridge, and so on. Now this project is complete. The process is smooth and the result is satisfactory.

keywords: Nanjing Yangtze River Bridge; two-way curved arch bridge; Strengthening; Durability

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新型小箱梁绞缝损伤前后横向分布系数的变化

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摘 要：文章对现有预制装配式小箱梁桥横向整体受力问题，提出了一种新型的横隔板构造形式，采用大比例模型试验的方法对比研究了新型横隔板构造和传统横隔板构造对小箱梁桥传力和荷载分配方式的影响，然后采用三维实体有限元数值仿真技术全面探讨了小箱梁的受力性能与传力方式，并与试验结果进行了比对验证。

关键词：小箱梁；横向分布；绞缝损伤

Variation of Transverse Distribution Coefficient of New Type Small Box Girder Before and After Damage

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Abstract:

In this paper, a new type of transverse bulkhead is proposed to solve the problem of transverse overall force of the prefabricated box girder bridge. The method of large-scale model test is used to compare the structure of the new type of transverse bulkhead and the traditional transverse Plate structure on the force transmission and load distribution of small box girder bridge, and then use the three-dimensional solid finite element numerical simulation technology to fully investigate the mechanical behavior and force transmission of small box girder, and compared with the test results were verified.

keywords: Small box girder; Horizontal distribution; Twist damage

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双薄壁墩防撞浮箱提升技术研究与工程应用

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（重庆交通大学）

摘 要：国内大部分桥梁都处于检修加固阶段，对双薄壁墩防撞浮箱下部河床进行清理或浇筑支撑平台时，需要将防撞浮箱进行整体提升，故本文根据实际工程需要研制了一种针对性强的防撞浮箱液压同步提升系统，确定了系统主要参数及工艺流程。并用于重庆黄花园嘉陵江大桥实体工程，结合具体实例对该系统进行了有限元模拟分析计算。工程现场实际应用效果表明该系统安全可靠，具有较强的使用价值。

关键词：双薄壁墩；防撞浮箱；同步提升；有限元分析

Lifting Technology Research and Engineering Application of the Anti-Collision Floating Pontoon for Double Thin-Walled Piers

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(Chongqing Jiaotong University)

Abstract:

Most bridges in China are in the stage of maintenance and reinforcement. When cleaning the lower riverbed of the anti-collision floating pontoon with double thin-walled piers or pouring the supporting platform, the anti-collision pontoon needs to be lifted as a whole. Therefore, a hydraulic synchronous lifting system of the anti-collision floating pontoon with strong pertinence is developed according to the actual engineering needs, and the main parameters and technological process of the system are determined. The system is applied to the real project of Chongqing Huanghuayuan Jialing River Bridge, and the finite element analysis and calculation of the system are carried out with a specific example. The practical application results show that the system is safe and reliable, and has strong application value.

keywords: double thin-walled piers; anti-collision floating pontoon; synchronous lifting; finite element analysis

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横向联系对双工字钢组合梁受力性能影响研究

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摘 要：本文通过有限元模拟分析了横向连接形式和数量对双工字钢组合梁在施工阶段钢主梁和混凝土桥面板的受力性能和稳定性的影响，得出在临时支撑的作用下钢主梁的失稳模态为侧弯失稳；通过在组合梁最不利位置布置车辆荷载分析了使用阶段横向连接对组合梁的受力性能影响规律，建议在横梁数量较少时做好桥面板抗裂措施。

关键词：桥梁工程；组合梁；横向联系

Research on Influence of Transverse Connection on the Mechanical Performance of Double I Girder Composite Beam

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(Chang'an University)

Abstract:

In this paper, the influence of the form and quantity of transverse connection on the mechanical performance and stability of steel girder and concrete deck of duplex steel composite girder in construction stage is analyzed by finite element simulation, and it is concluded that the instability mode of steel girder under temporary support is lateral bending instability. The influence of transverse connection on Composite girder in use stage is analyzed by arranging vehicle load at the most disadvantageous position of composite girder. It is suggested that crack resistance measures of bridge deck should be taken when the number of beams is small.

keywords: bridge engineering; composite beam; transverse connection

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耐候钢桥材料腐蚀行为及机理研究

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摘 要：钢桥腐蚀严重制约了桥梁在设计使用期内的耐久性能。采用耐候钢建造的桥梁可有效抑制钢表面腐蚀，节约桥梁寿命周期成本。针对耐候钢的材料特点，本文围绕材料研发现状、腐蚀行为、耐腐蚀机理三方面展开研究。通过介绍耐候钢材料研发现状，指出中国耐候钢研发存在问题及未来发展方向，促进耐候钢桥更好发挥其耐腐蚀性。针对耐候钢桥腐蚀行为研究，通过进行 HPS485W 耐候钢与普通钢暴露试验，比较两种钢材腐蚀行为差异，探究耐候钢腐蚀过程与特点。最后，通过研究耐候钢桥锈层成分及保护机理，明确耐候钢耐腐蚀机理与影响因素，为耐候钢桥合理耐久性设计奠定理论基础。

关键词：耐候钢桥；材料研发；腐蚀行为；耐腐蚀机理；耐久性设计

Study on Corrosion Behavior and Mechanism of Weathering Steel Bridge

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Abstract:

Corrosion limits the durability of steel bridges during its design life. Bridges constructed with weathering steel can be effectively inhibited from corrosion on the steel surface, saving bridge life cycle costs. According to the material characteristics of weathering steel, this paper focuses on the research of material development, corrosion performance and corrosion mechanism of weathering steel. By introducing the research and development status of materials, problems in the development of weathering steel in China and the direction development in the future are pointed out. For the corrosion behavior of weathering steel bridges, the corrosion behavior of the two steels is compared by the exposure test used by HPS485W weathering steel and carbon steel, and the corrosion process and characteristics of the weathering steel are explored. Finally, by studying the composition and protection mechanism of patina on weathering steel bridges, the corrosion resistance mechanism and influencing factors of weathering steel are clarified, which lays a theoretical foundation for the reasonable durability design of weathering steel bridge.

keywords: weathering steel bridge; material development; corrosion performance; corrosion mechanism; durability design

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既有正交异性钢桥面板弧形切口孔型优化及疲劳加固试验

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摘 要：钢桥面板 U 肋——横隔板连接位置弧形切口处为疲劳病害高发区，以优化此构造细节的疲劳性能、完善其疲劳加固和防治技术为目标，基于力流原理和有限元方法对弧形切口的构造特征和疲劳应力进行参数分析，提出某悬索桥横隔板弧形切口的孔型切割加固方案，在加固前、后分别开展轮载试验，测试了纵移和横移轮载下 2 片横隔板关注弧形切口断面、侧面的应力分布规律和应力——轮载位置关系。理论与试验研究表明：1）作用在桥面板上的轮载通过 U 肋以剪应力的形式传递到横隔板，导致弧形切口处力流高度密集；2）弧形切口开孔宜小，开孔半径宜大，开孔形状不宜阻碍力流传递路径。3）弧形切口优化加固后，最大应力降幅 87.6MPa，最大应力降幅比为 58.4%，考虑横向概率分布的等效常幅应力幅降低 55.2%。4）优化加固后，弧形切口周边应力减小，横隔板截面面积削弱而导致横隔板应力少量增大，不会造成新的疲劳开裂源。

关键词：钢桥面板；疲劳加固；弧形切口优化；疲劳寿命评估；轮载试验

Cope Hole Optimization and Fatigue Reinforcement Test of Existing Orthotropic Steel Deck

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Abstract:

The cope hole areas near U rib-diaphragm connections in steel bridge deck are easy to suffer fatigue damages, to optimize the structure details of fatigue performance, and to improve its fatigue reinforcement and the control technology, the structural characteristics and fatigue stress of arc incision are analyzed on the basis of the principle of power flow and finite element method, put forward a cope hole optimization scheme for transverse diaphragm in suspension bridge, wheel load test was applicated before and after the reinforcement, respectively, the longitudinal and transversal 2 slices under wheel loading, horizontal clapboard on curved section of the incision, lateral stress distribution and stress and wheel load position. Theoretical and experimental studies show that: 1) the wheel load acting on the bridge deck is transferred to the transverse diaphragm in the form of shear stress through the U rib, resulting in a highly intensive force flow at the curved notch;2) the arc-shaped incision should be small, the opening radius should be large, and the opening shape should not hinder the force flow transmission path.3) after the arc incision was optimized and strengthened, the maximum stress reduction was 87.6mpa, and the maximum stress reduction ratio was 58.4%. Considering the transverse probability distribution, the equivalent constant amplitude

stress amplitude was reduced by 55.2%.4) after the optimization and reinforcement, the peripheral stress of the curved incision decreases, and the cross-section area of the diaphragm weakens, resulting in a small increase in the stress of the diaphragm, which will not cause a new source of fatigue cracking.

keywords: Orthotropic steel bridge deck; Fatigue reinforcement; Cope hole optimization; Fatigue life assessment; Wheel load test

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波浪作用下吸力式桶形基础的冲刷特性试验研究

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摘 要：在设计结构和考虑有效的海洋工程基础的冲刷防护工程时，了解和预测海洋结构周围的冲刷发展机理是非常重要的。通过波流水槽研究了规则波作用下吸力式桶形基础的冲刷特性。试验主要考虑波高与结构尺寸对吸力式桶形基础周围局部冲刷的影响。分析了波浪冲刷过程中模型周围的时程地形、波浪作用后的冲刷坑性状、冲刷影响要素以及不同结构间的冲刷差异。结果表明：吸力式桶形基础的冲刷过程是震荡加深发展，最大冲刷深度与冲刷宽度随波高增大而增加，随上部结构直径增大而增加，最大冲刷深度位置随波高与结构尺寸而变化；不同结构间的冲刷坑形态与冲刷后的地形不同，最大冲刷深度相差可高达 4 倍；吸力式桶形基础结构直径比小于 0.5 时，结构自身具有防冲刷能力。

关键词：吸力式桶形基础；波浪；局部冲刷；结构尺寸

Experimental Study on Scouring Characteristics of Suction Bucket Foundation in Wave

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（中国海洋大学）

Abstract:

It is very important to understand and predict the scouring development mechanism around ocean structures when designing structures and considering effective scouring protection projects for offshore engineering foundations. In this paper, the scouring characteristics of suction bucket foundation in regular waves are studied by wave-current flume. The effect of different wave heights and structural sizes on local scour around suction bucket foundation is mainly considered in the test. The paper analyzes the time dynamic topographic height, scour pit characteristics, scour characterization parameters and scour differences among different structures around the model during wave scouring. The results show that the scouring process of suction bucket foundation is the development of shock. The maximum scouring depth and width increase with the increase of wave height, the diameter of superstructure and the position of maximum scouring depth change with wave height and structure size. The difference of maximum scouring depth between different structures can be as high as 4.1 times. When the diameter ratio of suction bucket foundation is less than 0.5, the knot will be formed. The structure itself has the ability to prevent scouring.

keywords: suction buction foundation; wave; local scour; structure dimensio

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UHPC 加固混凝土柱偏心受压试验研究

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摘 要：为研究 UHPC 单侧加固混凝土柱承受偏心荷载的能力，制作了 8 根混凝土柱并开展了单侧加固，通过小偏心受压试验，研究了加固柱在偏心荷载作用下的破坏模式、应变分布和承载能力。结果表明：UHPC 加固后，试件的破坏由突然的崩坏转变为原结构的局部破坏；平截面假定不完全适用，根据偏心距的正负，加固层应变可能滞后或者超前于普通混凝土应变；加固后试件抵抗偏心荷载的能力得到提高，偏心距为正时，承载力提升幅度达 40%以上，偏心距为负时，承载力提升幅度达 70%以上。

关键词：超高性能混凝土；加固；小偏心；平截面假定；承载能力

Experimental Study on Eccentric Compression of Concrete Columns Reinforced with UHPC

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(Chongqing Jiaotong University)

Abstract:

In order to study the capacity of UHPC reinforced concrete columns under eccentric load, eight concrete columns were fabricated and strengthened unilaterally. The failure mode, strain distribution and bearing capacity of reinforced columns under eccentric load were studied through small eccentric compression test. The results show that the failure of UHPC strengthened specimens changes from sudden collapse to local failure of the original structure; the assumption of plane section is not fully applicable; according to the positive or negative eccentricity, the strain of the strengthened layer may lag behind or advance the strain of ordinary concrete; the ability of specimens to resist eccentric load is improved after strengthening, when the eccentricity is positive, the bearing capacity is increased by more than 40%, and the eccentricity is greater than 40%. When it is negative, the increase of bearing capacity is more than 70%.

keywords: ultra-high performance concrete; reinforced; small eccentricity; plane section assumption; bearing capacity

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Bond-Slip Modeling of Strand Under Insufficient Confinement of Concrete Cover

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Abstract: Bonding between seven-wire prestressing strand and concrete is critical for the design and analysis of prestressed concrete structures, especially with insufficient concrete cover. An analytical model is proposed to predict the bond-slip characteristics between strand and concrete under insufficient concrete cover. First, the three-dimensional distribution characteristics of the interfacial force between strand and concrete are analyzed considering the twisting features of prestressing strand. Then, the analytical expressions of the bond stress under non-uniform mechanical interlock are derived. Subsequently, the rotation mechanism for strand embedded in concrete is described. The quantification method of the rotational slip is proposed based on the energy conservation equation. Finally, comparison of results between the prediction and experiment shows that the proposed model can be used to reasonably predict the bond-slip characteristics of twisting strand.

Key words : Prestressed concrete structures; Insufficient concrete cover; Bond-slip characteristics; Non-uniform mechanical interlock; rotation mechanism

山岭隧道施工机械化研究

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摘 要：随着我国国内交通建设迅速发展，隧道工程建设量快速增加，寒区山岭隧道建设往往有着工程施工工期、施工质量、施工技术要求高等特点，其对机械化的需求日益增强。隧道建设品质化是未来发展必然趋势，其中机械化更是隧道建设品质化的首要任务与前提。针对山岭隧道建设机械化、信息化水平不高的问题，国家交通运输部提出了打造品质工程的要求，许多山岭隧道建设开展了全工序大型机械配套条件下的施工技术探索，寒区山岭隧道建设机械化水平随着几十年来的发展，有很大提高，出现了许多新装备、新技术。

关键词：寒区山岭隧道；施工机械化；新装备

Research on Mechanization of Mountain Tunnel Construction

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Abstract:
with the rapid development of China's domestic transportation construction, the construction volume of tunnel construction has increased rapidly. The construction of mountain tunnels in cold regions often has the characteristics of engineering construction period, construction quality and high construction technical requirements, and its demand for mechanization is increasing. The quality of tunnel construction is an inevitable trend in the future development, and mechanization is the primary task and prerequisite for the quality of tunnel construction. In view of the problem of low mechanization and informatization level of mountain tunnel construction, the Ministry of Transport of the People's Republic of China has put forward the requirements for building quality engineering. Many mountain tunnel constructions have carried out exploration of construction techniques under the conditions of large-scale machinery supporting the whole process, and mechanization of construction of mountain tunnels in cold regions. With the development of decades, the level has greatly improved, and many new equipment and new technologies have emerged.
keywords: mountain tunnel in cold region; construction mechanization; new equipments

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Monitoring and Evaluation of Artificial Ground Freezing in Metro Tunnel Construction-A Case Study

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Abstract: The turn-back tunnel of Guangzhou Metro Line 3 Tianhe Station with a large span was excavated in sandy clay which may easily break and disintegrate. The artificial ground freezing technique was used to stabilize the soil and to prevent the collapse of soil nearby excavations. Field monitoring was conducted to measure the temperature of the brine and the ground (i.e. the soil). Analysis has been conducted in this study based on the field measurement, with the aim to evaluate the effectiveness and safety of the frozen zone.

Based on the measured brine temperature and ground temperature, the thickness of the frozen zone is computed by a simplified analytic formula under the condition of a single-circle-pipe freezing. The average temperature of the frozen zone is predicted using an empirical formula. In addition, numerical simulation is carried out to predict the extension of the frozen zone and the temperature field of the frozen zone. The analysis results show that the thickness and the average temperature of the frozen zone in this project meet the designed requirements, and that it is safe to carry out tunnel excavation during the maintenance freezing period.

In this paper, the coupled method of the field monitoring, the analytical formula, and the numerical method is used to evaluate the thickness and average temperature of the frozen zone. The analytical predicted thickness and average temperature of the frozen zone have a good agreement with the numerical simulation. According to the analytical and numerical analysis, the computed thickness and average temperature of the frozen zone meet the designed requirements of the project, which are further confirmed by the successful excavation of the tunnel. This indicates that the coupled method used in this paper is reliable and would be helpful for the AGF application in practical engineering.

Key words: Artificial ground freezing

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Nonlinear Transient Analysis of Temperature Fields in an AGF Project Used for a Cross-Passage Tunnel in the Suzhou Metro

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Abstract: Freezing method is a special construction technology in underground engineering constructions. In thispaper, the horizontal freezing technology is introduced in Guoquan road stop-Wujiaochang stop of Shanghai metro No.10 connecting aisle. The horizontal freezing technology has extensive application prospect in city underground engineering constructions and the paper can be used as reference by similar projects. Based on thermal-solid coupling theory in consideration of phase change, the complete construction process of horizontal ground freezing and excavation of connected aisle in metro were simulated; the change of temperature field and displacement field of ground were analyzed. The results of temperature field change show: It would take 26 days for frozen soil to enclose, and 40 days for the average thickness of frozen soil wall to reach to 120cm , after that the frozen soil wall should have been maintained for 36 days before the excavation is carried out; Higher temperature of salt water was adopted during the period of maintaining than it was during the active freezing period to prevent the area of frozen soil keeping expanding in order to avoid the encounter of high intensity frozen soil during the excavation; During a freezing design, frozen parameters such as temperature of freezing salt water, freezing time and freezing pipe distance and magnitude, should be set combined with the characteristic of ground and profile of the tunnel. Contrast was made between frozen ground displacement fields resulted from tunnel excavation under different thickness protection of frozen soil wall to prove that the effect by use of horizontal ground freezing to restrain the deformation of the ground is favorable, but it needs enough freezing time to make sure the displacement of ground is acceptable.

Key words: artificial ground freezing

雀儿山隧道冰碛地层冻胀力原位测试及计算分析

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摘 要：以国道 317 线雀儿山隧道为工程依托，进行了隧道洞口冰碛地层的冻胀力原位测试，同时结合数值模拟、理论模型计算等方法，得到了冻融圈厚度、冻胀压力以及冻结前后衬砌结构内外测的应力，在此基础上计算得到了衬砌结构的轴力、弯矩分布和变化规律，最后与已有研究结果进行了比较分析。研究结果表明：寒区隧道洞口段冰碛地层作为高原常见季冻土受低温影响显著，低温持续 22 小时冻融圈厚度达 2m 左右；采用隧道冻胀力计算模型计算得到的冻胀压力在 19.8kPa～158.3kPa 之间，原位测试的冻胀压力在 40kPa～240kPa 之间，其中拱脚处最小，仰拱处最大；冰碛地层冻结前后的衬砌结构内侧、外侧应力各自具有复杂的变化和分布规律，冻结状态下衬砌结构轴力呈“扇”形分布，弯矩呈“桃”形分布。与相关研究成果比较分析表明，现场采用的原位测试方法合理，结果更真实准确。

关键词：隧道工程；冰碛地层；冻融圈；冻胀力；原位测试

In-Situ Testing and Calculational Analysis on the Frost Heaving Force of Moraine Stratum in the Que’er Shan Tunnel

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Abstract:

Taking the Que’er shan tunnel in the project of No. 317 national highway as a background, the frost heaving force of the moraine stratum at the entrance of the tunnel was measured in situ by the self-designed test method. At same time，the thickness of the freeze-thaw circle and frost-heaving force in the cold region was obtained by combining the numerical simulation and the theoretical calculation. Based on the frost heave stress of inside and outside of the lining structure by measured, the axial force, the bending moment distribution and variation law of lining structure were calculated and analyzed compared with the existing research results. The results show that moraine stratum in the cold region are significantly affected by low temperature as the regular seasonal frozen soil in the plateau, and the thickness of freeze-thaw circle is about 2 m at low temperature for 22 hours. The frost heaving pressure is 19.8 kPa~158.3 kPa by frost heaving force calculation, and 40 kPa~240 kPa from the in-situ measurement, among of them, the smallest at the arch foot and the largest at the invert arch. The changes and distribution rules of the inner and outer stresses of the lining structure in the moraine stratum are complex and very different under the freezing and thawing conditions. The axial force and bending moment of the lining are fan-shaped and peach-shaped distribution respectively under frozen state. Compared with related research results, the in-site testing method is reasonable and the results are more accurate.

keywords: tunnel engineering; moraine stratum; the freeze-thaw circle; frost heaving pressure; in-situ measure

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Nonlinear Transient Analysis of Temperature Fields in an AGF Project Used for a Cross-Passage Tunnel in the Suzhou Metro

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Abstract: This paper examines the evolution process of the freezing curtain and the transition process of unfrozen water in an Artificial Ground Freezing (AGF) project used for a cross-passage tunnel in the Suzhou Metro, China. The focus of this study was on confirmation of the rationality of the freezing design on a weak silty clay layer, using a prognosis of the temperature development by numerical simulation and field monitoring. For the above purposes, basic mathematical techniques were employed to address the nonlinear transient thermal conduction problem considering the release of latent heat. The comparison analysis of the temperatures gained by field testing versus numerical simulation was performed to verify the accuracy of the numerical model. The results indicated that the formation of a stable freezing curtain with the design thickness required more time than the estimated active freezing period. The variation of unfrozen water volumetric content within the frozen fringe is normally exhibited as a process of increase and then decline until it vanishes, whereas there was a gradual and continuous increase near the frozen fringe. Although there was a deviation in the results between field monitoring and the numerical simulation, the general temperature curves from both methods were essentially consistent.

Key words: cross-passage; artificial ground freezing; numerical modeling; field temperature monitoring; distribution of temperature field

不同施工方法对浅埋软岩隧道围岩变形及力学特性的影响分析

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摘 要：为了研究浅埋软岩隧道施工时，采用不同开挖方法对围岩力变形及力学特性的影响，以红河隧道为工程依托，利用 MIDAS/GTS 有限元软件对不同施工方法进行了三维数值模拟计算。计算分析结果表明：三台阶开挖法和中隔壁法施工时所引起的竖向位移和水平位移分布规律基本一致，拱脚处围岩的位移变形较大。采用中隔壁法施工，围岩的总位移减少 21.4%，竖向位移减少 10.5%，水平位移减少 34.4%，中隔壁法控制围岩变形的效果更好。两种施工方法开挖时隧道的围岩应力水平较低，可基本保证围岩是稳定的。通过数值模拟计算系统，比较两种施工方法对围岩力学及变形特性的影响，可为具有类似地形地质的隧道施工方案比选提供参考。

关键词：隧道工程；软弱围岩；施工方法；数值分析

Analysis of Influence of Different Construction Methods on Surrounding Rock Deformation and Mechanics Characteristics of Shallow Buried Soft Rock Tunnel

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Abstract:

In order to study the influence of different excavation methods on the surrounding rock mechanics and deformation characteristics during the construction of shallow buried soft rock tunnel, the MIDAS/GTS finite element software was used to calculate the three-dimensional numerical simulation of different construction methods. The calculation and analysis results show that the vertical displacement and horizontal displacement distribution caused by the three-step excavation method and the CD method are basically the same, and the displacement deformation of the surrounding rock at the arch is larger. With the CD method, the total displacement of the surrounding rock is reduced by 21.4%, the vertical displacement is reduced by 10.5, and the horizontal displacement is reduced by 34.4%. The CD method is better for controlling the surrounding rock deformation. When the two construction methods are excavated, the surrounding rock stress level of the tunnel is low, which can basically ensure that the surrounding rock is stable. The influence of the two construction methods on the surrounding rock mechanics and deformation characteristics by numerical simulation system can provide reference for the comparison and selection of tunnel construction schemes with similar topography and geology.

keywords: tunnel engineering; soft surrounding rock; construction method; numerical analysis

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预制装配技术在地下工程中的应用研究

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摘 要：随着城市建设和地下空间的开发，为提高隧道及地下结构物的质量、降低工程造价，国内外都进行了地下工程预制装配化的尝试。本文系统介绍了预制装配技术在明挖隧道、暗挖隧道、地下综合管廊、明挖地铁车站、盾构隧道等地下工程中的应用，并针对基于新奥法开挖的山岭公路隧道的预制装配技术进行研究，提出一种全预制装配式衬砌分块方案并采用梁——弹簧模型对该方案进行模拟。

关键词：隧道及地下工程；公路隧道；预制装配结构；梁——弹簧模型

Application Research of Prefabrication Technology in Underground Engineering

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Abstract:

With the development of urban construction and underground space, in order to improve the quality of tunnels and underground structures and reduce the construction cost, attempts have been made to prefabricate the underground engineering at home and abroad. This paper systematically introduces the application of prefabrication technology in underground works such as open cut tunnel, undercut tunnel, underground integrated pipe gallery, open cut subway station, shield tunnel, etc., and prefabrication of mountain road tunnel based on new Austrian method excavation. The assembly technology was studied, and a full prefabricated lining block scheme was proposed and the beam-spring model was used to simulate the scheme.

keywords: tunnel and underground engineering; highway tunnel; prefabricated structure; beam-spring model

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公路山岭隧道采用硬岩掘进机 TBM 的适用性研究

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摘 要：劳动力资源趋于短缺、用工成本趋涨的新形势下，公路山岭隧道施工急需要研究采用硬岩掘进机（Tunnel Boring Machine,以下简称 TBM）实现“机器换人”的目标。为了研究浙江省公路山岭隧道采用硬岩掘进机 TBM 的适用性，以开挖断面类似的锦屏电站输水隧洞为参照，基于工程类比，从地质适应性、工程造价、施工工期等方面开展了对比分析。研究表明：TBM 适合浙江省的地质条件，尽管工程造价略高于传统矿山法施工工法，但是施工工效高，施工工期短。可以预见，随着隧道越来越长、劳动力成本越来越高、工期要求越来越短，TBM 的应用将越来越广。

关键词：公路；山岭隧道；硬岩掘进机；适用性

Feasibility Analysis on Adoption of TBM in Rocky Road Tunnels

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Abstract:

With the shortage of labour resources and rising labour costs, it is urgent to study the use of TBM (Tunnel Boring Machine) to achieve the goal of "machine replacement" in rocky road tunnel construction. Taking Zhejiang Province as an example and the water conveyance tunnel of Jinping hydropower station with similar excavation section as a reference, a comparative analysis was carried out concerning geological adaptability, engineering cost and construction duration. The research shows that TBM is suitable for the geological conditions of Zhejiang Province. Although the cost of TBM is slightly higher than that of the traditional method, it has high construction efficiency and short duration. It can be seen that the adoption of TBM will be much wider spread with the longer tunnel, the higher labour cost and the shorter construction duration given.

keywords: Road; rocky tunnel; TBM; Feasibility

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浅议植物维管组织在隧道设计和真空管道设计中的启示

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摘 要：植物维管组织中导管和隧道从结构和功能都有诸多相似之处，本文尝试借鉴植物维管组织中导管的结构优化复合衬砌隧道初期支护设计，尤其是在不良地质和特殊岩土地段的复合衬砌隧道初期支护设计可以借鉴植物导管次生壁的五种增厚结构形式。借鉴植物维管束类别和连接方式优化真空管道的管道设置和连接方式。

关键词：建筑仿生；维管组织；隧道设计；真空管道设计

The Inspiration of Plant Vascular Tissue in Tunnel Design and Vacuum Pipeline Design is Briefly Discussed

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Abstract:

There are many similarities between the structure and function of the duct and the tunnel. This paper attempts to use the structure optimization of the duct in the plant vascular tissue for the preliminary support design of the composite lining tunnel, especially in the bad geology and special geotechnical section of the composite lining tunnel preliminary support design can use for reference the five thickened structural forms of the secondary wall of the plant duct. Use the vascular bundle classification and connection mode of plants for reference to optimize the arrangement and connection mode of vacuum pipes.

keywords: Architectural bionics; Vascular tissue; Tunnel design; Vacuum Pipeline design

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地下建筑式立体车库设计方案与设备构成

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摘 要：近些年来，我国大中城市停车位需求量很大，尤其是在建筑密集、场地狭小的区域停车需求更为突出，亟待解决停车难问题。本文提出了地下多层建筑式立体车库概念，给出了 3 种典型的建筑方案，阐明了其存取车操作方式，并分析了其优缺点；针对具体方案，对车库的主体结构以及基坑围护结构进行设计；结合该类立体车库的设备构成，进行了汽车电梯配置、通风以及消防等设备选型、计算或设计；针对 3 种典型方案，分别计算得到了车均占地面积和库内车道面积率，分析评价了该类车库的经济性。该类车库利用深层地下空间，节省占地面积，车道面积率小，存取车设备简单、用时少，特殊楼层通过功能调整可提高投资效益。该类车库技术上是可行的，经济性较好，有推广应用前景。

关键词：地下车库；建筑方案；停车；设备构成；经济性

Architectural Design Scheme of Underground Structural Stereo Garage and Its Equipment Composition

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Abstract:

In this paper, the concept of a kind of underground structural stereo garage was put forward, its typical architectural schemes were recommended, its operation mode of access vehicle was expounded, and its advantages and disadvantages were analyzed. Aimed at a kind of typical scheme, the main structure and foundation pit support structure were designed. Combined with the equipment composition in this garage, the vehicle elevator configuration, ventilation and fire fighting equipment were selected, calculated or designed. Based on the typical architectural schemes, their economy was analyzed and evaluated through calculating the ground area used for every car and the rate of area used by driveway. In conclusion, there are plenty of advantages in this kind of garage such as using deep underground space, saving ground area, requiring unsophisticated equipment and taking a few time for accessing a vehicle and taking small driveway area. Also, the investment efficiency can be improved if the special storeys are transferred into other commercial function. As a result, this kind of garage will be technically feasible and economically cheap, and it will have broad application prospects.

keywords: underground garage; architecture scheme; parking; equipment composition; economical efficiency

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Radial Joints Displacement of a Large Cross-Section Precast Underpass Induced by Long-Term Loads of Ground Vehicles

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Abstract: The radial joints are vulnerable parts of a precast underpass due to the lower stiffness compared to the segments. Therefore, the behaviour of radial joints is important both in terms of structural safety and sealant. Numerous studies on joint behaviour have shown the joint behaviour under service static load and ultimate load, but results from joints behaviour induced by ground vehicles have been rare. However, vehicle loads on the ground surface may have adverse influence on the behaviour of the underpass radial joints which poses a potential threat to the safety and sealant of the underpass structure. Our focus is on the joint behaviour with different pre-stress levels and different number of shear keys under dynamic loads of ground vehicles. With this aim, we conducted a full-scale numerical modelling and a 1/10 scaled model test based on a real project of Moziqiao underpass in Chengdu. The analysis from numerical and model tests indicate that the opening is closely correlated with prestress levels and the opening and slipping values differ from different tunnel spans. This research reveals the characters of joints behaviour under long-term surface dynamic loads, which convinces us that displacement of radial joints should be taken into consideration during the design stage for similar projects.

Key words: Radial joint; Long-term ground vehicle loads; Joint opening and slipping

基坑支护体系局部失稳问题研究进展

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摘 要：为了研究钢管内支撑体系下基坑的连续倒塌影响因素和改进措施，分析了一系列建筑结构和基坑工程的连续破坏的案例，案例表明结构体系中重要节点的破坏是引起连续倒塌的重要因素，于是对钢管内支撑体系的一个重要节点—活络端进行了力学试验，对比分析了活络端与 18m、20m 和 24m 钢支撑的荷载-变形曲线。结果表明：目前所使用的活络端力学性能差别很大；对于跨度小于 24m，使用单跨对撑钢支撑支护形式的基坑活络端是局部薄弱区域，使用过程中活络端的破坏是引起基坑连续倒塌的一个重要因素。基于此提出了一种新型螺栓紧固锥楔式活络端，并在北京地铁 7 号线东延线黑庄户站明挖基坑工程得到了应用。

关键词：基坑工程；钢支撑；连续破坏；活络端

Research Progress on Local Instability of Foundation Pit Support System

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Abstract:

In order to study the influencing factors and improvement measures of progressive collapse of foundation pit under steel tube inner support system, a series of cases of progressive collapse of building structure and foundation pit engineering are analyzed. The case shows that the failure of important joints in the structure system is an important factor causing progressive collapse. The mechanical test of an important node of steel tube inner support system, the active node is carried out, and a comparative analysis is made. Load-deformation curves of movable end and 18 m, 20 m and 24 m steel braces. The results show that the mechanical properties of the active node used at present are quite different; for the foundation pit with length less than 24m, the active node of the foundation pit supported by single-span paired bracing steel support is a weak area, and the failure of the active node is an important factor causing the progressive collapse of the foundation pit. Based on this, a new type of bolt fasten wedge active node is put forward, which has been applied in the open excavation foundation pit of Heizhuanghu Station of Beijing Metro Line 7 East Extension Line.

keywords: foundation pit engineering; steel support; active node progressive collaps

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应力流守恒原理及地下洞室群支护结构设计方法

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摘 要：地下洞室群开挖引起的群洞效应使围岩和支护结构受力的计算异常复杂，目前通常采用的数值模拟方法受各种因素的影响，其计算结果的准确性难于满足支护结构设计的要求。本文基于力学平衡的思想提出了应力流守恒原理，即隧道开挖前后任意水平剖面围岩竖向应力流和任意竖直剖面的水平应力流将保持不变，从而计算洞室群中各个岩墙、岩板、岩柱的受力，并根据其稳定性设计支护结构措施。京张高铁八达岭长城站地下洞室群支护结构设计结果表明，与传统经验法和数值模拟法设计相比，基于应力流守恒原理的洞室群支护结构设计方法具有计算便捷、安全可靠的优点。

关键词：应力流守恒；洞室群；支护结构；设计方法

Principle of Stress Flow Conservation and Design Method of Support Structure of Underground Cavern Group

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Abstract:

The group holes effect caused by excavation of underground cavern group makes the calculation of force on surrounding rock and supporting structure extremely complicated. The numerical simulation methods commonly used at present are affected by various factors, and the accuracy of the calculation results is difficult to meet the requirements of support structure design. Based on the idea of mechanical balance, the principle of stress flow conservation is put forward in this paper, that is, the vertical stress flow of surrounding rock of arbitrary horizontal section and the horizontal stress flow of arbitrary vertical section will remain unchanged before and after tunnel excavation. Thus, the force of each rock wall, plate and pillar in the cavern group is calculated, and the supporting structure measures are designed according to their stability. The design results of underground cavern group in Badaling Great Wall Station of Beijing-Zhang high-speed railway show that, compared with the traditional empirical method and numerical simulation method, the support structure design method based on the principle of stress flow conservation has the advantages of convenient calculation, safety and reliability.

keywords: Principle of Stress flow conservation; cavern group; support structure; design method

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黄土隧道新型支护体系承载能力评价

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摘 要：传统支护结构因自身支护性能的限制造成了黄土隧道的病害时有发生，严重影响了施工期间的安全与工程进度。本文基于中国典型地区黄土隧道支护结构破坏的原因分析，提出了一种新型组合结构支护体系，并系统地阐述了它的设计理念与优势。通过围岩压力极大值法确定了隧道深浅埋的分界深度，并根据荷载结构法采用 ANSYS 有限元软件建立二维数值模型，对传统支护和组合结构支护的承载性能进行了对比分析。结果显示，组合结构支护的结构安全度较传统支护得到大幅提升，当传统初期支护发生破坏时，组合结构支护能够承担全部围岩荷载，安全系数分别 2.24（深埋）和 1.42（浅埋）。本文能为黄土隧道的建设提供新思路。

关键词：黄土隧道；新型支护；初期支护；承载能力；安全系数

Evaluation of Bearing Capacity of Novel Support System in Loess Tunnel

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Abstract:

Because of the limitation of the traditional support structure, loess tunnel diseases often occur, which seriously affect the safety and process of construction. This paper summarized the failure cases of tunnel construction in typical loess area and analyzed the causes. A new type support system was proposed with specific introduction of its conception and features. Through the derivation method and the load structure method, the cover depth threshold was determined, and the two-dimensional numerical model was established by using ANSYS, the comparative analysis on the bearing capacity of the traditional and the new support system was carried out. The results show that the structural safety of the new type support was significantly improved compared with the traditional support. When the traditional primary support was damaged, the new type support can bear total surrounding soil load, and the safety factor was 2.24 (deep tunnel) and 1.42 (shallow tunnel), respectively. This paper can provide a new method for loess tunnel construction.

keywords: loess tunnel; new type support; primary lining; bearing capacity; safety factor

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盾构施工长距离斜井泄压式管片设计参数研究

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摘 要：长距离煤矿斜井采用盾构法施工是一种全新的建井模式。然而在深埋煤系地层，地下水压力通常较高，如果按照全水头压力设计则会使管片厚度大幅增加，既不经济又造成盾构施工的困难，因此管片泄压成为了解决这一问题的必然途径，相应的泄压控制技术也成为深埋斜井面临的关键问题。针对盾构施工长距离斜井穿越高水压地段的问题，基于地层-注浆体-管片的渗流场分析、管片结构在水土压力下的受力分布效应与变形特性分析，研发了泄水降压式管片结构支护体系，对关键设计参数对泄水降压特性、结构承载能力的影响进行了评价与分析，并据此优化了泄水孔布置。研究结论可为盾构施工高水压地段管片结构泄水降压处置技术提供有益参考。

关键词：盾构法；长距离斜井；高水压；泄水式管片

Study on Design Parameters of Drainage Segment of Long Distance Shield Driven Inclined Shaft

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Abstract:

It is a new construction method for long distance inclined coal mine shaft using shield machine. However, in deep buried region, groundwater is mainly phreatic water and confined water and usually with relative high water pressure. If the segment lining is designed under total water head, it will bring out a much thicker segment, which not only uneconomical but also make it difficult for shield driving. Segment drainage is an effective solution for this problem. But how to deal with the control of water drainage amount is a key issue. According to the shield construction of long distance inclined coal mine shaft through the high water pressure region, a drainage segment support system is developed based on analysis of the seepage field of strata-grout-segment liner, of the mechanical mechanism and deformation characteristics of the segment liner under soil pressure and water pressure. Key design parameters and their effects on drainage mechanism, bearing capacity as well as structural characteristics are also evaluated and analyzed, being the basis for the optimization of drainage hole arrangement. The conclusion of the study can provide a useful reference for segment drainage technology of shield construction through high water pressure.

keywords: Shield construction; long distance inclined shaft; high water pressure; drainage segment

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Surface Settlement Study of Civil Architecture Induced by Shield Construction

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Abstract: Surrounding rock is inevitably disturbed by shield construction, which can induce soil deformation and surface settlement. Especially when the deformation and settlement are large, the surrounding structure is dangerous. This paper will take Zhengzhou Metro Line 5 Lot 12 West Station Street Station-Station Road tunnel construction project for example, based on the finite element method, three-dimensional model of shield excavation is established considering the synergistic effect of shield segment unit, and other units on behalf of the layer of soil unit. The in-site data are collected to verify the simulation results. The simulation curves and measured curves of settlement are great similar, which shows the presented model is accurate. However, the difference between the individual in-site values and simulation values is relatively large because of various uncertainties. The presented results can give theoretical guidance to shield construction of left line.

Key words: surface settlement; shield construction; numerical simulation; Zhengzhou Metro Line 5; finite element method

公路隧道衬砌结构裂缝分布现场检测及数值分析

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摘 要：裂缝是公路隧道衬砌结构的主要病害之一，为了探究裂缝成因机理及所发生的位置，本文结合实际工程，首先，对现有隧道衬砌结构的裂缝位置及长度、深度做了详细调查和检测，并初步判定产生裂缝的主要因素有：地基强度不均衡、偏压、塌方、寒潮降温等；尔后，依据混凝土损伤理论，借助有限元软件 ABAQUS 建立了钢筋混凝土结构非线性模型，计算了在各个影响因素作用下，隧道衬砌结构产生损伤的位置及区域大小。计算结果表明：地基强度不均衡将会导致拱脚位置产生损伤破坏；偏压作用将会导致仰拱的中间区域、拱顶和压力较大一侧的拱脚产生损伤破坏；山体塌方将会导致拱顶和仰拱发生较大面积的损伤破坏；寒潮降温将会导致拱脚部位出现损伤破坏。数值计算的混凝土损伤分布与现场调查的裂缝情况吻合度较高，说明本文所建立的钢筋混凝土非线性损伤模型可以做为预测隧道衬砌结构裂缝位置的有力工具。

关键词：公路隧道；衬砌结构；裂缝；损伤；ABAQUS

On-Site Testing and Numerical Analysis of Crackes in Highway Tunnel Lining Structure

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Abstract:

Crack is one of the main diseases of highway tunnel lining structure, In order to investigate the formation mechanism of the fracture, combined with practical project, firstly, this paper probed and detected the fracture location and length, depth of the tunnel lining structure, and determined preliminarily the major factors of feather cracking as following: imbalance of foundation strength, bias, collapse, cold wave; Secondly, the paper established nonlinear model of reinforced concrete structure based on the theory of concrete crack damage, and than calculated the damage location and size of the tunnel lining structure under the effect of various factors, using the finite element software ABAQUS. The results show: uneven foundation strength will result in damage at arch foot; bias will result in damage at middle of invert, vault and arch foot of the bigger presser; the collapse of mountain will result in damage at the vault and invert; the cold wave will result in damage at arch foot. The concrete damage distribution of numerical calculation is fit with the cracks location of field survey, which proved that the nonlinear damage model of reinforced concrete structure can be a useful tool forecasting the crack location of tunnel lining structure.

keywords: highway tunnel; lining structure; crack; damage; ABAQUS

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温度—围压作用下盾构隧道衬砌应力变化规律研究

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摘 要：围岩压力和温度变化对盾构隧道衬砌结构会产生极大影响，在衬砌内部产生的较大拉、压应力易导致结构开裂，对隧道衬砌结构的应力变化规律有大的影响。本文将盾构隧道管片视为厚壁圆筒，考虑围岩压力和温度变化作用对衬砌应力的影响，推导了衬砌结构应力计算公式，并基于某地铁工程实例，运用所得公式对衬砌应力变化规律进行了分析，结论表明：（1）对于围岩压力，衬砌各方向压应力随围岩压力的增大而线性增加；（2）对于温差变化，衬砌径向与环向应力随内外壁温差增加，压应力逐渐减小到 0 后转变为拉应力逐渐增大，纵向应力基本不随温差而发生改变；（3）对于衬砌半径，当内外壁温差为正时，径向拉应力和纵向压应力逐渐减小，环向压应力减小到 0 后转变为拉应力逐渐增大，当内外壁温差为负时，径向压应力减小，环向和纵向压应力随半径增加而变大。分析得到的衬砌应力变化规律对盾构衬砌结构设计有着很重要的参考价值。

关键词：盾构隧道衬砌；围岩压力；温度变化；应力变化规律

Research on Stress Variation Law of Shield Tunnel Lining Under Temperature and Confined Pressure

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Abstract:

The change of surrounding rock pressure and temperature will have great influence on the force of shield tunnel lining structure,and the large tensile and compressive stress caused by them in the lining can easily lead to structural cracking. They have a great influence on the stress variation law of tunnel lining structure.In this paper, the segment of shield tunnel is regarded as a thick-walled cylinder. Considering the influence of surrounding rock pressure and temperature change on the lining stress , the formula for calculating the stress of lining structure is deduced. Based on an example of a metro project, the variation law of the stress of lining is analyzed by using the formula.the results show that:(1)For surrounding rock pressure, the compressive stress of the lining in all directions is increased linearly with the increase of surrounding rock pressure;(2)For the variation of temperature difference,as the temperature difference between the inner and outer walls of lining increases,the radial and circumferential compressive stress gradually decrease to zero, and then change to the tensile stress gradually increased, the longitudinal stress does not change substantially with the temperature difference;(3)For the radius of the lining, with the increase of the segment radius: when the temperature difference between the inner and outer walls of lining is positive, the radial tensile stress and longitudinal compressive stress decrease gradually, the circumferential compressive stress decreases to zero, and then change to tensile stress

increased gradually; when the temperature difference is negative, the radial compressive stress decreases, the circumferential and longitudinal compressive stress increases. The variation law of lining stress obtained by analysis has important reference value for shield lining structure design.

keywords: shield tunnel lining; surrounding rock pressure; temperature change; law of stress variation

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地铁施工振动效应测试与分析

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摘 要：由于城市轨道交通在城区穿行，不可避免的需要近距离下穿重要建构筑物，如省博物（重要文物）、高架桥梁、磁悬浮专线等重要建构筑物。盾构掘进过程中的震动对重要建构筑物的影响具体有多大，这是我们不容忽视的问题，因此本文结合芙烈区间下穿省博物的施工情况，深入研究地铁施工的振动效应，主要是从振动传播机理、现场测试两方面分析地铁施工产生的振动对于地面和建筑物的影响。总结出纵波的能量衰减与两个因素有关一个是传递距离也就是振源深度，能量与振源深度成线性关系；另一个因素是土层阻尼效应，能量传递过程中，土层会吸收振动能量，不同的土体介质吸收能量的频段都不相同，模量越小的介质吸收能量的效应越强。

关键词：地铁施工振动；振动频率；振动阻尼

Measurement and Analysis of Vibration Effect in Metro Construction

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Abstract:

As urban rail transit travels through the urban core area, it is inevitable that important structures need to be traversed at close distance, such as provincial museums (important cultural relics), viaducts, magnetic levitation special lines and other important structures. How much impact the vibration of shield tunneling has on important structures is a problem that we can not ignore. Considering the construction of the provincial museum under metro section, the vibration effect of subway construction is studied in depth. In order to analyze the impact of the vibration generated by subway construction on the ground and buildings, mainly from two aspects of vibration propagation mechanism and on-site testing. Sums up the energy attenuation of longitudinal wave is associated with two factors is a transmission distance is the depth of the source of vibration, vibration energy and a linear relationship with the source depth; Another factor is that the soil damping effect, the process of energy transfer, the soil can absorb vibration energy, the different soil medium energy absorption band is different, the smaller the modulus of the medium energy absorption effect.

keywords: metro construction vibration; vibration frequency; vibration damping

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Study on Influence of Small Clear Distance Tunnel Construction on Settlement of Underground Pipeline

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Abstract: The excavation of small-sized tunnels in urban subways will have an adverse impact on existing pipelines and surface. It is of great significance to master the settlement laws of underground pipelines and surface. This paper employs the station project example of the B-district in Shangdu Road Station of Zhengzhou Metro Line 4, and uses the finite element software to establish a three-dimensional model of small clear tunnel excavation. Then, the influences of small clear tunnel construction on surface settlement and pipeline settlement are analyzed, and measured value is incorporated to compare the simulated results. On this basis, the settlements of underground pipelines and surface are analyzed considering different tunnel depth, pipeline depth and tunnel diameter. Research results show that the trend of pipeline and surface settlement is consistent during tunnel construction process, showing a “concave” type distribution. The settlements of pipeline and surface decrease with the increasing of the tunnel depth. When the tunnel depth is the same, the smaller the tunnel diameter is, the smaller the pipeline and surface settlement value are obtained. The results can provide references to similar design and construction.

Key words: small clear tunnel; underground pipeline; tunnel depth; pipeline depth; hole diameter

考虑层间粘聚力的水平层状围岩隧道顶板力学模型计算

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摘 要：水平层状岩体力学性质不仅受岩层组合和结构面控制，而且与层间粘聚力密切相关。水平层状围岩隧道在施工过程中对层间粘聚力考虑不当时，极易造成设计支护参数不合理，导致拱部掉块落石、离层、弯折，甚至局部坍塌、超欠挖等工程问题，严重影响工程安全、施工质量和建设进度。目前水平层状围岩隧道顶板一般简化为锚固梁和简支梁模型，但未考虑层间粘聚力。本文根据水平层状围岩隧道开挖的不同阶段，将隧道顶板分别简化为开挖初始阶段的锚固梁模型和施工扰动后的简支梁模型，并利用顶板梁体模型的协调变形条件，得出梁模型的层间粘聚力计算公式。以大梁峁隧道为工程依托，分别应用考虑层间粘聚力和不考虑层间粘聚力的梁模型进行隧道临界开挖跨度计算，结果表明：考虑层间粘聚力和不考虑层间粘聚力对水平层状围岩隧道临界开挖跨度影响较大。考虑层间粘聚力时，锚固梁模型临界开挖跨度为 3.36~4.75m，简支梁模型临界开挖跨度为 2.74~3.88m；不考虑层间粘聚力时，锚固梁模型临界开挖跨度为 0.14~0.30m，简支梁模型临界开挖跨度为 0.12~0.24 m。结合大梁峁隧道工程现场，隧道开挖跨度 3~6m 时，拱顶会出现平顶现象，产生离层和掉块，因此考虑层间粘聚力的水平层状围岩隧道顶板力学模型更符合工程实际情况。

关键词：隧道工程；水平层状围岩；理论分析；最大开挖跨度；现场监测

Mechanical Model Calculations of Tunnel Roof with Horizontal Stratified Rock Mass Tunneling Considering the Interlayer Cohesion

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Abstract:

The mechanical properties of horizontal stratified rock mass are not only controlled by the rock formations and structural planes, but also closely related to the interlayer cohesion. During the construction process of horizontal stratified surrounding rock mass tunneling, due to improper consideration of interlayer cohesion, it is prone to cause unsuitable support parameters and lead to engineering problems such as overbreak abundantly and rock falling in arch roof, roof separation, even partial collapse and so on, which seriously affect the safety of the project, construction quality and progress. At present, the roof of tunnels with horizontal stratified surrounding rock is generally simplified as an anchor beam and simply supported beam model, but the interlayer cohesion is not considered. In this paper, according to the different stage of excavation, the tunnel roofs are respectively simplified into the anchor beam model at the initial stage of excavation and the simply supported beam model after construction disturbance, and the coordinated deformation conditions of the roof beam model are used to obtain the formula for calculating the interlaminar cohesion. Based on the field test case in Daliangmao tunnel, the tunnel excavation span calculations were

carried out for beam models about whether considering interlayer cohesion. The results show that whether considering the interlayer cohesion has a great influence on the excavation span. Considering the interlayer cohesion, the critical excavation span of the anchor beam model is 3.36~4.75 m, and for simply beam model, it is 2.74 to 3.88 m. When the interlayer cohesion is not considered, the critical excavation span of the anchor beam model is 0.14~0.30 m, and for simply beam model, it is 0.12 to 0.24 m. In combination with the tunnel construction site, when the excavation span is 3~6m, there will be the flat top phenomenon in the crown, resulting in separation and rock falling. Therefore, the mechanical model of the tunnel roof, considering the interlayer cohesion, is more consistent with the actual situation of project..

keywords: tunnel engineering; horizontal stratified surrounding rock; theoretical analysis; maximum excavation span; site monitorin.

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利用全站仪量测隧道变形的精度分析

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摘 要：全站仪对边量测法只需采用普通全站仪，无需专门的后处理软件，该方法操作简便，结果准确度高。因此 RDM 在隧道工程变形量测中已被广泛应用。本文给出了利用全站仪进行 RDM 测量的隧道拱顶下沉和净空收敛的计算公式，并采用测量学中的误差传播定律，推导了对边量测隧道变形的中误差公式。当全站仪精度不低于“ms =2+2ppm，mα=1”，后视基准点和量测断面的水平距离在50～150m之间，测站点距离量测断面的水平距离在40～60m之间，且测站点在隧道中心线附近时，隧道拱顶下沉和净空收敛的测量精度均可达到 1mm 以内。

关键词：全站仪；对边量测；隧道变形；精度

Accuracy Analysis of Tunnel Displacement by Using of the Total Station

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Abstract:

The method of RDM just needs common Total Station, and doesn’t need some special post-processing software, which is easy to operate to get the results with high accuracy. Therefore, it has been widely used in the displacement monitoring of tunnel engineering. According to the basic principle of RDM, this paper provided the measurement formula of crown settlement and wall convergence in tunnel measured by the RDM with Total Station. And, in this paper, the mean error formula of tunnel displacement measured by RDM was derived, based on the error propagation law. Considering the characteristics of total station and tunnel engineering, the accuracy of crown settlement and wall convergence measured by RDM could be less than 1mm, when the Total Station accuracy of the ms was no less than 2+2ppm and the mα was no less than 1″; the horizontal distance between rear-view reference station and monitoring section was 50 ~ 150m; the horizontal distance between survey station and monitoring section was 40 ~ 60m and the survey station was near the tunnel centerline.

keywords: Total Station; RDM; Tunnel Displacement; Accuracy

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超大跨度公路隧道施工工法转换方案研究

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摘 要：超大跨度隧道开挖跨度大，结构稳定性差，全断面开挖跨度大，不同围岩级别施工工法不同，因此施工转换要求高。本文以老虎山隧道为依托，对进口段Ⅴ级围岩双侧壁导坑法和相邻段Ⅳ围岩 CRD 法两种工法施工转换进行分析和研究。结果表明：采用控制开挖起拱线高程一致，由双侧壁导坑法分部横向采用渐变方法过渡到 CRD 法，避免工法转换之间的时间间隔，减少了后期双侧壁导坑法临时支撑的拆除对围岩的扰动，从而加快了施工进度；双侧壁导坑法向 CRD 法转换前后和转换过程中钢架受力都满足规范要求，工法转换过程中施工安全。研究结果对超大跨度公路隧道开挖时施工工法转换具有一定的参考价值。

关键词：隧道工程；超大跨度；双侧壁导坑法；CRD 法；工法转换

Study on Transformation Method of Construction Method for Super-Long Span Highway Tunnel

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(Chang'an University)

Abstract:

When excavating the face of super-long-span tunnel, due to the large section size and poor structural stability, the tunnel construction technology is required to be higher. In this paper, the transformation of the two construction methods in the construction process is analyzed and studied by using the double-sided guide pit method of V-grade surrounding rock and the CRD method of adjacent IV surrounding rock in the entrance section of Tiger Mountain Tunnel. The research shows that the control of the excavation arch line is consistent, and the gradient of the double-side guide pit method is used to transition to the CRD method. Avoiding the time interval between the conversion of construction method and reducing the disturbance of surrounding rock caused by the demolition of temporary support of double-sided guide pit method in the later stage, thus speeding up the construction progress. On the other hand, through MIDAS numerical simulation, the double-wall guide pit method before conversion, the conversion process, and the converted CRD method are subjected to force analysis. The results show that the stress of steel arch frame meets the requirements of "Design Code for Highway Tunnels", which proves the safety of construction method conversion and ensures the safety of construction. This study has certain reference value for the conversion of construction methods in the excavation of super-long-span highway tunnels.

keywords: Tunnel engineering; Super large span; Double sidewall guide pit method; CRD method; Method conversion

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Mechanical Properties and Acoustic Emission Characteristics of Karst Limestone Under Uniaxial Compression

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Abstract: Firstly, I-RPT ultrasonic detector was used to test the wave velocity of karst limestone with different initial microstructure and water content. Then RMT-150B rock testing machine and DS2-16B acoustic emission system were used to test the acoustic emission (AE) under uniaxial compression. Mechanical properties and AE characteristics were obtained during rock failure. The detailed relationship between stress-strain and AE characteristics was studied in this paper. Research results indicated the following: (1) For samples with many primary fissures and defects, wave velocity in dry state was larger than that in its natural state. From natural state to

saturated state, the wave velocity tended to increase. For samples with good integrity, wave velocity increased with increasing of water content. (2) In the dry state, the samples presented tension failure. In saturated state, the samples presented tension-shear failure. For samples with cracks and good integrity, samples showed brittle failure. For samples with many corrosion pores showed ductile damage under natural and saturated state, the spalling phenomenon was enhanced under saturated state. (3) With increasing of water content, the peak-stress and AE peak reduced dramatically. In brittle failure, AE peak could be considered a sign of failure. In ductile failure, AE activity decreased gradually with the decrease of stress. (4) The mechanical properties and AE characteristics corresponding to four main fracture propagation types were also discussed.

Key words: Acoustic Emission; karst limestone; uniaxial compression; mechanical properties; failure mode

浅埋黄土隧道中系统锚杆支护作用的数值模拟

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摘 要：为了研究系统锚杆在浅埋黄土隧道中的支护效果，以陕西吴堡—子洲高速公路刘家坪 5 号隧道为依托，利用MIDAS/G TS 有限元分析软件分别建立有 、无系统锚杆的分析模型，计算分析了 6 个开挖阶段和截止到二衬施作阶段的隧道变形量，并将数值模拟结果与实测结果进行了对比分析。结果表明:浅埋黄土隧道施工过程中 ，有系统锚杆的隧道变形值大于无系统锚杆的变形值，这是由于锚杆是在钢架支设后进行打设，锚杆的打设不仅破坏了土体的稳定，而且延误了喷射混凝土和钢架支护的最佳时机，使变形量增加;有、无系统锚杆拱顶下沉和净空收敛的现场实测值基本处于同一数量级，说明在浅埋黄土隧道中系统锚杆的作用不显著，可以取消。

关键词：隧道

Numerical Simulation of Support Action of Systematic Anchorage Bolts in Shallow-Buried Loess Tunnel

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Abstract:

In order to study the actional function of systematic anchorage bolts in shallow-buried loess tunnel, this paper taking Liujiaping 5# tunnel of Wubao—Zizhou freeway as an example, two-dimensional plane models with systematic anchorage bolts and without systematic anchorage bolts were established by using the finite element analysis softw are MIDAS/GTS. In the process of numerical analysis, the displacement amounts were simulated during the six excavation stages and the stage before secondary lining construction, and the numerical simulating results were compared with the ones of measuring. The results show that the displacement of the model with systematic bolts is bigger than that of the model without systematic bolts during the construction of shallow-buried loess tunnel, because the rock bolts are constructed after steel arch. Constructing the anchorage blots, not only the stability of soil mass is broke, but also the best time of constructing shotcrete and steel support is delayed. Moreover, both the two modes have almost the same settlement in the tunnel arch crown and horizontal convergence during insitutest. Through comprehensive analysis, it is found that the role of systematic anchorage bolts is not obvious in shallow-buried loess tunnel and can be eliminated. 4 tabs, 7 figs, 8 refs.

keywords: tunnel

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隧道锁脚锚管受力测试方法试验研究

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摘 要：为研究隧道锁脚锚管在端头竖向荷载作用下的受力特性，采用了一种隧道锁脚锚管受力特性的测试方法——应变片外贴导线内引的电测法，该方法克服了钢管表面贴片易损坏、引线困难等难题。以工程上经常使用的长为 3.5m、直径为 42mm、壁厚为 4mm 的热轧无缝钢管为例，系统介绍了测试锁脚锚管受力特性的试验设计方案，包括锁脚锚管管身轴向应变测试和管身弯矩测试。给出了锁脚锚管受力测试装置的设计与工艺，包括测力锚管的加工和温度补偿条的加工工艺。采用现场实测的方法，在某土质边坡对该方法进行了应用，将锁脚锚管安装在边坡土体中，然后在锁脚锚管端头加载，测试其受力状况。试验结果表明：锁脚锚管受力测试装置安设完毕后，测点成活率达到 100%；锁脚锚管端头垂直加载，管身最终变形和试验测试结果相吻合；该试验方法能够真实反映锁脚锚管的受力特性。

关键词：隧道；锁脚锚管；受力特性；测试方法；应变片外贴

Experimental Study on Force Test Method of Tunnel Lock Anchor Pipe

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Abstract:

A new stress testing method for tunnel foot locking bolts，electric measuring method by externally bonded strain gauge，is adopted so as to study the stress characteristics of foot locking bolts under vertical load at bolt end． The stress testing design scheme of foot locking bolt，including strain test along axial line of foot locking bolt and bending moment test，is systematically introduced by taking widely used hot-rolling seamless tube of 3.5 m in length，42 mm in diameter and 4 mm in thickness for example． The design and technologies for stress testing device of foot locking bolts， including manufacturing of dynamometry bolt and temperature compensation strip，are presented． In addition，the above- mentioned method is applied by field test method at a soil slope． The testing results show that: 1) The monitoring points are all effective after installation of stress testing device． 2) The final deformation of foot locking bolt coincides with testing results under vertical loading at foot locking bolt end． 3) The above-mentioned method is reliable.

keywords: tunnel; foot locking bolt; mechanical characteristic; testing method; externally bonded strain gauge

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Stability Analysis of Large-Section Tunnel in Loess Ground Considering Water Infiltration Caused by Lrrigation

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Abstract: Constructing large-section loess tunnels is a highly challenging task. One reason is that the strength of the loess decreases when it is soaked, which endangers the safety and stability of the tunnel. In this study, Ma Jia Zhuang Tunnel is selected as a relying project based on in-situ monitoring and measuring data, and Midas GTS NX software is used to build a tunnel structural calculation model under the coupled function of seepage and stress fields. Combined with the change law of physical and mechanical property for unsaturated loess, a simulation is made for surface infiltration, the integral soaking and partial soaking caused by concentrated infiltration. Results show that when the topsoil has good integrity, the effective influence depth of irrigation water in Q3 clayed soil layer is approximate 4m. When considering the most unfavorable case that the irrigation water collectively infiltrates to the stratum of a tunnel's buried layer, the moisture content of Q2 silty clay increases from natural moisture content 16.6% to saturated moisture content 24.3%, the force, deformation, surface subsidence, and thickness of plastic zone for supporting structure increase significantly, the late rate of increase is 9.6 times that early. Conversely, the force of surrounding rocks tends to decrease. The concentrated infiltration at crown has the greatest influence on the stability of tunnel structure. Therefore, for large-section loess tunnels under an irrigation area, construction during irrigation periods should be avoided, and the prevention and treatment of surface-water infiltration should be strengthened through immediate detection and treatment. These approaches can prevent unstable failure caused by the increase of surrounding rock stress at the later stages of increasing moisture content.

Key words: Large-section loess tunnel; Irrigation; Infiltration; Water content; Plastic zone; Stability analysis

软弱围岩隧道锁脚锚杆受力特性及其力学计算模型

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摘 要：锁脚锚杆在软弱围岩隧道中应用非常广泛，为了研究其受力特性，以包茂线西康高速公路包家山特长公路隧道为依托，采用现场试验的方法，对典型断面锚杆轴向应力进行测试，结果表明：拱部锚杆受力较小，最大应力仅为锚杆极限应力的 11.5%，作用不大；锁脚锚杆受力较大，最大应力达到锚杆极限应力的 55.4%，作用很大；锁脚锚杆受长度和角度限制，不能发挥锚固作用。在分析其受力特性的基础上，采用结构力学和弹性地基梁的方法，建立了钢架和锁脚锚杆力学计算模型。应用该模型对隧道测试断面处的锁脚锚杆受力进行了分析计算，给出了锁脚锚杆弯矩分布图。根据弯矩推算锚杆应变值，并与实测值进行对比，结果表明：实测值和计算值规律一致，在距离孔口最近位置处锚杆应变最大，随着距离孔口距离增大，应变逐渐变小。

关键词：锁脚锚杆

Mechanical Characteristics and Mechanical Calculation Model of Tunnel Feet-Lock Bolt in Weak Surrounding Rock

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Abstract:

The feet-lock bolt is widely used in weak surrounding rock tunnel. In order to study the mechanical characteristics, based on the Baojiashan extra-long highway tunnel in Baomao line Xikang highway, the field test method was used to test the bolt axial stress at the typical section. The results show that the stress of arch department bolts is small, the maximum stress is only 11.5% of the bolt's ultimate stress and the effect is not big; the stress of feet-lock bolts is larger, the maximum stress is 55.4% of the bolt's ultimate stress and the effect is very big; and the anchorage effect cannot be used very much at the feet-lock bolts as a result of the length and the angle limitations. Based on the analysis of its mechanical characteristic, the mechanical calculation model of the steel frame and feet-lock bolt is established using structural mechanical and elastic foundation beam methods. And the model is used to analyze the stress of feet-lock bolts at the tunnel test section, and the bending moment distribution of feet-lock bolt is given. The strain value of bolt is calculated from the bending moment and compared with measured values. The results show that the calculated values are consistent with the measured ones, that the strain of bolt is the largest at the closest point to the orifice and that the strain decreases gradually with the increasing distance between orifice and anchor body.

keywords: feet-lock bolt

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软弱围岩隧道施工过程荷载释放特性

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摘 要：针对软弱围岩隧道施工过程中荷载释放过程的复杂性和多样性这一问题，以明垭子隧道为例，采用现场试验和数值模拟等手段，对明垭子隧道施工过程中的围岩荷载释放特性进行分析。结果表明：上台阶施工对围岩压力释放的影响较小；中台 阶开挖会引起围岩压力释放速率急剧增大；下台阶开挖时围岩压力释放速率有一定程度的加快。仰拱闭合后减缓了围岩压力 的释放速率，可用周边位移作为围岩压力释放的判断依据。分析得到了软弱围岩隧道施工过程中荷载释放特性和工序、位移的 关系，旨在为软弱围岩隧道的设计和施工提供参考。

关键词：隧道工程；软弱围岩；施工过程；荷载释放

Stress Release Characteristics During the Construction Process of Soft Rock Tunnel

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Abstract:

Mingyazi tunnel was used to study the complexity and variety of stress release process during the construction process of soft rock tunnel. Field test and numerical simulation methods were employed to analyze the stress release characteristics during the construction process of Mingyazi tunnel. It was known that the upper step construction has less influence on the pressure re-lease of surrounding rock. The pressure release rate of the surrounding rock increased sharply with the excavation of the middle steps. The pressure release rate of surrounding rock was accelerated to a certain extent when the lower steps were dug. The pressure release rate of the surrounding rock was slowed by the closing of the inverted arch. The peripheral displacement can be used as the basis for the determination of surrounding rock pressure release. The relationship between the load release characteristics during the construction process and construction sequence as well as displacement were obtained. This can be used as a reference for the design and construction of soft rock tunnel.

keywords: tunneling; soft rock; construction process; load release

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绿泥石片岩地层隧道施工过程中围岩压力变化规律研究

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摘 要：本文采用现场监测的方法，对绿泥石片岩地层隧道施工过程中的围岩压力变化规律进行研究，并利用三种函数对围岩压力随变形、开挖时间和空间的变化规律进行拟合分析，结果发现：（1）在变形急剧增长时，围岩压力反而出现先减小后增大的趋势；（2）围岩压力值多在 0.1～0.3MPa，其变化持续时间约 65～70 天；（3）监测断面距掌子面 2.5 倍洞径范围内时，围岩压力受掌子面推进的影响较大，超出此范围后，围岩压力基本不受掌子面开挖影响；（4）下台阶开挖至仰拱施作期间围岩压力变化比例最大，说明下台阶与仰拱的施工间隔太长；（5）利用 logistic 函数可以更好的表征围岩压力随变形、开挖时间和距掌子面距离的变化规律。

关键词：隧道工程；绿泥石片岩；施工过程；围岩压力；拟合分析

Change Law of Rock Pressure During Construction Process of the Chlorite Schist Tunnel

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Abstract:

In this paper, the method of field monitoring is used to study the change law of rock pressure during the construction process of the chlorite schist tunnel, and three kinds of functions are used to fit and analyze the change law of rock pressure with deformation, time of excavation and the distance to tunnel face. The results are as follows: (1) When the deformation increases rapidly, the rock pressure decreases first and then increases. (2) The value of rock pressure is 0.1 to 0.3 MPa, and the duration of the change is about 65~70 days. (3) When the distance of monitoring section and tunnel face is less than 2.5 times the tunnel diameter, constrction of tunnel face has obvious effct on rock pressure, when beyond this range, it has little effect on rock pressure. (4) The rock pressure changes the most between the construction of lower bench and invert, which shows the construction of lower bench and invert is late. (5) By using the logistic function, the change law of rock pressure with deformation, time of excavation and the distance to tunnel face can be better expressed.

keywords: tunnel engineering; chlorite schist; construction process; rock pressure; fitting analysis

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基于现场实测的隧道 CO 基准排放量折减率研究

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摘 要：随着我国城市化进程的加快，为了适应城市综合交通的发展，城市公路隧道越修越多。同时由于城市机动车保有量的迅猛增长，城市公路隧道机动车污染问题日益凸显。机动车尾排气体中有害物质很多，其中 CO 是隧道内最主要的、对人体危害最严重的污染物。本文以城市公路隧道 CO 基准排放量及其折减系数为研究对象，以深圳市具有代表性的横龙山隧道、深港西部通道深圳侧接线地下通道、九尾岭公路隧道、大梅沙公路隧道为依托，通过实地调研和现场实测获得了 4 座隧道的交通状况和通风情况。基于隧道内实测数据，首次采用反算分析法获得深圳市隧道在目前实际工况下 CO 基准排放量的年递减率范围在 4.9%~12.6%之间，表明城市公路隧道 CO 基准排放量年递减率采用《公路隧道通风设计细则》规定的 2%偏于保守。

关键词：隧道通风；基准排放量；年递减率；反算分析法

Study on Discount Rate of CO Baseline Emission Based on Field Measurement

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Abstract:

With the quickening of the urbanization process, more and more urban road tunnels are built to meet the demand of urban comprehensive transportation. Meanwhile, due to rapid growth of urban vehicles poputation, the vehicle pollution problem in tunnels is increasingly highlighted. There are many kinds of harmful substances in car exgaust, among which CO is one of the main pollutants in tunnels and the most harmful pollutant to human body. The paper took CO baseline emission and its discount rate as research object and choosed the four typical urban road tunnels, Henglongshan Tunnel, Shenzhen side-connection subway item of Shenzhen-Hong Kong west channel project, Jiuweiling Tunnel and Dameisha Tunnel respectively, as the project background. By ways of field research and tunnel tests, the traffic and ventilation conditions of four tunnels have been obtained. Based on large amounts of measured data, the value of CO baseline emission and its discount rate have been gotten by using the method of inversion calculation for the first time, which is between 4.9%~12.6%. It is suggested that at present the 2% discount rate which set according to China's Guidelines for Design of Ventilation of Hghway Tunnels is conservative.

keywords: tunnel ventilation; baseline emission; discount rate; back calculation method

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隧道冻害等级的划分

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摘 要：为了给隧道冻害防治提供基本依据，通过分析隧道冻害发生的条件，选取气候和地下水条件作为等级划分的主要因素。在划分气候的寒冷程度和地下水危害程度的基础上，采用综合评判的方法，对隧道冻害等级进行划分。结果表明，气候和地下水条件是影响隧道冻害程度的最主要因素；气候条件选取最冷月平均气温和冻结深度 2 个控制指标，将隧道所处地区的寒冷程度划分为 5 级；地下水条件选取赋存与补给形式和渗入隧道情况 2 个指标，将地下水的危害程度划分为 5 级；综合考虑气候和地下水条件对隧道冻害程度的影响，将隧道冻害等级划分为 5 级；全多年冻土隧道的气候条件虽然更加恶劣，但是隧道处于含冰围岩中，常年处于冻结状态，冻害现象并不严重，只是在隧道开挖过程中人为影响或暖季促使围岩融化，冻害等级可划分为Ⅱ级。

关键词：隧道工程；冻害；综合评判

Classification of Frost Damage Grades in Tunnel

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Abstract:

Abstract :In order to supply basic principles for preventing frost damage in tunnels , through analyzing the conditions of frost damage occurred in tunnels , climate and groundwater were chosen as main influencing factors to grading. On the basis of partition for climate cold level and groundwater harm degree ,the classification of frost damage in tunnels is partitioned with a comprehensive evaluation method. The results show that the climate and groundwater are main influencing factors of frost damage ;The cold level is partitioned into five grades by the control indicators of climate including the average temperature of the coldest month and the freezing depth ;The harm degree of groundwater is partitioned into five grades by the control indicators of groundwater including the form of groundwater occurrence , supplying and the situation of groundwater spreading into tunnel. The classiffication of frost damage in tunnels is divided into five grades according to the influencing factors of climate and groundwater for frost damage levele ;In permafrost , although the climate is cold in extreme , frost damage happens less seriously in the tunnels where surrounding rocks are freezing all the year round. The frost damage of permafrost tunnels is classified as grade Ⅱ while the ice on the surrounding rocks melts by the impacting of human activities in excavation or warming.

keywords: tunnelling; frost damage; comprehensive; evaluation

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Deformation and Mechanical Model of Temporary Support Sidewall in Tunnel Cutting Partial Section

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Abstract: A large cross-section shallow tunnel excavated by center cross diagram method (CRD) was constructed on a site with weak surrounding rock. Crown settlement and horizontal convergence were extensively monitored to investigate the performance of a temporary support wall. Based on field observations, effects of zone excavation on the temporary support sidewall were analysed extensively. Influenced by earth pressure applied by a subsequently zone excavated, the deformation of the temporary support sidewall at upper bench successively undergoes convergence, expansion, convergence, expansion and stabilisation five stages; and the deformation at lower bench undergoes convergence, expansion and stabilisation three stages. Based on the deformation and restriction condition of the temporary support sidewall during tunnel excavation, a small curvature beam was used to simulate the stress and deforma- tion change of the temporary support sidewall. Then, mechanical model of the temporary support sidewall under the surrounding rock horizontal pressure and the upper structure loads were suggested, respectively. The total deformation of the temporary support sidewall induced by zoned excavation can be determined by superposition the deformation caused by different loads.

Key words: Lager cross-section tunnel; Temporary support wall; Deformation; Mechanical model

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Monitoring and Analysis of the Operational Environment in an Extra-Long Highway Tunnel with Longitudinal Ventilation

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Abstract: Owing to their ability to dilute pollutant concentrations and enhance visibility, which significantly improves driving safety, ventilation systems have become one of the critical subsidiary facilities in extra-long highway tunnels. The spatiotemporal distribution characteristics of toxic gases, visibility, and air velocity in the Qin Mountains No. 1 tunnel (uphill bore, 6.02 km) were analyzed by combining a traffic survey with an analysis of environmental monitoring data. The analysis indicated that CO and visibility are unsuitable as primary control indexes for mountain tunnel ventilation when heavy goods vehicles (HGVs) represent a fairly large proportion of the traffic composition. The maximum in-tunnel NO2 concentration was 2.3 ppm, which is 2.3 times the design standard. Differences in the NO2/NOx ratio proved that gaps still exist between the diesel vehicle exhaust gas after-treatment technologies used in China and Europe. Consequently, stricter diesel exhaust emission standards and more intelligent ventilation-control technologies should be adopted in future tunnel designs. The results not only offer data that support the establishment of in-tunnel air quality control standards but also provide a feasible method for predicting the levels of various pollutants and developing ventilation-control strategies.

Key words: Extra-long highway tunnel; Operational environment; Air quality; Data analysis; Longitudinal ventilation

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Longitudinal Deformation Profile of a Tunnel in Weak Rock Mass by Using the Back Analysis Method

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Abstract: Analysis of the rock mass deformation behavior is a very important aspect of the safety assessment for tunnel construction in weak rock mass. In this paper, the deformation characteristics of a soft rock mass tunnel using three beaches construction method were investigated, which include the crown settlement and horizontal displacement and have 9 sections with 3 different construction schemes. The optimized construction schemes by decreasing the beaches length and changing the geologist of primary support were proposed. Then, applying the displacement back analysis method to calculate the rock mass parameters, double parameters were analyzed by using the golden section method. Results show that the tunnel deformations were affected by the elastic modulus E and the lateral pressure coefficient λ of rock mass, and the change of E has greater influence than λ on the tunnel deformation. The change of λ has greater influence on the crown settlement than that on the horizontal displacement. Furthermore, the regularity and characteristics of longitudinal deformation profile (LDP) in a weak rock mass tunnel was studied by utilizing the Fast Lagrangian Analysis of Continua (FLAC), and the LDP of the three long-beach construction scheme and the three short-beach construction scheme were compared. The results show that the complete displacements of tunnel under the three short-beach construction scheme condition by decreasing the lengths of the middle and lower benches are smaller than that under the three shortbeach construction scheme condition, however the pre-deformation of the tunnel deformation under this two construction scheme conditions is nearly the same. The extrusion deformation at the tunnel face of the three short-beach construction scheme is larger than that of the three long-beach construction scheme. Therefore, increasing the area of the core soil is a feasible measure to control the extrusion deformation on the tunnel face. Finally, the tunnel optimized construction scheme was verified benefit the tunnel stability. The measures of decreasing the length of middle and lower bench and closing the invert early and immediately will benefit the tunnel stability.

Key words: Weak rock mass tunnel; Longitudinal deformation profile (LDP); Complete deformation; Displacement back analysis; Numerical simulation

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顺序开挖法施工土质隧道临时支护的变形规律及力学特性

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摘 要：采用分部开挖法施工的隧道，临时支护变形大，结构受力复杂，属于施工中的薄弱环节。本文以两座土质隧道为工程依托，采用现场测试的方法，对 CRD 法和双侧壁导坑法的临时支护变形进行施工阶段的监控量测，水平方向呈现出“收敛—扩张—稳定”的规律，垂直方向呈现出“下沉—上隆—稳定”的规律。同时，采用有限元数值模拟的方法，以隧址地层地质参数为基础，得到临时支护位移和受力，结果表明：数值模拟与现场实测变形数值有一定的偏差，但变形规律和现场实测规律一致；临时支护施工时受力复杂；临时支护不仅受轴向压力，而且受弯矩和反复变化的剪力作用，提出临时支护每榀钢架之间设置纵向连接钢筋，喷射混凝土中设置钢筋网，必要时采用钢纤维喷射混凝土。

关键词：变形规律

Resecrown on the Deformation Rule and the Mechanical Property of Temporary Support in Soil Tunnel Cutting Partial Section

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Abstract:

The temporary support, of which the tunnel constructed by partial excavation method, is one of the weakest bench because of the lager deformation and complex force. In this paper, on the basis of two soil tunnel, the method of field test was used to monitoring the temporary support deformation during the construction by CRD method and the double sides heading method. The analysis shows that the temporary support presents the "convergence-expansion-stability" regularity in the horizontal direction and the "settlement-uplift-stability" regularity in the vertical direction influenced by the first pilot tunnel excavation and the unloading of uncut soil. At the same time, using the finite element numerical simulation method to get the displacement and force of the temporary support based on the tunnel site stratum geological parameters. The result shows as follows: the numerical simulation and field measurement deformation rules have a certain bias, but the deformation rules corresponds with the field measurement rules; the force of the temporary support is complex since the forces are different in the different parts and the force would change repeatedly; the temporary support forces not only by the axial force, but also by the bending moment and repeatedly changed shear force. Then the measures are proposed that the temporary support sets the longitudinal connection reinforced between each steel frame and the steel fabric in the shotcrete, or even uses steel fiber reinforced shotcrete when necessary.

keywords: deformation rule

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Stability Analysis of Super-Large-Section Tunnel in Loess Ground Considering Water Infiltration Caused by Irrigation

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Abstract: Constructing a super-large-section loess tunnel under the irrigation area is a highly challenging task. One reason is that the strength of the loess decreases when it is soaked, which endangers the safety and stability of tun- nels. In this paper, Majiazhuang tunnel is selected as a project case which provides in situ monitoring and measuring data, and Midas GTS NX software is used to build a tunnel structural calculation model under the coupled function of seepage and stress fields. Combined with the change law of physical and mechanical property for unsaturated loess, simulations are performed under different situations, which include the surface infiltration, the integral soaking, and par- tial soaking caused by concentrated infiltration. The results of in situ monitoring show that the complete structure of super-large-section tunnel buried at 50 m depth below the clayey loess was effected negligibly by irrigation and heavy rainfall, and it is stable during irrigation and heavy rainfall. The results of simulation show that when the integrity of the farmland topsoil is good and the weak structural planes, cracks, and fractures do not exist, the effective depth of irri- gation water in Q3 clayed loess is 4 m approximately; when the tunnel soil layer is integral soaked, the moisture content of the Q2 silty clay loess increases from 16.6 to 20.5% and becomes saturated at the moisture content of 24.3%. The crown settlement, ground surface settlement, thickness and strain of the plastic zone significantly rise, and they slowly increase in the early stages while rapidly increase in the later stages. In addition, the rate of increase in the later stages is approximately 9.6 times faster than that in the early stages; when the crown, upper arch, and side wall are partial con- centrated soaked, the thickness of plastic deformation zone at the crown has the most significant effect. The thickness of plastic deformation zone at the crown increased more than 100%, at the other two positions both have approxi- mately 40% increasement compared with that without irri- gation water. It indicates that the irrigation water infiltrates to the tunnel soil layer, the structural stability of the tunnel is affected by the surface irrigation, and the partial soaking at the upper crown has the greatest effect on the stability of the tunnel structure.

Key words: Large-section loess; tunnel; Irrigation; Infiltration; Water content; Plastic zone; Stability analysis

Analysis of Tunnel Displacement Accuracy with Total Station

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Abstract: The remote distance measurement (RDM) method requires only common total stations and not special post-processing software. Moreover, this method is easy to operate and highly accurate results can be obtained. Therefore, RDM is used in the displacement monitoring of tunnel engineering. This study presents the calculation formulas for the crown settlement and wall convergence of tunnel as measured by RDM with total station. The mean error formulas are derived based on error propagation laws. When tunnel displacements mea-sured by using total station with the ms not more than 2 mm+2D ppm (D is the measure-ment distance) and ma not more than 100, the horizontal distance between the rear viewpoint and the monitoring section is in the range of 50–150 m, the horizontal distance between the total station and the monitoring section ranges from 40 m to 60 m, and the total station is near the tunnel centerline, the measurement accuracy can reach 1 mm.

Key words: tunnel

Investigation of Microstructural Damage in Shotcrete Under a Freeze-Thaw Environment

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Abstract: Shotcrete is extensively used in underground engineering and other fields. In cold regions, the initial shotcrete lining of tunnels is repeatedly frozen and melted several times in a single year when tempera-tures alternately change. Thus, the freeze-proof durability of shotcrete is significantly impacted by the freeze-thaw cycle. Computed tomography (CT), a non-destructive scanning method, was adopted to demonstrate the process of shotcrete microstructural damage in a freeze–thaw environment. CT scanning results showed that looseness and slippage of the cement mortar became increasingly apparent and that the number of internal micro-pores significantly decreased with increasing number of freeze-thaw cycles. In addition, the axial compressive strengths of the shotcrete prism specimens significantly decreased. After 300 freeze-thaw cycles, the total number of micro-pores in specimens DR1-1 and DR1-2 decreased by 50.32% and 34.20%, respectively, and the axial compressive strength loss reached 63.78%.

Key words: Shotcrete Freeze-thaw cycles; Computed tomography scanning; Microstructural damage

CATIA-Based BIM Technology in Highway Tunnel Design

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Abstract: Referring to CATIA's 'assemblies + parts' modeling method, CATIA-based BIM (Building Information Modeling) technology has been proposed for highway tunnel design in this paper. A tunnel BIM is created by CATIA, which is based on a real case in China, focusing on the following 3 aspects: (1) Creating tunnel bolts by UDF + Loop cyclic arrangement method; (2) Using Sketch Tracer module to create tunnel portal; (3) Parameter is used to create and call the Catalog database. Then, bolt collision inspection and U-shaped groove concrete statistics are conducted with the help of the tunnel BIM created. Finally, the finite element analysis of tunnel construction process is carried out through the CATIA-Midas interface. The results demonstrate that the CATIA-based BIM technology can well adapt to the characteristics of tunnel and have well potential applications in tunnel design.

Key words: Highway tunnel; Design; CATIA; BIM; Function application.

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冻融荷载作用下喷射混凝土的损伤

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摘 要：目前，喷射混凝土已被广泛应用于隧道施工中，且实践证明引气剂的添加能够有效地改善寒区隧道喷射混凝土的抗冻耐久性。本文的主要研究内容是以 CT 无损扫描技术为基础，混合 RM-YQ 引气剂，并结合相应的质量损失试验、动弹性模量测试试验、超声波波速测试试验，分析比较在不同冻融循环次数下 C25 引气喷射混凝土与普通喷射混凝土内部孔隙结构的变化情况，得到引气喷射混凝土的抗冻耐久特性。研究得到，喷射混凝土的冻融耐久性与混凝土的抗冻融耐久性有关，添加引气剂可以在很大程度上减少气孔的数量。主要集中在 0.01-1.00mm^{2}之间（由于 CT 扫描的精度限制，不包括小于 0.01mm^{2}的微孔隙与气泡），因此可以改善成形喷射混凝土的初始孔隙结构。在最初的几次冻融循环中，仅形成少量小孔。水泥砂浆破碎后，普通喷射混凝土中小孔（0.01mm^2-0.50mm^2）的数量明显增加，孔隙结构严重恶化。而引气剂的添加能够有效地减弱这种影响，从而使喷射混凝土的冻融耐久性得到改善。

关键词：喷射混凝土

Damage of Shotcrete Under Freeze-Thaw Loading

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Abstract:

The freeze-thaw durability of shotcrete can be improved by adding an air-entraining agent in cold areas. The main focus of this paper is to investigate the changes in the internal pore structure of C25 ordinary shotcrete and shotcrete mixed with a RM-YQ air-entraining agent using computed tomography (CT) scanning technique during freezethaw cycles. The macroscopic tests were conducted, including mass loss, dynamic modulus of elasticity and ultrasonic wave velocity tests. Results were compared, and the freeze-thaw durability characteristics of shotcrete mixed with the air-entraining agent were revealed. Adding an air-entraining agent could reduce the number of pores largely that ranged mainly from 0.01 mm(2) to 1.00 mm(2) (excluding the pores or bubbles < 0.01 mm(2) because of the precision of the CT scanning system), and could therefore improve the initial pore structure of the formed shotcrete. During first few freeze-thaw cycles, just few small pores formed. After cement mortar fragmentations appeared, the number of small pores (0.01 mm(2) to 0.50 mm(2)) in ordinary shotcrete increased significantly. The pore structure deteriorated largely. However, this could be prevented effectively by adding an air-entraining agent. Therefore, the freeze-thaw durability of shotcrete was improved.

keywords: shotcrete

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浅埋隧道下穿高压铁塔注浆加固效果的数值分析

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摘 要：为分析浅埋隧道 CD 法施工对既有高压铁塔的影响，以九景衢铁路某隧道工程为背景，建立二维弹塑性有限元模型，对有无注浆加固两种方案进行模拟，对比分析了高压铁塔水平及竖向位移，隧道周边收敛变化规律。结果表明：地表注浆加固后采用 CD 法可明显控制高压铁塔的基础沉降和不均匀沉降，其中基础沉降值减少了 43.63%，不均匀沉降值减少了 54.39%；在隧道上部的施工过程中，铁塔和隧道的沉降位移和沉降速率较大；数值模拟结果与实测值较为接近，加固后能够保证隧道和铁塔的安全。研究结果可为类似工程提供一定的参考。

关键词：隧道施工；高压铁塔；数值分析；沉降；加固方案

Numerical Analysis of Grouting Reinforcement Effect of Shallow Tunnel Under High Pressure Steel Tower

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Abstract:

In order to analyze the influence of the shallow tunnel constructed by CD method on the existing high voltage tower, taking a tunnel project in nine Jing Qu railway as the background to establish two-dimensional elastic-plastic finite element model and to simulate two kinds of grouting reinforcement schemes. Comparing and analyzing the horizontal and vertical displacements of the high voltage tower and the variation law of tunnel peripheral convergence. The results show that using the CD undermining method can obviously control the vertical displacement and the uneven settlement of the High-voltage tower, among which, the foundation settlement decreases by 43.63% and the value of uneven settlement decreased by 54.39%. During the construction of the upper part of the tunnel, the sedimentation and settlement rates of the tower and tunnel are larger. The numerical simulation results are close to the measured values. After reinforcement, it can ensure the safety of the tunnel and the tower. The results can provide some reference for similar projects.

keywords: tunnel construction; High-voltage tower; numerical analysis; settlement; reinforcement scheme

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TBM 施工超前地质预报现状及发展趋势

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摘 要：超前地质预报是隧道施工中必不可少的环节，对隧道信息化施工、灾害防治和安全保障具有重要作用。相较于钻爆法，TBM 施工环境具有特殊性和复杂性，对超前地质预报技术提出了更多的挑战。结合 TBM 施工的特点，分析 TBM 施工环境中地质预报的难点，介绍适用于 TBM 施工的超前地质预报技术，分析比较其对 TBM 施工的适用程度；最后，通过对以往研究成果的总结，对隧道 TBM 施工超前地质预报的发展方向进行预测。

关键词：隧道工程

Current Status and Development Trend of Advanced Geological Prediction for TBM Construction

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Abstract:

Advance geological prediction is an indispensable link in tunnel construction, and plays an important role in tunnel information construction, disaster prevention and safety protection. Compared with the drilling and blasting method, the TBM construction environment has speciality and complexity, which poses more challenges to the advanced geological prediction technology. Combined with the characteristics of TBM construction, analyze the difficulties of geological prediction in TBM construction environment, introduce advanced geological prediction technology applicable to TBM construction, analyze and compare its applicability to TBM construction; finally, through the summary of previous research results, tunnel TBM The development direction of construction advanced geological prediction is predicted.

keywords: Tunnel engineering

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隧道进出口路面结冰积雪和能见度实时预警研究

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摘 要：进出口是隧道交通事故的频发处，根据隧道进出口交通事故汇总分析，定义隧道进出口过渡段，提出了一个针对隧道进出口的路面能见度与结冰积雪安全预警系统，其包括数据处理系统、能见度监测系统、积雪结冰监测系统、预警发布及响应系统。通过模型实验研究表明，该系统在多种不利天气的模拟下，均能准确的检测，及时预警，以及改变隧道进出口渐变灯的亮度。本系统能够对公路隧道路面能见度与路面实际状况进行实时监测、预警和反馈，能够保证隧道进出口过渡段的行车安全。

关键词：隧道进出口；路面结冰；能见度；实时检测；安全预警

Real Time Early Warning of Ice and Snow and Visibility in Tunnel Entry and Exit

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Abstract:

Entrance and exit of tunnel are the frequent places of traffic accidents. According to the summary analysis of tunnel traffic accidents, the transition section of tunnel entrance and exit is defined. A road visibility and snow icing safety early warning system for tunnel entrance and exit is proposed, which includes data processing system, visibility monitoring system, snow icing monitoring system, early warning issuance and response system. The model experiments show that the system can accurately detect, warn in time and change the brightness of the gradient lamp at the entrance and exit of the tunnel under the simulation of various adverse weather conditions. This system can real-time monitor the visibility of highway tunnel pavement and the actual condition of pavement, provide immediate feedback and early warning, and ensure the traffic safety of the transitional section between the entrance and exit of the tunnel.

keywords: entrance and exit of tunnel; road icing; visibility; real-time detection; safety early warning

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浅埋暗挖软岩隧道管棚预注浆变形监测及加固分析

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摘 要：为了研究浅埋破碎软岩隧道采用管棚预注浆超前支护后的加固效果，使施工顺利安全进行，以某实建隧道工程为依托，采用MIDAS/GTS有限元软件，建立了管棚加预注浆超前支护、仅采用管棚支护以及无任何支护作用下的三种开挖模型进行数值模拟分析。结果表明：管棚预注浆超前支护措施在隧道拱顶上部形成加固带，承受了大部分隧道拟开挖区域的围岩荷载，改善地层成拱能力，有效控制了地表下沉、拱顶沉降和应力集中现象，使地表下沉减小52.7%，拱顶沉降减小58.9%，拱脚收敛减小61.4%，仰拱隆起减小63.8%，竖向应力减小79.2%。管棚支护显著支承隧道上覆围岩压力，有效减小衬砌弯矩，阻止喷射混凝土的开裂破坏，降低土层变形过程中锚杆所承受的拉力；且相比于管棚预注浆超前支护，仅采用管棚支护对隧道边墙收敛及隧道仰拱隆起的加固效果同样显著。

关键词：隧道工程；破碎软岩；管棚支护；预注浆加固；数值分析

Numerical Simulation Analysis of Shed-Pipe Combined with Grouting Technology in Shallow Crushed Soft Rock Tunnel

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Abstract:

In order to study the reinforcement effect of the shallow burial and soft rock tunnel after the pre-grouting of the pipe shed, the construction is carried out smoothly and safely. Based on a real tunnel project, the MIDAS/GTS finite element software is used to establish the pipe shed. The pre-grouting advance support, only the pipe shed support and the three excavation models without any support are used for numerical simulation analysis. The results show that the pre-grouting support of the pipe shed forms a reinforcement belt in the upper part of the tunnel vault, which bears the surrounding rock load of most of the tunnel excavation area, improves the arching ability of the stratum, and effectively controls the surface subsidence and vault. Settlement and stress concentration, the surface subsidence decreased by 52.7%, the arch settlement decreased by 58.9%, the arch convergence decreased by 61.4%, the inverted arch ridge decreased by 63.8%, and the vertical stress decreased by 79.2%. The pipe shed support significantly supports the surrounding rock pressure on the tunnel, effectively reducing the bending moment of the lining, preventing the cracking damage of the shotcrete, reducing the tensile force of the anchor during the deformation of the soil layer; and comparing the pre-grouting of the pipe shed Supporting, only the pipe shed support is also effective for the reinforcement of the tunnel side wall and the tunnel arch bulge.

keywords: tunnel engineering; broken soft rock; pipe shed support; pre-grouting reinforcement; numerical analysis

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富水漂石地层土压平衡盾构施工参数分析与模型研究

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摘 要：依托成都地铁某区间盾构隧道工程，根据现场施工实测数据，利用统计分析、模型回归等方法对高富水大粒径漂石地层的盾构施工参数进行研究，分析参数间的相关性，建立了高富水大粒径漂石地层中的刀盘扭矩模型。研究结果表明：若采用 T=αD3 对大漂石地层中土压平衡盾构的刀盘扭矩进行简单估算，α 值的范围是在 1.0~1.9 之间；影响刀盘扭矩最大的因素依次是推力、掘进速度与刀盘转速的比值。这些关系对成都地区漂石地层土压平衡盾构的参数选择和匹配有重要的指导意义，所建立的模型可应用于成都地区漂石地层土压平衡盾构施工时的参数控制。

关键词：富水漂石地层；土压平衡盾构；施工参数；模型研究

Research on the Key Construction Parameters and Mathematical Model for EPBS in Saturated Cobble and Large Diameter Boulder Stratum

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Abstract:

Taking one of the shield tunnel interval in Chengdu metro for background, on the basic of field construction data, the key construction parameters of earth pressure balanced shield(EPBS) tunneling in saturated cobble and large diameter boulder stratum were studied and the correlation between parameters is discussed by statistical analysis and model regression. The mathematical models of torque of cutting wheel of EPB shield in cobble and boulder stratum are obtained. The achieved results show that if taking T=αD3 to estimate torque of cutter disc, the range of α is between 1.0 ~ 1.9; the construction parameters which affect the torque of cutter disc are thrust force、the ratio of advance speed and cutting wheel rotation in succession. These relationship have important guiding meaning in EPBS' parameters settings in saturated cobble and large diameter boulder stratum of Chengdu.

keywords: cobble and boulder stratum; EPBS; construction parameter; model research

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大断面软塑黄土隧道塌方处置及效果分析

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摘 要：黄土的水文地质和工程地质特性决定了塌方是黄土隧道主要地质灾害之一。富水软塑黄土含水率高、稳定性差、承载力低使得大断面隧道在穿越软塑黄土层时极易发生塌方事故。本文针对银西高铁上阁村隧道塌方事故，运用 FLAC3D 软件并结合现场实测数据，分析了塌方原因，提出现场塌方处理措施，并对处理效果进行评价。结果表明：软塑黄土层处于隧道拱顶时支护结构受力较大，黄土垂直节理发育等因素加剧了隧道掌子面周边围岩塑形挤出，进而发生坍塌、地表塌陷。处治后塌方段初期支护和二次衬砌的变形趋于稳定，且均未发生异常变化，处治效果良好。研究结果可为类似隧道工程塌方处治提供借鉴。

关键词：隧道工程；软塑黄土；塌方；处置措施

Cause Analysis and Disposal Method of Tunnel Collapse Caused by Large Section Soft Loess Tunnel

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Abstract:

The hydrogeological and engineering geological characteristics of loess determine that landslide is one of the main geological hazards of Loess tunnel. Due to the high water content, poor stability and low bearing capacity of water-rich soft plastic loess, large-section tunnels are prone to collapse when crossing soft plastic loess. Aiming at the collapse accident of Shangge Village Tunnel on Yinxi High-speed Railway, this paper uses FLAC3D software and field measured data to analyze the causes of the collapse, puts forward on-site treatment measures, and evaluates the treatment effect. The results show that when the soft plastic loess layer is on the top of the tunnel arch, the supporting structure is under great stress, and the development of vertical joints in the Loess intensifies the plastic extrusion of surrounding rock around the tunnel face, which leads to collapse and surface collapse. After treatment, the deformation of initial support and secondary lining in the collapse section tends to be stable, and no abnormal changes occur. The treatment effect is good. The research results can provide reference for similar tunnel collapse treatment.

keywords: Tunnel engineering; Soft-plastic loess; Landslide; Treatment measures

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冲沟地形浅埋黄土隧道不同开挖方向围岩变形特征研究

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摘 要：为研究冲沟地形浅埋黄土隧道开挖的稳定性问题，采用有限元法对浅埋黄土隧道的施工动态进行模拟，结合现场测试，分析了冲沟地形浅埋黄土隧道在施工过程中的围岩变形演变规律。结果表明：隧道开挖产生的预先沉降与收敛沉降比为 1:4，水平影响范围为 2 倍洞泾。地表沉降在边坡处与在边坡前、坡脚、坡顶与坡顶各处差异明显，呈现明显的纵向差异性。沿开挖推进方向，在边坡底部、边坡中部和坡顶三处产生的拱顶沉降和拱底隆起比其他部位更大。冲沟地形下，背坡开挖围岩稳定性、隧道拱顶沉降和地表沉降明显优于向坡开挖，建议隧道施工时可采用背坡开挖，以保证隧道施工安全。

关键词：黄土隧道；冲沟地形；现场测试；数值模拟；纵向效应；沉降

Study on Deformation Characteristics of Rock Mass with Different Excavation Directions of Shallow Loess Tunnel Under Gully Terrain

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Abstract:

To study the stability of loess tunnel excavated under the gully topography, finite element method is used to simulate the construction dynamics of shallow-buried loess tunnel. Combining with field test, the evolution law of surrounding rock deformation during excavation of shallow-buried loess tunnel under gully topography is analyzed. The result shows that The ratio of pre-settlement to convergent settlement is 1:4, and is horizontal influence range is 2D, in which D is the tunnel excavation diameter. Ground settlement exhibits an obvious longitudinal effect, in which the values of ground settlement in the bottom of gully terrain, foot and top of the slope vary sharply. Along the direction of excavation, the vault settlement and bottom uplift in bottom, middle and top of the slope are larger than those at other parts. Excavating in the gully terrain, the performance of rock mass stability, vault settlement and ground settlement by back-slope excavation are obviously better than those by the toward-slope excavation. It is suggested that back-slope excavation can be used in tunneling to ensure the construction safety.

keywords: loess tunnel; gully terrain; field monitoring; numerical simulation; longitudinal characteristics; settlement

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湿陷性黄土高速公路分岔隧道动力稳定性研究

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摘 要：本文通过动力仿真数值模拟对湿陷性黄土高速公路分岔隧道开挖过程中的变形特性以及地震动力响应进行了分析研究。计算结果表明，一衬或初期支护受力最大部位出现在拱脚，弯矩最大值出现在中部及中隔墙连接部位，二衬位移的最大位置为拱顶，受力最大部位发生在拱脚处，中隔墙位移最大处出现在顶部，所受轴力最大位置出现在底部以及中隔墙底部侧壁处，地震作用下，中隔墙顶部及仰拱受力逐渐增大，建议施工时要注意这几处的保护。

关键词：湿陷性黄土；分岔隧道；数值模拟；开挖变形；地震动力响应

Research on Dynamic Stability of Freeway Bifurcated Tunnel in Collapsible Loess Area

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Abstract:

In this paper, the deformation characteristics and seismic dynamic response during excavation of collapsible loess highway bifurcated tunnel were analyzed and studied by means of dynamic simulation numerical simulation. The calculation results show that the maximum stress of the first lining or initial support occurs at the arch foot, the maximum bending moment occurs at the connecting part of the middle and middle partition walls, the maximum displacement of the second lining occurs at the arch top, the maximum displacement of the middle partition wall occurs at the top, the maximum axial force occurs at the bottom and the side wall at the bottom of the middle partition walls, and under the earthquake action, the maximum displacement of the second lining occurs at the arch foot of the arch. The force on the top of partition wall and inverted arch increases gradually. It is suggested that attention should be paid to the protection of these places during construction.

keywords: collapsible loess; bifurcated tunnel; numerical simulation; excavation deformation; seismic dynamic response

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城市地铁复杂地段隧道施工关键控制技术

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摘 要：随着城市建设进程的加快，地铁的建设蓬勃发展，地铁隧道施工过程中遇岩溶、富水、瓦斯等复杂的地质情况越来越多，施工过程中必须保证隧道自身及周边环境的安全[1]，因此在隧道施工前制定切实可行的方案尤为重要。本文就施工过程中安全有效的施工方法和过程中的一些关键控制技术进行分析和阐述，确保城市地铁复杂地质隧道施工过程中的安全，为今后类似工程的施工提供一定的借鉴。

关键词：地铁隧道施工

Key Control Technology for Tunnel Construction in Complex Section of Urban Subway

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Abstract:

With the acceleration of the urban construction process and the vigorous development of the subway, the construction of the subway tunnel has encountered more and more complex Geological conditions such as Karst, rich water, and gas. During the construction process, it is necessary to ensure the safety of the tunnel itself and its surrounding environment. Therefore, it is particularly important to formulate practical solutions before the tunnel construction. This paper analyzes and expounds the safety and efficiency of Shigongfangfa and some key control techniques in the construction process to ensure the safety of the complex Geological tunnel construction in the city subway, and provides some reference for the construction of similar projects in the future.

keywords: Metro tunnel construction

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黄土液化机理与防治方法的综述与展望

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摘 要：世界上的黄土分布十分广泛，总面积占陆地面积的 1/10，其地震液化是主要存在的地质灾害之一，而世界上的黄土分布最广泛、厚度最大的国家就是我国。为减小黄土液化对地基及上部建筑物的影响，降低因黄土液化而造成的经济损失，以黄土液化机理与防治方法为基础，对现有研究成果进行总结与分析。结果表明：黄土液化的研究主要以试样的动三轴试验、波速测试、黄土场地的现场贯入试验为基础，液化指标为土性条件、土的初始应力条件、地震强度；黄土液化的防治从加强基础方面入手，主要采用灰土挤密桩来处理地基，而从减轻或消除土层液化可能性方面入手，有强夯加密、化学处理等方法。

关键词：黄土；液化；机理；防治方法

Review and Prospect of Liquefaction Mechanism and Control Methods of Loess

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Abstract:

Loess is widely distributed in the world, accounting for ten percent of the global land area, its liquefaction is one of the potential geological disasters in the loess region, and China is the world's most widely distributed and the largest thickness of loess. To reduce the influence of foundation and the upper part of the building, decrease the economic losses, the existing research results were analyzed to summary the mechanism and prevention control methods of the loess liquefaction. The results show that the research of loess liquefaction is mainly based on the dynamic penetration test of three axis test, wave velocity test, field penetration test of loess site, and liquefaction index of loess are the initial soil conditions, soil stress conditions, seismic liquefaction of loess strength. Control methods of the loess liquefaction from strengthening the basic aspects, mainly using lime soil compaction pile to the treat foundation, and from eliminating and reducing liquefaction possibility, usually using a dynamic encryption, or chemical processing method and so on.

keywords: loess; liquefaction; mechanism; prevention control measures

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浅埋暗挖岩溶富水隧道下穿河流施工技术探讨

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摘 要：随着城市建设的不断发展，地上空间资源越发紧张，因此加大地下空间的开发已是大势所趋，在复杂地质条件下地铁的建设也越来越多，下穿河流、周边建筑的地铁隧道工程成为重要的交通建设。本文结合贵阳轨道交通 1 号线延中区间隧道施工实例，从隧道施工过程中的岩溶富水地质和下穿河流风险出发，提出相应解决方法，重点探讨浅埋暗挖岩溶富水隧道下穿河流施工关键技术。较好控制了岩溶富水地质环境下穿河流的地铁隧道施工风险，取得了良好的成效，可为今后类似的工程施工提供借鉴和参考。

关键词：下穿河流

Discussion on Construction Technology of Shallow-Buried Underground Excavation of Karst Water-Rich Tunnel Crossing River

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Abstract:

With the continuous development of urban construction, the resources of overground space become more and more tense, so it is a general trend to increase the development of underground space. Under the complex geological conditions, the construction of subway is more and more. Tunnel engineering under rivers and surrounding buildings has become an important traffic construction. Combining with the construction example of Yanzhong section tunnel of Guiyang Rail Transit Line 1, this paper puts forward the corresponding solutions based on the karst water-rich geology and the risk of downstream river in the tunnel construction process, and focuses on the key technology of construction of shallow-buried and undercut karst water-rich tunnel underneath the river. The construction risk of metro tunnels crossing rivers in Karst water-rich geological environment has been well controlled, and good results have been achieved, which can provide reference for similar projects in the future.

keywords: Undergoing rivers

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Statistical Analysis of Influence of Cover Depth on Loess Tunnel Deformation in NW China

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Abstract: Loess is a kind of special soil with structure and hydro collapse behavior, due to the particularity of loess, the deformation regularity of tunnel in loess shows different characteristics from those in rock. To ensure the safety of construction, crown settlement (CS) and horizontal convergence (HC) are widely used to assess the stability of the tunnel structural system. Based on statistical analysis, this study focused on analyzing the influence of cover depth on the deformation of surrounding rock of loess tunnels by ANOVA, and relationships between them were presented by regression analysis. The achieved results indicated that the influence of cover depth on deformation was not obvious in shallow tunnels, while the cover depth had a significant effect on deformation in deep tunnels. Based on the difference of influence of cover depth on deformation between shallow tunnels and deep tunnels, a method for determining the cover depth threshold (CDT) in the tunnel by statistical analysis was proposed. The horizontal and vertical deformations in shallow tunnels were discrete and obeyed the positive distribution, mainly concentrated within 200 mm. The deformation allowance in shallow tunnels was recommended to be 200 mm. In deep tunnels, as the cover depth increased, the deformation increased linearly, while the CS/HC decreased.

Key words: loess tunnel; deformation; cover depth; statistical analysis

微膨胀岩隧道围岩压力模拟计算方法研究

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摘 要：本文指出了膨胀岩隧道围岩压力现有的模拟计算方法所存在问题的基础上，探讨并提出了采用围岩升温膨胀的方法来模拟计算膨胀岩所引起隧道围岩压力的方法，提出了一种成功解决了膨胀压力大小与温度变化值的关系的办法。通过算例及对比，表明该方法具有更合理的计算结果和更广泛的实用性。

关键词：膨胀围岩；隧道压力；数值计算；隧道衬砌

Research on Simulation Calculation Method of Surrounding Rock Pressure of Micro-Expansive Rock Tunnel

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Abstract:

This paper points out the problems existing in the existing simulation calculation methods for the surrounding rock pressure of expansive rock tunnels, and discusses the method of simulating the surrounding rock pressure caused by expansive rock by using the method of temperature expansion of surrounding rock. A method to successfully solve the relationship between the magnitude of the expansion pressure and the temperature change value. Through examples and comparisons, it shows that the method has more reasonable calculation results and wider practicality.

keywords: expansive surrounding rock; tunnel pressure; numerical calculation; tunnel lining

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“上堵下排、泄水降压”注浆在高富水断层隧道施工中的应用

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摘 要：山岭隧道中存在较多的高富水断层破碎带，不可避免的遇到突水情况，因此突水处治问题十分突出。本文结合东天山特长隧道，详细地阐述了 “上堵下排、泄水降压”注浆的具体施工措施，取得了良好的实际应用效果，为今后类似工程提供了有益的实例借鉴。

关键词：隧道突水；“上堵下排、泄水降压”注浆；经济效益分析

Application of "Upper Plugging, Discharge and Buck" Grouting in the Construction of High Water-Rich Fault Tunnel

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Abstract:

There are many high water-rich fault crushing zones in the mountain tunnel, which inevitably encounter the water inrush situation, so the problem of water inrush treatment is very prominent. Combining with the special tunnel of East Tianshan, this paper expounds in detail the concrete construction measures of grouting of "upper plugging row and discharge pressure", and obtains good practical application effect, which provides a useful example for similar projects in the future.

keywords: Tunnel water inrush; "Upper plugging row, discharge buck" grouting; economic benefit analysis

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基于突变理论的重载铁路隧道底板隐伏溶洞安全厚度研究

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摘 要：蒙华铁路是我国在南方穿越岩溶地区修建的第一条重载铁路，为了保证施工和运营期间的安全，在重载铁路岩溶区隧道修建过程，分析隧道底板以下潜在的隐伏溶洞安全厚度具有重要意义。分析隧道受力特点，建立隧道底板以下隐伏溶洞的力学模型，应用尖点突变理论分析隧道失稳破坏力学效应，确定隧道底板以下隐伏溶洞与隧道的安全厚度。结合在建隧道，根据探测到的隐伏溶洞，利用建立的模型计算安全厚度，并采用数值模拟进行分析，确定隐伏溶洞的安全厚度，为工程处理措施提供了理论设计依据。

关键词：重载铁路隧道；尖点突变模型；安全厚度；数值分析

Study on Safety Thickness of Hidden Karst Cave Under Floor of the Heavy-Haul Railway Tunnel Based on Catastrophe Theory

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Abstract:

The Menghua Railway is the first heavy haul railway built in the south of China through the karst area. In order to ensure the safety during construction and operation, it is of great significance to analyze the potential safety thickness of hidden karst caves under the tunnel floor during the construction process of the tunnel in the karst area of heavy haul railway. The mechanical model of concealed karst cave under tunnel floor is established. The mechanical effect of instability and failure of tunnel is analyzed by cusp catastrophe theory, and the safety thickness of concealed karst cave and tunnel under tunnel floor is determined. Combined with the tunnel under construction, according to the detected hidden karst caves, the safety thickness is calculated by using the established model, and analyzed by numerical simulation to determine the safety thickness of hidden karst caves, which provides a theoretical basis for engineering treatment measures.

keywords: heavy-haul railway tunnel; the cusp catastrophe model; safe thickness; numerical analysis; heavy-haul railway tunnel; the cusp catastrophe model; safe thickness; numerical analysis

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隧底隐伏溶洞对重载铁路隧道稳定性影响数值分析研究

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摘 要：以在建蒙华重载铁路在南方岩溶区的隧道工程为依托，对隧道底部以下隐伏溶洞对隧道围岩稳定性的影响进行分析，采用数值分析方法，考虑隐伏溶洞洞径、长度、与隧道底板距离等因素，进行多种工况计算分析，初步得到了不同工况下隐伏溶洞与隧道安全距离，为设计和施工提供了依据。

关键词：重载铁路隧道；隐伏溶洞；安全距离；数值分析

Numerical Analysis of the Influence of Hidden Karst Cave Below the Bottom of Tunnels on the Stability of Heavy-Haul Railway Tunnels

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Abstract:

Based on the tunnel construction of the Menghua heavy-duty railway in the southern karst area, the influence of the hidden karst cave below the tunnel bottom on the stability of the tunnel surrounding rock is analyzed. The numerical analysis method is adopted to consider the hidden cave diameter, length and tunnel. Based on the factors such as the distance between the bottom plate and the calculation of various working conditions, the safety distance between the hidden cave and the tunnel under different working conditions is obtained, which provides the basis for design and construction.

keywords: heavy-haul railway tunnel; hidden karst cave; safe thickness; numerical analysis

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Prediction for Disaster Source of Water Inrush and Escape Route Optimization After Water Inrush in River Undercrossing Karst Tunnel

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Abstract: While tunneling in karst terrains, engineers may encounter well-developed karst conduits which will lead to water inrush accidents frequently occur. To ensure the construction safety of river undercrossing karst tunnel, engineering geological and hydrogeological conditions of Yuelongmen tunnel was analyzed firstly.Second,in order to accurately predict the water-bearing structures ahead the tunnel face, tunnel induced polarization method was utilized to detect the three-dimensional position, spatial distribution pattern of rich water area. According to the forecast conclusion, case study was investigated under certain velocity of water inrush by numerical simulation. For each probing line set in the double-line tunnel and cross passage, the velocity and pressure curves are obtained, flow characteristics of water after inrushing in excavated tunnel were summarized. Finally, optimized escape route was designed in the double-line tunnel. Research results provide a theoretical basis for making scientific and rational escape routes in high risk karst tunnel.

Key words: karst tunnel; Water inrush; tunnel induced polarization method; Escape route optimization

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大跨度隧道断层破碎带衬砌结构应力分布规律研究

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摘 要：断层破碎带对隧道的施工存在安全隐患，广西某大跨度公路隧道穿越长约 50 米的断层破碎带，为了保证隧道施工的安全，监控量测了该破碎带处初衬混凝土结构、钢拱架、锚杆及二衬混凝土结构的应力特性，采用压力盒、格栅拱架钢筋计、混凝土应变计、锚杆计等四种仪表，跟踪测试该工程。测试结果表明：该隧道的衬砌结构起到了很好的支护效果。研究结果可以反馈给本工程的建设以及后期运营管理，并对其他类似的大跨度隧道断层破碎带的衬砌结构的设计与施工有一定的参考价值。

关键词：大跨度隧道；断层破碎带；衬砌结构；应力；监测

Study on Stress Distribution of Lining Structure in Large Span Tunnel Fault Fracture Zone

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Abstract:

There is a hidden danger to the construction of the tunnel in the fault zone, a large span tunnel in Guangxi passes through the fault rupture zone about 50 meters. In order to ensure the safety of tunnel construction, the stress characteristics of the initial lining concrete structure, steel arch, anchor, and secondary lining concrete were studied, using pressure box, grid arch reinforced, concrete strain gauge, bolt stress meters. The results show: the lining structure can meet the requirements. The results of this study can give feedback to the late operation management of the project, and have some reference value for the design and construction of the lining structure of other similar large span tunnel fault broken zone.

keywords: large span tunnel; fault fracture zone; lining structure; stress; monitor

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全风化花岗岩隧道进洞施工综述

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摘 要：花岗岩在我国东部和东南部沿海等有着较为广泛的分布，在长期的外动力作用下，地表形成较厚的全风化层，为减小在全风化花岗岩地层中进洞过程沉降过大问题，降低因沉降过大造成的经济损失，以全风化花岗岩的性质和隧道进洞施工技术为基础，对现有成果进行总结与分析，结果表明：干燥无水的全风化花岗岩物理性质与流沙相似，而在富水状态下，受水的影响，其易于崩解；在施工过程中，加强超前支护强度、使用水平旋喷+超前小导管技术，并结合有效的降排水措施及施工方法，保证隧道开挖安全，快速进洞，有效解决进洞过程沉降过大的问题。

关键词：隧道工程

Review of Tunnel-Entering Construction of Fully Weathered Granite Tunnel

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Abstract:

Granite is widely distributed in the eastern and southeastern coastal areas of China, under the influence of long-term external force, the surface is thick and full of weathered layers. In order to decrease the problem of vault settlement during tunnel excavation in fully weathered granite strata and reduce the economic loss caused by excessive settlement, the existing research results are summarized and analyzed, which based on the nature of fully decomposed granite and tunnel-entering construction technology, the result indicated that the physical properties of completely weathered granite with low water content are similar to those of quicksand, while under the condition of rich water, it is easy to disintegrate because of the influence of water. In the construction process, the safety of tunnel excavation and rapid access to the tunnel can be guaranteed through strengthening the advanced support strength, using horizontal swirling spray + advanced small catheter technique, adapting effective measures for reducing drainage and construction methods and it can effectively solve the problem of too large settlement.

keywords: tunnel engineering

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Displacement and Stress Characteristics of Tunnel Foundation in Collapsible Loess Ground Reinforced by Jet Grouting Columns

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Abstract : Collapsible loess tunnel foundation reinforcement is a new challenge in the construction process of tunnel engineering. According to the field displacement and stress monitoring of Fujiayao loess tunnel, this paper investigates the reinforcing effect of high-pressure jet grouting pile on collapsible loess tunnel foundation in the deep large-span tunnel. The field monitoring method was employed to address the performance of tunnel foundation settlement, additional stress, earth pressure, rock pressure, etc. The results indicate that the stress on the pile tops and the earth pressure between piles increase gradually over time in two stages: stress increase rapidly in the first 45 days and after this period, stress tend to gradually stabilize. Further, stress increases uniformly with the distance from the centerline of the tunnel, and the rock pressure of the tunnel sidewalls tends to be stable within two months of being constructed. Additional stress on tunnel foundation increases linearly with time, and it is uniformly distributed in vertical and horizontal directions of the tunnel section. Settlement of the tunnel foundation also gradually increases with time, and it tends to be stable at 50 days from the time of construction. Additionally, the settlements of different monitoring points are similar at the same depth. The research results will further improve the theoretical knowledge of tunnel bottom reinforcement in loess tunnel, which not only can effectively guide the design and construction of loess tunnel and reduce disease treatment cost, but also can provide the necessary basic research data and scientific theoretical basis for revision of the corresponding specifications of highway tunnels and railway tunnels.

Key words: tunnel engineering; foundation reinforcement; field monitoring; collapsible loess; jet grouting pile

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岩溶帷幕灌浆单位注浆量与岩层透水率关系的研究

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摘 要：岩溶帷幕灌浆是灌浆技术的研究热点之一。单位注浆量与岩层透水率是岩溶帷幕灌浆中很重要的两个物理量。本文首先初步分析了岩溶帷幕灌浆中单位注浆量与岩层透水率的关系；然后，采用灌浆工程中的压水试验透水率计算方法和水力学的基本方程，提出了岩溶帷幕灌浆中单位注浆量与岩层透水率的关系公式，建立了两者之间的定量联系；最后，结合具体的工程实例进行现场应用，验证了该理论公式的合理性和适用性。研究结果表明，岩溶帷幕灌浆中单位注浆量与岩层透水率之间存在一种幂函数关系；基于该理论关系，可利用岩层透水率定量计算岩溶帷幕灌浆中单位注浆量。本研究为今后岩溶帷幕灌浆设计与施工中灌浆量的预测提供了一种新思路。

关键词：岩溶帷幕灌浆；单位注浆量；岩层透水率；关系公式；灌浆量预测

The Research of Relationship Between the Unit Grouting Amount and the Permeability of Rock Strata in Karst Curtain Grouting

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Abstract:

Karst curtain grouting is one of the research hotspots of grouting technology. The unit grouting amount and the permeability of rock strata are two important physical quantities in karst curtain grouting. In this paper, the relationship between the unit grouting amount and the permeability of rock strata in karst curtain grouting is firstly analyzed. Then, based on the calculation method of water permeability in the water pressure test in the grouting engineering and the basic equation of hydraulics, the formula of the relationship between the unit grouting amount and the permeability of rock strata in the karst curtain grouting is proposed, and the quantitative relationship between the two is established. Finally, combined with a specific engineering example for field application, the rationality and applicability of the theoretical formula are verified. The results show that there is a power function relationship between the unit grouting amount and the permeability of rock strata in karst curtain grouting. Based on the theoretical relationship, the unit grouting amount in karst curtain grouting can be quantitatively calculated by using the permeability of rock strata. This study provides a new idea for the prediction of grouting amount in the design and construction of karst curtain grouting in the future.

keywords: karst curtain grouting; unit grouting amount; the permeability of rock strata; relationship

formula; the prediction of grouting amount

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上软下硬地层隧道施工方法转换时机及可靠性研究

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摘 要：为了确定隧道穿越上软下硬地层段开挖方法的转换时机，以某地下公路隧道为工程依托，首先分析了工法转换及其时机研究的必要性，基于压力拱理论，采用 ANSYS 建立模型，并考虑掌子面与上软下硬地层分界面不同位置关系的影响，设计了 20 种工况，分析了洞室开挖前后拱部水平与竖向应力的变化特点，研究掌子面与地层分界线不同相交位置关系时围岩的成拱能力，拟确定了工法转换的时机；其次，考虑岩土参数的随机性，采用 ANSYS 中的可靠度（PDS）模块对转换时机的可靠性进行分析，并结合蒙特卡罗随机抽样方法，得出地表沉降的统计特性；最后，对现场监测数据进行统计分析，进一步验证工法转换时机的可行性。研究结果表明：为了减少对围岩的扰动及保证施工进度，需提前进行中隔壁台阶法向台阶法的转换；当基岩覆盖隧底 13m 后，压力拱厚度减小速率减慢并进入稳定状态，因此确定基岩覆盖隧底 13m 时进行开挖方法转换；可靠度分析结果显示地表沉降不超过 25mm 的概率为 0.925。现场数据表明，工法转换后围岩稳定性较好，拱顶、地表沉降皆满足工程要求，且施工进度可达 3m/d，有效解决了施工进度无法满足工期要求这一难题。

关键词：隧道；上软下硬；压力拱；开挖方法转换；可靠度

Study on the Conversion Time and Reliability of Tunnel Excavation Through Upper Soft and Lower Hard Strata

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Abstract:

In order to determine the timing that the excavation method converted when the tunnel passes through the upper-soft and lower-hard stratum section, the necessity of research on the transformation of the method and its timing was analyzed based on a case of underground highway tunnel. Based on the theory of pressure arch, considered the influence of the different positions between the tunnel face and the interface of the upper-soft and lower-hard stratum, 20 conditions were designed by ANSYS. The variation characteristics of horizontal and vertical stresses of the arch before and after excavation were analyzed. The arching ability of the surrounding rock was studied when the intersection of the face and the stratum boundary was different, and the time of construction method transformation was determined. Moreover, considering the randomness of geotechnical parameters, the reliability of the conversion time was analyzed by using the reliability (PDS) module of ANSYS, and the Monte Carlo sampling method was also used to obtain the statistical characteristics of surface settlement. Finally, the on-site monitoring data is statistically analyzed to further verify the feasibility of the conversion time. The results show that in order to

reduce the disturbance to the surrounding rock and ensure the construction progress, it is necessary to convert the excavation method in advance; when the bedrock covers the tunnel bottom 13m, the reduction rate of the pressure arch thickness slows down and enters a stable state. Therefore, it is determined that the excavation method is converted when the bedrock covers the tunnel bottom 13m; the reliability analysis results show that the probability of surface subsidence not exceeding 25mm is 0.925. The field data show that the stability of surrounding rock is good after the transformation of construction method, the settlement of vault and surface can meet the engineering requirements, and the construction progress can reach 3m/d, which effectively solves the problem that the construction progress can't meet the requirements of the construction period.

keywords: tunnel engineering; upper-soft and lower-hard strata; pressure arch; conversion of construction method; reliability

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Study on Vertical Deformation of Soil Caused by Curved Shield Tunnel Construction

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Abstract: This paper presents a series of analytical solutions of ground settlement induced by construction of a curved shield tunnel. Firstly, a calculation model of ground settlement due to ground loss was established based on the three-dimensional image theory. This model can take the parameters of "integrative gap at shield tail" (IGST) and overcutting gap in a curved tunnel into account. Secondly, a theoretical formula of ground displacement was deduced by the rewritten of Mindlin solutions. According to this theoretical formula, analytical solutions of ground settlement were proposed due to construction loads, such as additional thrust, friction force and grouting pressures. Thirdly, a case study was conducted to analyze the axial ground settlement and the transversal ground settlement. The results show that the ground settlement above the axis of the curved tunnel is not different from that of the straight-line tunnel. However, the transversal settlement troughs of the curved tunnel are nonsymmetrical about the tunnel axis, which is unlike the straight-line tunnel. The peak of ground settlement caused by IGST has a tendency of offset towards the inner side of the curved tunnel.

Key words: Image theory; Mindlin solution; Curved tunnel; Soil displacement

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高水压条件下封顶块位置对通缝拼装管片结构受力性能的影响研究

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摘　要：为了研究盾构隧道通缝拼装管片封顶块位置对管片结构受力特性的影响，基于苏通GIL综合管廊隧道工程，选取封顶块在拱顶和拱腰两种代表性工况，开展了高水压条件下通缝拼装管片结构原型试验，从管片结构的变形、受力、裂纹开展情况和最终破坏状态等方面对两种工况的试验结果进行分析。研究结果表明：1)不同封顶块位置对管片结构的影响总体表现为对于结构整体刚度的削弱不同，其形成刚度削弱区域抵抗指向洞外变形的能力要强于指向洞内变形的能力；2)相较于封顶块位于拱顶位置，封顶块位于拱腰时结构整体刚度更大，管片结构整体位移和单点最大位移均大幅减小，达到位移限值时的容许荷载明显增大；3）封顶块位于拱顶时结构抗弯刚度削弱明显，易出现较大的纵缝张开，而封顶块位于拱腰时管片最大纵缝张开量明显减小，且连接螺栓受力明显减小；4）封顶块位于拱腰时管片结构整体刚度明显增大，但在管片环拱底内弧面更容易产生裂纹、开裂荷载相对更小，管片内部主筋更早进入受拉状态；5)封顶块位于拱顶时管片结构由于纵缝张开量较大，在较高水压的情况下破坏始于纵缝出混凝土的压剪破坏进而导致的结构失稳。

关键词：水下盾构隧道

Study on the Influence of K Block Position on Mechanical Behavior of Straight Assembling Segmental Lining Structure Under High Water Pressure

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Abstract:

In order to obtain the influence of the position of the capping block of the shield tunneling joint on the force characteristics of the segment structure, based on the Sutong GIL integrated pipe gallery tunnel project, the capping block is selected in the two representative working conditions of the vault and the arch waist. The prototype test of the joint structure of the joints under high water pressure conditions was carried out. The results show that: 1) The influence of the position of different capping blocks on the segmental structure is generally different for the weakening of the overall stiffness of the structure. The ability to form a weakened zone against the shape of the hole is stronger than the ability to point into the deformation of the hole; 2) Compared with the topping block at the position of the arch, when the capping block is located at the arch waist, the overall rigidity of the structure is greater, and the overall displacement of the segment structure and the maximum displacement of the single point are greatly reduced, especially the single point displacement at the position of the dome is reduced The allowable load is significantly increased when the displacement limit is reached; 3) When the capping block is located at the vault, the

bending stiffness of the structure is weakened obviously, and the large longitudinal joint is easy to open, and the maximum longitudinal joint opening of the segment is obviously reduced when the capping block is located at the arch waist, and the connecting bolt is obviously The force is obviously reduced; 4) The overall stiffness of the segment structure is obviously increased when the capping block is located at the arch waist, but the arc surface is more likely to be cracked and the cracking load is relatively smaller in the bottom of the segment ring arch, and the main rib inside the segment is earlier. Entering the tension state; 5) When the capping block is located at the vault, due to the longitudinal joint opening of the segmental structure is large, the structural instability is caused by the compressive shear failure of the concrete which starts from the longitudinal joint in the case of high tensile force.

keywords: underwater shield tunnel

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妈湾跨海通道工程隧道选线快速评价模型研究

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摘　要：为了解决滨海地区跨海隧道选线难题，本文依托妈湾跨海通道工程，在分析影响海底隧道建设安全的地质因素基础上，从隧道线位地质适应性角度出发，综合考虑地质条件、设计方案、施工方法等因素，基于打分制提出了选线快速评价模型。模型包含平面曲率半径、纵坡坡度、抗浮安全系数、隧道埋深、与平面控制因素水平距离、差异沉降 6 项评价指标。选线快速评价模型前 5 项指标不满足设计要求时采用一票否决制，差异沉降指标考虑地下水位、土层性质、土层厚度、先期固结压力、车辆荷载等因素的影响，依据分层总和法计算隧道沉降，同时，结合经验法推导出沉降曲率半径计算公式，并将沉降曲率半径划分为 5 个等级，从而构建出妈湾跨海通道工程隧道选线快速评价模型，并将其嵌入到三维参数化选线分析平台，实现隧道地质参数快速选取和隧道线位快速评价。采用选线快速评价模型对妈湾跨海通道 3 条盾构线位进行选线评价，评分分数分别为 79.3、71.3、84.1 分，对隧道选线设计具有一定的参考意义。

关键词：海底隧道；选线设计；选线评价；差异沉降；曲率半径；数字化平台

Research on the Fast Evaluation Model of Tunnel Line Selection in Ma Wan Cross-Sea Channel Engineering

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Abstract:

To evaluate the tunnel route from geological aspect, based on the analysis of geological factors affecting the safety of subsea tunnel construction, from the perspective of geological adaptability of tunnel route, considering factors such as the geological conditions, design scheme, construction method and so on, the fast route evaluation model is put forward according to marking system, which contains six indices, for instance, coefficient of plane curvature radius, longitudinal gradient, anti-floating stability, tunnel depth, horizontal distance from the plane control factors and differential settlement. The first five indices of the fast route evaluation model adopt a single vote when they not meeting the design requirement, while differential settlement index calculates tunnel settlement according to layer-summation method and considers the influence of groundwater level, soil properties, soil thickness, preconsolidation pressure, vehicle load and so on. The radius of settlement curvature is divided into five levels after calculated by empirical method. The fast route evaluation model of MaWan cross-sea passage project is then constructed and embedded into the three-dimensional parametric selection line analysis platform, which could get the tunnel geological parameters and estimate the tunnel geological condition quickly. According to the fast route evaluation model, the score of the 3 lines of MaWan cross-sea passage is 79.3, 71.3, 84.1,

respectively, which has reference meaning to the selection of tunnel route.

keywords: subsea tunnel; route selection; route evaluation; differential settlement; curvature radius; digital platform

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长大隧道双护盾 TBM 齿轮油润滑系统设计探讨

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摘　要：针对某引水工程的长大隧道双护盾 TBM 齿轮润滑系统的设计，分别对比了三种掘进机的齿轮油系统形式，包括常规盾构齿轮油系统、双护盾 TBM 齿轮油系统、主梁式 TBM 齿轮油系统。通过对双护盾 TBM 主驱动工况和直径大小的分析，分别计算出小齿轮、主轴承、前后小轴承所需的润滑油量；根据双护盾 TBM 主驱动发热功率及热交换原理得出润滑油量，从而为双护盾 TBM 齿轮油系统提供量化指标。

关键词：双护盾 TBM；齿轮油系统形式；齿轮油系统计算

Discussion on Design of Double Shield TBM Gear Oil Lubrication System for Long Tunnel

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Abstract:

For the design of the long tunnel double shield TBM gear lubrication system for a water diversion project, the gear oil system forms of the three Tunnel Boring Machines are compared, including the conventional shield gear oil system, the double shield TBM gear oil system, and the main beam type. TBM gear oil system. Through the analysis of the main driving condition and diameter of the double shield TBM, the amount of lubricating oil required for the pinion, main bearing and small front and rear bearings is calculated respectively. According to the principle of heating power and heat exchange of the main shield of the double shield TBM The amount of lubricant, which provides a quantitative indicator for the double shield TBM gear oil system.

keywords: double shield TBM; gear oil system form; gear oil system calculation

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盾构隧道刀具更换技术综述

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摘　要：盾构穿越复杂水文地质地层时，常因刀盘刀具过量磨损而导致盾构被迫停机，这已成为困扰盾构施工的重要难题之一，进行刀具更换是目前解决这一难题，恢复盾构掘进的主要方法。然而，工程界尚未形成系统的盾构换刀技术体系。针对这一问题，在对已有技术研究理解和总结的基础上，阐述了盾构刀具更换技术的内涵和主要分类，并结合典型盾构工程换刀作业实例和笔者所在课题组的研究成果，对加固地层-常压换刀、基于常压可更换刀盘设计的换刀、带压换刀等 3 种主要换刀技术的原理、技术流程、关键技术、适用范围和优缺点等进行系统的分析和总结。最后介绍了日本最新的刀具更换技术，并对中国盾构隧道刀具更换技术进行了展望。结果表明：地层加固-常压换刀技术和带压换刀技术都是在常规刀盘设计条件下形成的，其关键都是保障开挖面地层的稳定性；差别在于，前者是使加固开挖面地层使其达到自稳后，在常压条件下实施的，而后者则是通过泥浆渗透成膜等辅助工艺提高开挖面地层的闭气性后，在气压支护条件下实施的；对于基于常压可更换刀盘设计的换刀技术来说，开挖面地层的稳定性不需要重点考虑，盾构机特殊的中空刀盘辐臂和常压可更换刀具设计才是该技术的关键。

关键词：隧道工程；刀具更换；综述；常压换刀；带压换刀；地层加固；开挖面稳定

Technical Review of Cutter Replacement in Shield Tunnelling

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Abstract:

Shield tunnelling machines are often used in complex hydrogeological environments and have to be frequently shut down owing to excessive wear of the cutters. This has become one of the important problems affecting construction during tunneling operations. Cutter replacement is the primary method of solving this problem and restoring tunnelling shields. However, a scientific system of cutter replacement has not yet been formulated for the engineering field. On the basis of understanding and summarizing the existing research, a technique and classification of shield cutter replacement technology were expounded. Three main techniques of cutter replacement, namely exchanging cutters under normal pressure after formation reinforcement, exchanging cutters based on the design of permanent pressure replaceable cutter, and exchanging cutters under pressure, were utilized frequently in construction sites. The principles, processes, key technologies, applications, advantages, and disadvantages were analyzed and summarized based on the typical cutter replacement operations and research results of the project .Moreover, the latest cutter replacement techniques used in Japan were introduced, and the cutting tool replacements for shield tunnelling in China were evaluated. The results show that, the cutter replacement techniques under normal

pressure after formation reinforcement and under pressure were formulated for conventional cutterhead design, and the key requirements were to ensure the stability of excavation face. The differences between these were that, the former was performed under normal pressure after stabilizing the excavation face to achieve self-stability, whereas the latter was conducted under the condition of air pressure support using the auxiliary technology of slurry infiltration and filter cake formation to improve the air-tightness of the excavation face. The stability of the excavation face was not considered for the cutter replacement owing to the design of permanent pressure replaceable cutterhead. The significance of this technique is the special design of the hollow cutter arm and the permanent pressure replaceable cutter for the shield machine.

keywords: tunnel engineering; cutter replacement; review; exchanging cutter under normal pressure; cutter exchange under pressure; formation reinforcement; face stability

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砂地层孔径分析及对泥浆在地层中渗透影响研究

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摘　要：为明确砂地层孔径分布特征及其对泥浆在地层中渗透的影响，采用压汞试验对砂地层孔径进行实测，并对砂地层孔径计算方法进行改进，同时在不同孔径的砂地层中开展不同性质的泥浆渗透试验，分析地层孔径对泥浆渗透的影响。研究表明，采用改进公式计算的孔径与压汞法实测的孔径结果相符，该方法可用于较均匀砂地层孔径大小计算；地层孔径越大，形成泥皮或泥皮+渗透带所需泥浆颗粒粒径越大，孔径大小决定了通过孔隙的泥浆颗粒粒径大小；渗入地层孔隙中的泥浆颗粒在地层中形成的稳定淤堵，降低了地层的渗透性，阻碍了泥浆的渗透过程。地层孔径与泥浆颗粒粒径对应关系是影响泥浆工程中泥浆渗透行为的关键因素。

关键词：泥浆渗透；砂地层；地层孔径；压汞试验；颗粒粒径

Study of Pore Size Analysis and Its Influence on Slurry Infiltration in Sandy Layers

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Abstract:

In order to define the pore size distribution and its influence on slurry infiltration in formation, the pore size was measured by mercury injection experiment, and the calculation method was improved, meanwhile the mud infiltration tests of different properties were carried in different sandy layers, and the influence of pore size on slurry infiltration were analyzed. The study indicates the pore size calculated by improved formula agrees well with that measured by mercury injection test, and the formula can be used to calculate the pore size of sandy layers in homogeneous. The size of the particles increases with the increase of the pore size of formation when required for filter cake or filter cake with an infiltrated zone, and the pore size of formation determines the size of the slurry particles through the pores. A stable clogging is formed by the mud particle infiltrated in formation pores, leading to the decrease of formation permeability, and the penetration process of the slurry is blocked. The relationship between pore size of formation and particle size of slurry is the key factor affecting mud penetration behavior in mud engineering.

keywords: slurry infiltration; sandy layers; formation pore size; mercury injection test; particle size

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盾构水平偏角变化对盾构——土相互作用影响研究

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摘　要：盾构掘进过程中机—土相互作用机理和多相平衡控制理论仍缺乏充分认识。针对此问题，首先基于地基反力曲线，通过等效弹簧近似模拟盾构与土的相互作用，计算盾构水平偏角变化过程中周围土层发生的位移，从而得到了作用于盾构外壳的围岩荷载的理论方法。然后采用改进的松动土压力计算方法，得到了盾构初始土压力的计算方法，解决了盾构水平偏角计算的初始边界问题，并结合土对盾构的作用荷载的计算方法得到了盾构水平偏角计算方法。而后对内摩擦角、盾构机质量、地层类型以及地层开挖损失率等因素对盾构-土相互作用的影响进行了分析和讨论。最后，结合济南地铁 R2 线盾构隧道工程，对盾构的水平偏角进行了实时监测，并与盾构水平偏角理论值进行了对比分析。结果表明：盾构水平偏角理论值的变化趋势与实测值基本一致，但理论值普遍大于实测值。研究成果可为盾构在进行水平面的姿态调整提供有益参考。

关键词：水平偏角；盾构姿态；盾构；相互作用；盾构千斤顶

Influence of Shield Yawing Angle Variation on Shield-Soil Interaction

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Abstract:

The mechanism of shield-soil interaction and multi-phase equilibrium control theory in shield tunneling process still lack sufficient understanding. Aiming at this problem, based on the ground-based reaction force curve, the interaction between the shield and the soil was simulated by the equivalent spring approximation, and the displacement of the surrounding soil layer was calculated during the change of the yawing angle, then the theoretical method of surrounding rock load acting on the shield shell has been obtained. Then, with the improved calculation method of loose earth pressure, the calculation method of the initial soil pressure of the shield was obtained, and the initial boundary problem of the yawing angle calculation of the shield was solved. Combined with the calculation method of soil-to-shield action load, the calculation method of shield yawing angle was obtained. Then the effects of internal friction angle, shield machine quality, stratum type and stratum excavation loss rate on the shield-soil interaction have been analyzed and discussed. Finally, combined with the Jinan Metro R2 shield tunnel project, the yawing angle of the shield was monitored in real time and compared with the theoretical value of the shield yaw angle. The results show that the trend of the theoretical value of the yawing angle of the shield was basically the same as the measured value, but the theoretical value was generally larger than the measured value. The research results can provide a useful reference for the shield to adjust the attitude of the horizontal plane.

keywords: yawing angle; shield attitude; shield; interaction; shield jacks

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孟加拉国卡纳普里河盾构隧道液化处置效果评价

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摘　要：孟加拉国卡纳普里河盾构隧道项目具有地质条件复杂、地震烈度高的特点。潜在地震液化问题对盾构隧道结构的安全性构成严重威胁。须进行合理的液化分析并采取相应的处置方案才能确保隧道结构的安全性。本文对液化程度高的典型断面，提出了抗震液化桩基布置方案。并建立了盾构隧道结构与周围地基的三维耦合动力学模型，对比分析了液化处置前后隧道结构周围土体的超孔压比、超静孔隙水压力、隧道结构的抗浮特性等，定量评价液化处置效果。研究表明：该液化桩处置方案有效提升了隧道结构的抗震特性。

关键词：盾构隧道；地震液化；效果评价；FLAC 3D

Evaluation of Liquefaction Disposal of Gravel Piles in Shield Tunnel of Kanapuri River, Bangladesh

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Abstract:

The shield tunnel of Kanapuri River, Bangladesh has the characteristics of complex geological conditions and high seismic intensity. The potential seismic liquefaction problem poses a serious threat to the safety of shield tunnel structures. A reasonable liquefaction analysis and appropriate disposal plan are required to ensure the safety of the tunnel structure. This paper analyzes the advantages of liquefaction disposal of anti-liquefaction piles and proposes a reasonable liquefaction disposal plan. On the basis of qualitative analysis, the numerical analysis and evaluation of the anti-liquefaction effect is carried out. Using the finite difference program FLAC3D, the three-dimensional coupled dynamics model of shield tunnel structure and surrounding foundation is established. The liquefaction disposal effect was quantitatively evaluated by the excess pore pressure ratio, the excess pore water pressure, and the anti-floating property of the tunnel structure before and after the liquefaction treatment. The research shows that the liquefied pile disposal scheme effectively improves the seismic behavior of the tunnel structure.

keywords: shield tunnel; seismic liquefaction; effect evaluation; FLAC 3D

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考虑自重作用的注浆理论方法与模型试验

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摘　要：浆液注入土层后会与土体颗粒粘结形成注浆结石体，而注浆结石体的尺寸则是反映注浆加固效果的重要指标。基于均匀管组理论和球形扩散理论，推导了考虑自重作用的浆液渗透扩散模型，在此基础上，建立了注浆结石体尺寸预测模型。利用自主研发的注浆模型试验系统，开展了砂土层中水泥浆液注浆试验，对注浆结石体尺寸试验值与理论值进行验证分析。研究表明：水泥浆液从开始注入到完成大致需要 3min~4min，可以分为快速增加阶段、缓慢增加阶段、稳定阶段等三个阶段；结石体纵向尺寸试验值和理论值变化趋势几乎一致，均呈近似线性增加；结石体横向尺寸、纵向尺寸理论值大致为试验值的 1.5 倍；结石体竖向尺寸理论值大致为试验值的 2 倍。从而验证了理论模型能够较好对结石体尺寸进行预测。

关键词：扩散半径；注浆压力；水泥浆液；结石体尺寸；理论方法；模型试验

Theoretical Method and Model Test on Grouting Considering Self-Weight

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Abstract:

When slurry is injected into the soil, it will bond with the soil particles to form a grouting stone body. And the size of grouting stone is the important indicator to reflect the effect of grouting reinforcement. Based on the even capillary group theory and spherical diffusion theory, a grout permeability diffusion model considering gravity was deduced. On this basis, a prediction model of grouting stone size was established. The grouting test of cement slurry in sandy soil was carried out with the self-developed grouting model test system, and the test value and theoretical value of the size of grouting stone were verified and analyzed. The results show that it takes about 3 to 4 minutes for cement slurry to be injected from the beginning to the completion, which can be divided into three stages: rapid increase stage, slow increase stage and stable stage. The change trend of the test value and the theoretical value of the longitudinal size of the stone body is almost the same, and both of them increase linearly. The theoretical value of the lateral size and the longitudinal size of grouting stone is approximately 1.5 times of the experimental value, and that of the vertical size of grouting stone is approximately 2 times of the experimental value. It is proved that the theoretical model can predict the size of grouting better.

keywords: diffusion radius; grouting pressure; cement slurry; the size of grouting stone; theoretical method; model test

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考虑浆液自重的砂卵石地层盾构壁后注浆驱替渗透扩散模型

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摘　要：以宾汉姆流型浆液为研究对象，考虑浆液自重条件下，基于驱替效应分析不同位置注浆孔浆液的渗透扩散特征，并针对宾汉姆流体求解其在上下部注浆孔的扩散方程，与忽略重力的情况对比分析，探讨注浆压力和地层渗透率对浆液扩散效果的影响。结果表明：考虑浆液自重，浆液的扩散形状呈椭球型，在上部注浆孔中注入浆液水平方向扩散距离较垂直方向远，在下部注浆孔注入浆液则现象相反；浆液自重对浆液扩散半径的影响程度与浆液注浆时间和地层渗透系数等因素呈正相关关系，与注入压力呈负相关关系。

关键词：盾构隧道；壁后注浆；驱替效应；浆液自重

Penetration Diffusion Model by Displacement Effect for Backfill Grouting of Shield Tunnel in Sandy Stratum Considering Self-Weight of Grout

Han Xin , Ye Fei , Ying Kaichen , He Biao , Wang Bin , Gao Xiang
（Chang'an University　CCCC Second Highway Consultants Co.,Ltd.）

Abstract:

Taking Bingham flow slurry as the research object, considering the self-weight of grout, based on the displacement effect, the infiltration and diffusion characteristics of grouting slurry at different positions were analyzed, and the diffusion equation of Bingham fluid from the upper and lower grouting holes was solved. Contrasting with the situation of ignoring gravity, the effects of grouting pressure and formation permeability on the diffusion of slurry were discussed. The results show that the diffusion shape of the slurry is ellipsoidal in consideration of the self-weight of the slurry. The horizontal diffusion distance of the slurry in the upper grouting hole is farther than the vertical direction, while the slurry that injected from the lower grouting hole represents the contrary condition. The influence degree of the slurry self-weight to the slurry diffusion radius is positively correlated with factors such as slurry injection pressure, formation permeability coefficient and grouting time.

keywords: shield tunnel; backfill grouting; displacement effect; self-weight of grout

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深埋盾构隧道同步注浆施工扰动力学问题研究

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摘　要：为研究深埋盾构隧道施工过程中同步注浆对周边土体及既有连拱隧道的扰动影响，将同步注浆浆液对土体的作用简化为无限空间土体中的柱孔扩张问题，基于柱形扩孔理论和统一强度理论，考虑同步注浆时浆液渗流对土体的作用，建立了同步注浆施工扰动力学模型，推导了同步注浆扰动下周围土体弹塑性区内应力场、应变场及位移场的理论计算公式。并以西安地铁四号线航～航区间盾构隧道为例进行了算例分析，研究表明：新建盾构隧道在近距离侧穿既有连拱隧道时，同步注浆产生的施工扰动影响显著，可实时调整同步注浆的注浆压力、注浆量及采取隔离加固措施，确保安全通过。

关键词：深埋盾构隧道；同步注浆施工扰动；统一强度理论；柱形扩孔理论；浆液渗流理论

Study on Disturbance Mechanics Problems Induced by Synchronous Grouting in Deep Shield Tunnels

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Abstract:

In order to study the disturbance influences of surrounding soil and existing double-arch tunnels induced by the synchronous grouting during the construction of the deep shield tunnel, the effect of grouting on soils during the synchronous grouting is simplified as the problem of cylindrical cavity expansion in the infinite space. Considering the seepage effect of grouting on soils during the synchronous grouting, the construction disturbance mechanical model of synchronous grouting is established on the basis of the cylindrical cavity expansion theory, unified strength theory. And the theoretical calculation formulas of stress field, strain field and displacement field in the elastic-plastic zone under the influence of the synchronous grouting disturbance are deduced. There is the Hang to Hang zone shield tunnel of Xi’an subway No. 4 line taken as an example to be analyzed. The results show that: for the significantly apparent disturbance influence of the existing tunnel under the action of the synchronous grouting when the adjacent double-arch tunnel is passed by newly-bulit shield tunnel, the grouting pressure and grouting capacity can be adjusted in real-time and isolation and reinforcement measures are adopted to ensure the passing safety.

keywords: deep shield tunnel; disturbance induced by synchronous grouting; unified strength theory; cylindrical cavity expansion theory; grout seepage theory

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考虑粘度时效性与空间效应的 C-S 双液浆盾构隧道管片注浆机理分析

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摘　要：在假定 C-S 双液浆符合宾汉姆流体的基础上，考虑了双液浆粘度时变性与空间效应，假定盾构隧道管片注浆符合球形渗透模型，通过平衡方程与 D.F 公式，对宾汉姆流体壁后注浆渗透扩散规律进行了理论推导，得到了 C-S 双液浆扩散半径计算公式以及管片受力计算公式。通过具体实例分析了注浆压力、注浆管内浆液流速对浆液扩散半径及管片受力的作用，对比了不同注浆参数对注浆效果的影响。分析结果表明，浆液扩散半径随注浆压力与注浆管内浆液流速的增大而增大；管片受力随注浆压力与注浆管内浆液流速增大而增大，但注浆压力的影响效果不断增大而后趋于稳定，注浆管内浆液流速的影响效果不断减弱而后趋于稳定。

关键词：C-S 双液浆；盾构隧道；球形渗透；粘度参数

Analysis of Grouting Mechanism for Shield Tunnel Segment by Cement and Sodium Silicate Mixed Grout Based on Time Variation and Space Effect of Viscosity Taken into Consideration

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（Chang'an University）

Abstract:

Supposing that cement and sodium silicate mixed grout is in accordance with Bingham Fluid pattern, with time variation and space effect of viscosity of cement and sodium silicate mixed grout taken into consideration, and supposing that grouting through shield tunnel segment conforms to spherical penetration model, the theoretical derivation has been carried out for backfill grouting penetration and diffusion pattern of Bingham Fluid according to equilibrium equation and D.F formula to obtain calculation formula for diffusion radius of cement and sodium silicate mixed grout and calculation formula for pressure on segment thereof, with influence of grouting pressure, of flow rate of grout in grouting pipe, and sodium silicate mixed grout on grout diffusion radius and pressure on segment analyzed and influence of different grouting parameter on grouting effect compared. The analysis results show that the diffusion radius of the slurry increases with the increase of the grouting pressure and the slurry flow rate in the grouting tube; the force of the tube increases with the grouting pressure and the slurry flow rate in the grouting tube, but the influence of grouting pressure The effect is continuously increased and then stabilized. The effect of the slurry flow rate in the grouting pipe is continuously weakened and then stabilized.

keywords: cement and sodium silicate mixed grout; shield tunnel; spherical penetration; viscosity

parameter

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考虑浆液自重的管片注浆浆液渗透扩散模型计算

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摘　要：为研究盾构隧道管片注浆的渗透扩散模型，以宾汉姆浆液流体为研究对象，基于广义达西定律（毛管组理论），并运用相关流体力学理论，推导了考虑浆液自重的盾构隧道管片注浆渗透扩散模型的计算公式，并分析了其适用范围及各参数的确定方法。结合具体计算案例，讨论了浆液对管片总压力的影响。结果表明：注浆压力增大，管片所受的注浆压力增大，单位管片所受的浆液压力呈线性增长，考虑浆液自重后，上部单位管片所受的浆液压力大于下部单位管片所受的浆液压力。

关键词：盾构隧道；壁后注浆；宾汉姆流体；渗透扩散

Calculation of Permeation and Diffusion Model of Pipe Grouting Slurry Considering Self-Weight of Slurry

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Abstract:

In order to study the percolation and diffusion model of shield tunnel segment grouting, the Bingham slurry fluid is taken as the research object. Based on the generalized Darcy's law (the capillary segment theory), and the relevant fluid mechanics theory is used, the shield considering the slurry's own weight is derived. The calculation formula of the tunnel segment grouting penetration diffusion model is analyzed, and its application scope and determination method of each parameter are analyzed. Combined with specific calculation cases, the influence of slurry on the total pressure of the segment was discussed. The results show that the grouting pressure increases, the grouting pressure of the segment piece increases, and the slurry pressure of the unit segment piece increases linearly. After considering the self-weight of the slurry, the slurry pressure of the upper unit segment piece is greater than that of the lower unit segment about the pressure of the slurry received by the sheet.

keywords: shield tunnel; backfill grouting; Bingham fluid; permeation diffusion

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基于球孔扩张的盾构隧道壁后注浆压密模型

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摘　要：为研究盾构隧道壁后注浆的压密效应，假设压密阶段浆体在土体中呈半球形扩张。应用弹塑性理论对球形浆体的扩张过程进行了理论推导，建立了盾构隧道壁后注浆压密模型，计算了压密注浆体的扩张率、土体塑性区扩张率以及注浆对管片产生的压力，分析了注浆压力和土体特性对管片压力荷载的影响。结果表明：注浆对管片的压力随着注浆压力和土体泊松比的增大而增大，随着土体弹性模量、粘聚力和内摩擦角的增大而减小；注浆对单位面积管片产生的压力不随注浆压力和土体特性的改变而改变；注浆对管片产生的压应力随着远离注浆孔而减小。

关键词：隧道工程；盾构；壁后注浆；球形扩张；压力分布

Back-Filled Grouting Compaction Model of Shield Tunnel Based on Spherical Cavity Expansion

Wang Bin , Ye Fei
（Chang'an University）

Abstract:

In order to study the compaction effect of back-filled grouting for shield tunnel, it is assumed that the grout expanded as a semi-sphere in clay stratum during compaction stage. The elastoplastic theory is used to theoretically deducing the expansion process of spherical slurry. The post-grouting compaction model of shield tunnel wall is established. The expansion rate of compacted grouting body, the expansion rate of soil plastic zone and the grouting pair are calculated. The pressure generated by the segments analyzed the effects of grouting pressure and soil properties on the compressive load of the segments. Analysis result shows that the pressure of grouting on the segment increases with the increase of grouting pressure and soil Poisson's ratio, and decreases with the increase of soil elastic modulus, cohesive force and internal friction angle. The pressure of grouting on unit area segment do not change with the change of grouting pressure and the soil characteristics; the pressure stress of back-filled grouting on segment decreases when it moves away from the grouting hole.

keywords: tunnel engineering; shield; back-filled grouting; spherical cavity expansion; pressure distribution

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盾构隧道管片注浆幂律流型浆液渗透扩散模型

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摘　要：为研究盾构隧道管片注浆的渗透扩散模型，以幂律流型浆液为研究对象，运用流体力学理论及毛细管组理论，推导了盾构隧道管片注浆渗透扩散模型的理论计算式，分析了其公式的各参数的确定方法。结合具体计算案例，讨论了注浆压力、浆液性质、地层条件等因素对浆液扩散半径的影响及浆液对管片总压力的影响。结果表明：注浆压力与浆液扩散半径成线性关系；注浆压力、水灰比及地层渗透系数增大，浆液扩散半径也增大；地下水压力增大，浆液扩散半径减小；注浆压力、水灰比、地层渗透系数增大，浆液对管片的总压力增加；地下水压力的变化不会影响管片所受的总压力。

关键词：盾构隧道；管片注浆；幂律流体；渗透扩散

Penetration Diffusion Model of Exponential Fluid for Backfill Grouting Through Segments of Shield Tunnel

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Abstract:

In order to study the penetration diffusion model for backfill grouting through segments of shield tunnel, taking the exponential fluid as the research object and applying the fluid mechanical theory and capillary group theory, the formulae for calculating the backfill grouting through segments of shield tunnel are deduced, and the application scope and determination methods for the parameters of the formulae are analyzed. Based on a specific case, the influences of the grouting pressure, grout properties and ground conditions on the grout diffusion radius and the total pressure on segments are discussed. The result shows that the grouting pressure is linear to the diffusion radius. The diffusion radius increases along with the increase of the grouting pressure, water-cement ratio and permeability coefficient, and decreases along with the increase of the groundwater pressure. The total grouting pressure on segments increases with the increase of the grouting pressure, water-cement ratio and ground permeability, but does not change along with the change of the groundwater pressure.

keywords: shield tunnel; backfill grouting through segment; exponential fluid; penetration diffusion

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盾构隧道斜螺栓接头受力性能与火灾下温度分布规律

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摘　要：为研究盾构隧道复合管片环向斜螺栓接头在常温下的力学性能及衬砌和接头在火灾下的温度分布规律，利用有限元计算软件 ABAQUS 建立了环向复合管片及环向斜螺栓接头的三维实体模型；考虑复合管片材料的非线性，采用弹塑性本构模型，对环向斜螺栓接头在常温下的力学特性进行了计算分析；根据 HC 升温曲线，对接头模型进行传热分析，研究复合管片衬砌和环向斜螺栓接头在火灾下的温度分布规律。研究结果表明：采用高强螺栓能够有效的减小接头张开量，增大接头刚度；在采用高强螺栓的情况下，斜螺栓最大轴应力易在初始阶段达到屈服，屈服后接头弯矩和轴力的增大对斜螺栓的应力影响并不大，对斜螺栓变形影响较大，当接头负弯矩从 7 kN·m 增加到 122 kN·m，接头轴力从 368 kN 增加到 734 kN 时，斜螺栓最大应变增加为 1.6 倍，当接头正弯矩从 53 kN·m 增加到 182 kN·m，接头轴力从 903 kN 增加到 1056 kN 时，斜螺栓最大应变增加为 5.9 倍；在常温下，接缝附近斜螺栓的轴应力呈现反对称分布，除接缝外其他部位斜螺栓的轴应力基本相等，约为 400 MPa，接缝处轴应力绝对值最大值可达 700 MPa；火灾情况下手孔处温度上升最快且达到的温度最高，80 min 时即可达到 1 000 ℃，接缝处混凝土在 100 min 后达到稳定温度，螺母处混凝土在 150 min 后达到稳定温度，稳定温度均在 1 000 ℃左右。

关键词：隧道工程；复合管片；斜螺栓接头；力学性能；火灾；温度分布

Mechanical Properties of Shield Tunnel with Inclined Bolt Joint and Temperature Distribution Law under Fire

Zhang Xinxin , Zhang Gaole , Zhang Wenjun
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Abstract:

In order to study the mechanical properties of composite segments with inclined bolt joint of shield tunnel under normal temperature, and the temperature distribution law of lining and bolt joint under fire, the three-dimensional solid model of circumferential composite segments and circumferential inclined bolted joint is established by the finite element calculation software ABAQUS. The nonlinearity of composite segment material is considered, and the elastoplastic constitutive model is adopted. The mechanical properties of the circumferential inclined bolted joint under normal temperature is calculated and analyzed. According to heating up curve of HC, the heat transfer analysis of the joint model is carried out, the temperature distribution law of the composite segment lining and circumferential inclined bolted joint under fire is studied. The results show that the use of high-strength bolt can effectively reduce the opening of joint and increase the joint stiffness. In the case of high-strength bolts, the maximum axial stress of inclined bolt is easy to yield at the initial stage, then the increase of bending moment and axial force of the joint has little

influence on the stress of the bolt, but has more influence on the deformation of the bolt. When the negative bending moment of the joint increases from 7 kN • m to 122 kN • m, the axial force of the joint increases from 368 kN to 734 kN, the maximum strain of the inclined bolt is increased by 1.6 times. When the positive bending moment of the joint increases from 53 kN • m to 182 kN • m, and the axial force of the joint increases from 903 kN to 1056 kN, the maximum strain of the inclined bolt is increased by 5.9 times. Under normal temperature, a special antisymmetric distribution of the axial stress of inclined bolt is shown near the seam. The axial stresses of inclined bolt except the joint are basically equal, about 400 MPa, and the maximum absolute value of the axial stress at the joint can reach 700 MPa; In the case of fire, the temperature rise at the hand hole is the fastest and the temperature reached the highest, it can reach 1 000 ° C at 80 min. The temperature of concrete at the seam reaches a stable temperature after 100 min, and the temperature of concrete at the nut reaches a stable temperature after 150 min, the stable temperature is about 1 000 ℃.
keywords: tunnel engineering; composite segment; inclined bolt joints; mechanical property; fire; temperature distribution

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斜螺栓等级对盾构隧道接头受力和变形的影响

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摘　要：盾构隧道管片接头的性能对衬砌环的受力和变形有很大影响，尤其在软土地区，接头变形过大会造成渗水和漏泥等危害。本文以盾构隧道复合管片斜螺栓接头为研究对象，基于实际隧道工程，利用 ABAQUS 建立了复合管片及斜螺栓的三维实体模型，对管片环向斜螺栓接头在荷载作用下的受力及变形规律进行研究，分析不同等级普通螺栓和高强螺栓对接头错台量和张开量以及斜螺栓应力应变的影响。分析结果表明：斜螺栓接头承受正弯矩的能力优于负弯矩；采用高强螺栓能够有效的减小接头张开量，增大接头刚度，从而减小渗漏现象；弯矩较大时，螺栓等级越高，高强螺栓对错台量的控制越好；同样荷载条件下，高强螺栓应力大于普通螺栓，但应变较小，等级越高应变越小。

关键词：盾构隧道；斜螺栓接头；螺栓等级；力学性能；变形

Influence of Inclined Bolt Grade on Bearing Capacity and Deformation of Shield Tunnel Joint

Li Yao , Zhang Wenjun , Zhang Gaole
（Tianjin University）

Abstract:

The performance of the segment joint of the shield tunnel lining has a great influence on the bearing capacity and deformation of the lining ring. Especially in the soft soil area, excessive deformation of the joint will cause seepage and leakage. In this paper, based on the actual tunneling engineering, the three-dimensional solid model of the ring composite segment and the inclined bolt joint was established by using ABAQUS. The effect and rule of the segment circumferential direction inclined bolt joint under the load were studied. Then the influence of different grades of common bolts and high strength bolts on the dislocation and the opening of the joint and the stress and strain of the inclined bolt is analyzed. The results show that the ability of the inclined bolt joint to bear the positive moment is better than the negative moment; The high-strength bolt can effectively reduce the joint opening and increase the joint stiffness, so as to reduce the leakage phenomenon; When the bending moment is large, the higher the high-strength bolt grade is, the better control of the dislocation; Under the same load condition, the stress of the high-strength bolt is greater than that of the common bolt, but the strain is smaller, the higher the grade, the smaller the strain.

keywords: shield tunnel; inclined bolt joint; bolt grade; mechanical property; deformation

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盾构隧道锚式接头地震响应分析

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摘　要：为研究盾构隧道锚式接头在水平地震作用下的受力变形特征，以某工程为背景，分别建立了地层-结构-弹簧整体模型与锚式接头局部精细化模型。首先采用动力时程法，结合黏弹性人工边界对锚式接头在不同单向水平地震波、双向水平地震波作用下的张开与错台变化进行了重点分析。以此为依据，充分考虑锚式接头的结构形式特点，基于反应位移法原理进一步研究了锚式接头在地震荷载作用下的应力、应变分布情况。研究结果表明：水平地震波入射方向不同时，锚式接头张开量与错台量包络值的分布形态存在明显区别；水平地震波沿隧道轴向输入时造成的接头张开量和错台量更大；水平双向地震波作用下的锚式接头变形特征不能仅通过单向地震波作用结果的简单叠加进行考虑。地震引起的张开与错台能够削弱锚式接头的整体性和承载能力；锚式接头主要构件的最大塑性应变分布范围在地震动力荷载作用下有所扩大。本文提出的研究方法和成果可作为进一步研究锚式接头地震响应特性的参考。

关键词：盾构隧道；锚式接头；地震响应；接头错台；接头张开

Seismic Response Analysis of Anchor Joints for Shield Tunnel

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Abstract:

In order to study the stress and deformation characteristics of anchor joints for shield tunnels under horizontal earthquake, the integral model of stratum-structure-spring and the local refined model of anchor joints are established respectively with the background of a project. Firstly, the dynamic time history method and viscoelastic artificial boundary are used to analyze the opening and staggering changes of anchor joints under different unidirectional and bidirectional horizontal seismic waves. Based on the above results, the stress and strain distribution of anchored joints under seismic loads are further studied by taking full account of the structural characteristics of anchored joints and on the basis of the principle of response displacement method. The results show that when the incident direction of horizontal seismic wave is different, the distribution of the envelope value of anchor joint opening and staggered station number is obviously different. The joint opening and staggered station amount caused by horizontal seismic wave input along the tunnel axis are larger. The deformation characteristics of anchor joints under the action of horizontal two-way seismic wave can not be considered only by simple superposition of the results from unidirectional seismic wave action. Earthquake-induced opening and staggering can weaken the integrity and bearing capacity of anchor joints, and the maximum plastic strain distribution range of the main components of anchored joints is enlarged under seismic dynamic loads. The research methods and results

presented in this paper can be used as a reference for further study of seismic response characteristics of anchor joints.

keywords: shield tunnel; anchor joint; seismic response; joint dislocation; joint opening

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天津滨海 Z2 号线盾构隧道接头螺栓比选及抗弯刚度研究

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（天津大学）

摘　要：基于 ABAQUS 有限元软件，充分考虑复杂接缝间的不连续性及接头预紧力，建立了螺栓接头-双管片结构的三维精细化数值模型。针对不同形式螺栓接头，结合工程实例，以天津滨海 Z2 号线盾构隧道管片纵缝为研究对象，分析比较了直螺栓、斜螺栓和弯螺栓三种接头在不同弯矩和轴力条件下对管片接缝力学性能的影响。最后，根据分析结果给出了三种螺栓接头的适用性。研究结果表明：不同形式的螺栓最大应力、应变均出现在接缝附近的螺杆处；接头弯矩保持不变时，接头抗弯刚度随轴力的增大而增大；接头所受轴力保持不变时，接头抗弯刚度随弯矩的提升而减小。

关键词：盾构隧道；螺栓接头；力学性能；接缝面；抗弯刚度

Research on Bolt Joint Selection and Bending Stiffness of Shield Tunnel in Tianjin Coastal Soft Soil Area

Zhang Qi , Zhang Wenjun , Zhang Gaole
（Tianjin University）

Abstract:

Based on ABAQUS finite element software, a three-dimensional refined numerical model of bolted joint-double segment structure was established, taking into account the discontinuity of complex joints and the pre-tightening force of joints. Aiming at different types of bolted joints, combined with engineering practice, the longitudinal joints of shield tunnel segments of Tianjin Binhai Z2 line were studied. The effects of straight bolts, oblique bolts and bending bolts on the mechanical properties of segment joints under different bending moments and axial forces were analyzed and compared. Finally, according to the analysis results, the proposed the applicability of three kinds of bolted joints. The results show that: The maximum stress and strain of bolts in different forms all appear at the screw near the joint. When the joint bending moment remains unchanged, the joint bending stiffness increase with the increase of axial force. When the axial force of the joint remains unchanged, the bending stiffness of the joint decreases with the increase of bending moment.

keywords: shield tunnel; the bolted joint; mechanical properties; joint surface; bending stiffness

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地铁盾构隧道衬砌管片密封槽尺寸优化分析

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摘　要：本研究以天津市地铁 Z2 号线衬砌管片密封槽截面尺寸为基础，根据经验公式提出了一种密封垫断面形式，从弹性橡胶密封垫防水机理及防水失效影响因素出发，提出不同密封槽尺寸对应的密封垫修改方法，并根据此方法建立不同工况下的二维数值模型。通过数值计算，得到张开量为 0 时密封垫表面平均接触应力、闭合压力，分析密封槽尺寸对密封垫防水性能影响规律，并提出密封槽尺寸设计及优化建议。

关键词：数值模拟；橡胶密封垫；衬砌管片密封槽；接缝防水

Optimization Analysis of Sealing Groove of Lining Segment of Subway Shield Tunnel

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Abstract:

Based on the cross-section dimensions of the sealing groove of the lining segment of Tianjin Metro Z2 line, this paper designs a gasket section form according to the empirical formula. Based on the waterproof mechanism of the elastic rubber gasket and the influencing factors of the waterproof failure, the modification method of the gasket when the sealing groove size is different is proposed, and the two-dimensional model under different working conditions is established according to this method. Through numerical simulation, the average contact stress and closing pressure of the gasket surface when the opening amount is 0 are obtained. Then analyze the influence of the size of the sealing groove on the waterproof performance of the gasket, and propose the seal groove size design and optimization suggestions.

keywords: numerical simulation; rubber gasket; lining segment sealing groove; joint waterproof

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软土地区地铁盾构隧道弯曲刚度有效率取值研究

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摘　要：修正惯用法以其概念明确、理论成熟和计算便捷的特点在盾构隧道设计中被广泛使用。弯曲刚度有效率η是修正惯用法中的重要参数，其取值对于隧道结构的计算结果具有至关重要的影响。本文基于荷载结构法，利用有限元计算软件 ABAQUS 建立了均质圆环模型和梁-弹簧模型，研究了盾构隧道在软土地区通错缝拼装、基床系数和接头相对刚度对弯曲刚度有效率η的影响。通过对数值模拟计算结果进行整理，得到了弯曲刚度有效率η的拟合公式和通错缝拼装弯曲刚度有效率η的转化公式，为确定修正惯用法中的曲刚度有效率η提供了计算方法和参考依据。

关键词：软土地区；修正惯用法；弯曲刚度有效率；影响因素；盾构隧道

Study on the Value of Effective Bending Rigidity Ratio of Subway Shield Tunnel in Soft Soil Area

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Abstract:

The modified routine method is widely used in shield tunnel design because of its clear concept, mature theory and convenient calculation. The effective ratio of bending rigidity η is an important parameter in the modified routine method, and its value has a crucial influence on the calculation result of the tunnel structure. Based on the load structure method, this paper uses finite element calculation software to establish a homogeneous ring model and a beam-spring model are applied to the calculation of the effective ratio of bending rigidity η. The effect of the coefficient of subgrade reaction, joint relative stiffness and erection method on the effective ratio of bending rigidity η is studied. By arranging the numerical simulation results, the fitting formula of the effective ratio of bending rigidity η and the conversion formula of the bending stiffness effective efficiency η of the fault-stitching assembly are obtained, which provides a calculation method for determining the effective stiffness η of the modified idiom and reference basis.

keywords: shield tunnel; soft soil area; modified routine method; effective ratio of bending rigidity; influencing factor

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盾构隧道管片接缝复合型密封垫防水性能研究

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（TJU 天津大学）

摘　要：针对盾构管片接缝密封垫单一型与复合型密封垫断面，利用非线性有限元软件 ABAQUS 对盾构隧道密封垫防水进行数值模拟研究，分别对单一型密封垫和复合型密封垫在不同张开量条件下的防水性能进行量化分析，并通过复合型密封垫遇水膨胀橡胶块的膨胀作用进行分析。研究表明：1）随着接缝张开量不断增大，复合密封垫的防水性能逐渐由密封垫压缩产生的接触应力转化为遇水膨胀橡胶的膨胀作用产生的膨胀应力，对比单一型密封垫，其具有二次防水效果；2）增大复合密封垫遇水膨胀橡胶块厚度与宽度有利于提高密封垫二次防水性能，其防水性能在允许张开量范围内和允许张开量范围外分别增长 39%和 117%左右，同时考虑应力松弛因素，需要对遇水膨胀橡胶块几何截面进行合理取值。

关键词：盾构隧道；复合型密封垫；遇水膨胀橡胶；数值模拟

Study on Waterproofing Performance of Composite Sealing Gasket for Segment Joints of Shield Tunnel

Ding Chao , Zhang Wenjun , Gao Wenyuan , Li Hongliang , Lu Quanwei
（TJU Tianjin University）

Abstract:

In the paper, specific to shield segment joint sealing gasket single type and compound type sealing gasket section, the non-linear finite element software ABAQUS is used to simulate the waterproofing of shield tunnel sealing gasket，quantitative analysis of waterproof performance of single and composite gaskets under different opening conditions was carried out respectively and expansion effect of compound gasket encountering water expanding rubber block is analyzed. Conclusions drawn are as following: 1) With the joint opening increasing, the waterproof performance of composite gaskets is gradually transformed from contact stress caused by compression of gaskets to expansion stress caused by expansion of rubber encountering water, compared with single type gasket, it has secondary waterproofing effect; 2) Increasing the thickness and width of the expanded rubber block when the composite gasket meets water is beneficial to improving the secondary waterproofing performance of the gasket. Its waterproofing performance increased by 39% and 117% respectively in the allowable opening range and outside the allowable opening range, considering the stress-relaxation factors, it is necessary to select the geometric section of water-swelling rubber block reasonably.

keywords: shield tunnel; composite sealing gasket; water swelling rubber; numerical simulation

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软土地区地铁盾构隧道弯矩传递系数取值研究

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摘　要：弯矩传递系数是修正惯用法中的重要参数，其取值对于隧道结构的计算结果具有至关重要的影响。本文基于荷载结构法，利用有限元计算软件 ABAQUS 建立了均质圆环模型和梁-弹簧模型，研究了错缝拼装盾构隧道在软土地区中隧道埋深、基床系数和接头相对刚度对弯矩传递系数的影响。通过对数值模拟计算结果进行分析，得到了各个因素对弯矩传递系数的影响规律和作用机理，明确了弯矩传递系数取值中环向相对刚度和纵向相对刚度具有相关性，基床系数与接头相对刚度相关性较弱，进而提出了弯矩传递系数的拟合计算公式。

关键词：盾构隧道；软土地区；修正惯用法；弯矩传递系数；影响因素

Study on the Carry-Over Factor of the Moment of Subway Shield Tunnel in Soft Soil Area

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Abstract:

The carry-over factor is an important parameter in the modified routine method, and its value has a crucial influence on the calculation result of the tunnel structure. Based on the load structure method, a homogeneous ring model and a beam-spring model are established by using the finite element software ABAQUS. The effects of tunnel depth, subgrade reaction and joint relative of shield tunnels in soft soil are studied. Through the analysis of the numerical simulation results, the influence rule and mechanism of each factor on the carry-over factor of the moment are obtained. It is clear that the relative stiffness and longitudinal relative stiffness of the carry-over factor of the moment have correlation, the subgrade reaction and the joint relative stiffness correlation is weak. Then the fitting formula of the moment transfer coefficient is proposed.

keywords: shield tunnel; soft soil area; modified routine method; the carry-over factor of the moment; influencing factor

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盾构隧道密封垫外轮廓尺寸优化分析

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（天津大学）

摘　要：针对密封垫截面外轮廓尺寸取值对密封垫防水性能影响进行了数值模拟，采用ABAQUS 内嵌网格求解变换技术解决数值模拟计算收敛困难的问题，结合前人研究成果验证该技术的可行性，通过对比分析不同尺寸密封垫接触应力、闭合压力随压缩量或压缩度变化规律，为密封垫截面形式设计、优化提供新的思路。

关键词：数值模拟；橡胶密封垫；外轮廓尺寸；防水性能

Optimization Analysis of the Size of the Outer Corridor of Shield Tunnel Seals

Zhang Wenjun , Li Hongliang , Gao Wenyuan , Lu Quanwei , Wang Yi
（Tianjin University）

Abstract:

The numerical simulation of the waterproof performance of the gasket is carried out according to the size of the outer cross-section of the gasket. The ABAQUS embedded grid solution transformation technology is used to solve the problem of difficulty in numerical simulation calculation. The feasibility of the technology is verified by the previous research results. By comparing and analyzing the contact stress of different size seals and the change law of the closing pressure with the compression amount or compression degree, the design method of optimizing the gasket cross section is proposed.

keywords: numerical simulation; rubber gasket; outer gallery size; waterproof performance

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盾构隧道复合管片环向直螺栓接头抗弯性能的影响因素研究

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摘　要：基于现有地铁盾构隧道衬砌结构建立了复合管片及环向直螺栓接头的三维精细化数值模型，采用有限元法对地铁盾构隧道复合管片直螺栓接头的力学性能进行了数值模拟计算。针对复合管片的直螺栓接头，分别研究了螺栓预紧力、复合管片钢壳厚度、荷载组合等对张开量和抗弯性能的影响，探讨了管片及接头的应力分布，并进一步总结了各因素对直螺栓接头抗弯性能的影响，为确定复合管片环向直螺栓接头的抗弯刚度提供了新的参考。数值计算结果表明：复合管片直螺栓接头的抗弯刚度随着外荷载的变化而变化，并表现出明显的非线性；相同的荷载条件下，复合管片钢壳越厚，螺栓应力越低，接头张开量越小；采用不同等级螺栓时，接头弯矩值较低时管片接头张开量差别较小，弯矩值较高时螺栓接头抗弯刚度与螺栓等级呈现出较大的相关性，即螺栓等级越高，接头的张开量越小。

关键词：复合管片

Study on the Influence Factors of Flexural Performance of Shield Tunnel Composite Segment Circumferential Straight-Bolt Joint

Wang Yi , Zhang Wenjun
（Tianjin University）

Abstract:

Abstract: Based on the actual full-scale metro shield tunnel lining structure, a three-dimensional refinement numerical model of composite segment and straight bolt joint shield tunnel lining structure was established. With the usage of the finite element software ABAQUS, the mechanical properties of composite segment and its straight-bolt joint were simulated and explored. By adopting models respectively in the bolt preload, composite segment with different steel shell thickness, different combination of loads, analyzing the opening angle and bending stiffness of the composite segment joint. What’ s more, the stress distribution of the whole segment and joint was also studied. The relationship between bending moment and bending stiffness of composite segment’ s circumferential straight bolt joint was concluded. The numerical results show that the bending stiffness of the composite segment circumferential straight bolted joint varies with the change of the external load, and the nonlinear properties is obvious; Under the same loading condition, the bolt stress is low while thicker steel shell was adopted; The higher the strength level of the joint bolt, the smaller opening angle of joint.

keywords: composite segment

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封顶块位置对地铁隧道通用环力学性能影响研究

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（天津大学）

摘　要：盾构隧道施工和运营期，封顶块位置对盾构隧道的整体结构受力及变形有显著影响，因此对其位置的合理选择进行研究非常必要。采用 ABAQUS 有限元软件建立壳-弹簧模型，对封顶块不同软土不同埋深及在不同位置下盾构隧道通用管片结构力学行为进行研究分析。结果显示：同种软土中，通用管片整体结构弯矩随着埋深增加，弯矩增大；同种埋深下，随着软土由坚硬到软弱，弯矩逐渐增大。通用环封顶块在拱顶和拱底时，结构弯矩最大，对结构安全最不利；其次为两侧拱肩位置；封顶块在两侧拱腰以上，拱肩以下时结构弯矩值最小，对结构安全最有利，其次为两侧拱腰偏下位置。研究结果可以对施工阶段封顶块点位选择提供指导，同时还能为设计阶段的管片优化设计提供理论参考。

关键词：通用管片；错缝拼装；壳-弹簧模型；封顶块位置；力学性能

Study on Influence of Location of Capping Block on Mechanical Performance of General Ring of Metro Tunnel

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Abstract:

During the construction and operation of the shield tunnel, the position of the capping block has a significant impact on the overall structural stress and deformation of the shield tunnel. Therefore, it is necessary to study the reasonable selection of its position. The shell-spring model was established by using ABAQUS finite element software. The mechanical behaviors of different sections of different soft soils of the capping block and the general segment of the shield tunnel were studied and analyzed. The results show that in the same kind of soft soil, the bending moment of the overall structure of the common segment increases with the depth of the burial, and the bending moment increases. Under the same burial depth, the bending moment increases with the soft soil from hard to weak. When the universal ring capping block is in the vault and the bottom of the arch, the structural bending moment is the largest, which is the most unfavorable for the structural safety; the second is the position of the arched shoulders on both sides; the capping block is above the arched waist on both sides, and the structural bending moment value is the smallest when the arched shoulder is below. It is most beneficial to structural safety, followed by the lower side of the arch waist. The research results can provide guidance for the selection of the top block in the construction stage, and also provide a theoretical reference for the design optimization of the segment at the design stage.

keywords: general tube piece; staggered assembly; shell-spring model; position of capping block;

mechanical properties

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盾构隧道弯螺栓接头力学特性受预紧力影响的数值研究

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摘　要：利用 ABAQUS 有限元分析软件，通过数值模拟对盾构隧道弯螺栓接头在预紧力作用下的力学特性进行研究，为螺栓接头的设计和施工提供理论依据。采用符合混凝土受力特性的 DP 本构模型和符合钢材受力特性的塑性本构模型，研究预紧力对于弯螺栓接头力学特性的影响;施加不同的荷载,分析不同工况下预紧力作用效果的差异,揭示预紧力作用的机理。结果表明：预紧力改善了弯螺栓接头的力学特性，增强了螺栓约束管片的能力，减小了结构的整体变形。

关键词：盾构隧道；弯螺栓；预紧力；DP 模型

Numerical Study on Mechanical Behavior of Bent Bolted Connection in Shield Tunnel Under Effect of Preload

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Abstract:

With the help of ABAQUS FEM software, a numerical study is carried out on the mechanical properties of bent bolted connection in shield tunnel under the effect of preload, which offers theoretical evidence for the design and construction of bolted connection, considering the DP constitutive model fit for concrete as well as the plastic constitutive model fit for steel. The differences between the effect of preload under different load cases are analyzed, and the principle of the preload effect is revealed. The results show that the preload can improve the structural behavior of bent bolted connection, the restraint on the segment increases, and the entire deformation decreases.

keywords: shield tunnel; bent bolt; preload; DP constitutive model

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高水头跨海盾构隧道结构静力特性研究

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摘　要：湛江湾隧道作为国内代表性的跨海盾构隧道工程，具有高水压、长距离和海水环境下确保管片耐久性等技术难点。本文介绍了湛江湾跨海隧道衬砌结构优化设计方案，通过对监测资料的分析，研究了高水压作用下隧道管片及环向钢筋的受力特性，基于三维精细有限元模型揭示了整环管片在外水压力、土层侧压力系数影响下的受力及变形规律。研究表明：（1）管片环内、外侧钢筋应力变化在监测全程经历了四个阶段，自管片拼装结束后的初始阶段钢筋应力波动较为明显。（2）实测与数值结果均表明高外水压作用下管片环受力以“整体受压”为主。（3）管片环结构变形量与外水压力呈线性关系，且受到土层侧压力系数的影响。随着外水压增大，管片环变形模式由“横椭圆”发展成“整体向内压缩”。（4）坚硬土层中外水压力的提升将减缓管片环整体“横椭圆”变形趋势；软弱土层中外水压力的提升则导致隧道结构整体受压状态加剧。

关键词：高水头

Static Behavior of Sea-Crossing Shield Tunnel Lining Under High Hydraulic Pressure

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Abstract:

As a representative sea-crossing shield tunnel in China, Zhanjiang Bay Tunnel has to overcome several challenges including high hydraulic pressure, long-distance and the durability of segmental lining in submarine environment. In this paper, the optimal design of the lining structure is introduced. Field stress monitoring on the circumferential rebar and contact surface between segments are implemented during construction period, to analyze the mechanical characteristics of lining structure under high water pressure. A detailed three-dimensional modeling approach is proposed to investigate the evolution of transverse deformation and static behavior of entire segmental ring with different external water pressure and lateral coefficient of earth pressure. The results show that: (1) The stress development of reinforcement in segmental ring can be divided into four stages. The most significant fluctuation of rebar stress occurs in the initial stage since assembling completion of segments. (2) Both the measured and simulated values indicate that the state of segmental ring is overall compression under high external water pressure. (3) A linear relationship between transverse deformation and external water pressure is displayed, which is greatly influenced by the lateral coefficient of earth pressure. With the increase of water pressure, the deformation pattern is transformed from “horizontal oval” to “overall inward compression”. (4) In stiff stratum, the increase of water pressure mitigating the tendency to “horizontal oval”;

in soft stratum instead, the increase of water pressure aggravates overall compression of segmental ring.

keywords: high hydraulic pressure

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纵向整体式反应位移法在水下盾构隧道纵向动力特性分析中的应用

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摘　要：水下地基场地动力响应的分析是研究水下隧道抗震的前提，但由于其动力问题是一个多场耦合的复杂问题，现有的研究成果多是分析水下隧道横断面且将水下饱和土体视为单相介质，针对水下隧道纵向动力性能的研究还比较少见。分析隧道纵向动力特性常用的传统反应位移法采用离散的弹簧来模拟结构周围的土层，无法反映土层自身存在的相互作用，并且水下地基场地的现场试验存在着试验条件困难成本巨大的问题，以致海洋地勘资料匮乏，通过试验或者经验取值的方法难以确定地基弹簧系数，因此，传统反应位移法在适用于水下隧道纵向研究方面存在诸多困难。为了避免引入地基弹簧系数引起不确定的误差和减小计算工作量，尝试将陆上隧道纵向整体式反应位移法应用到水下隧道抗震分析中。首先，利用水下成层饱和地基场地等效线性化方法和纵向整体式反应位移法，得到隧道纵向非线性位移响应；然后利用 ABAQUS 有限元软件建立自由场地模型，得到等效地震荷载；最后建立土-结构相互作用模型，在天津波或唐山波斜入射时，分析了水深、土层刚度、地震波强度和结构刚度对水下隧道变形和弯矩的影响规律。结果表明：自由场地和相互作用有限元模型反算的位移，在边界效应的影响下，除了端点及离端点一段距离外，其余部分的位移吻合较好，验证了本文建立水下隧道纵向整体式反应位移法的正确性；水深和饱和土的刚度对相互作用模型和隧道结构的弯矩均为表现出单调变化的趋势，而且这两个因素的影响还与入射波的类型有关；相互作用模型的位移和弯矩均随着地震波入射强度和隧道刚度的增大而增大。

关键词：水下地基场地；水下隧道；等效线性化法；纵向整体式反应位移法；纵向动力特性。

Application of Integral Response Deformation Method in Seismic Analysis of Underwater Tunnel Structure

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Abstract:

The analysis of dynamic response of underwater foundation site is the precondition to study the seismic performance of underwater tunnel. However, the dynamic problem of underwater tunnel is a complex problem of multi-field coupling. The existing research results mostly focus on the cross-section of underwater tunnel and regard the underwater saturated soil as a single-phase medium. The study of longitudinal dynamic performance of underwater tunnel is relatively rare. The traditional response displacement method uses discrete springs to simulate the soil and cannot reflect the interaction of the soil itself. Moreover, the field test of the underwater foundation site is a difficult test and huge cost, which leads to the lack of marine geological prospecting data. It is difficult to determine the foundation springs by means of experiments or empirical values. Therefore, there are many difficulties in applying the traditional response displacement method to the

longitudinal study of underwater tunnels. In order to avoid the uncertainty error caused by the introduction of foundation spring coefficient and reduce the calculation workload, the longitudinal integral response displacement method of land tunnel is applied to the seismic analysis of underwater tunnel. Firstly, the longitudinal non-linear displacement response of tunnel is obtained by using the equivalent linearization method and the longitudinal integral response displacement method of the saturated underwater layered foundation. Then, the free site model is established by ABAQUS, and the equivalent seismic load is obtained. Finally, the soil-structure interaction model is established. When Tianjin wave or Tangshan wave obliquely incident, the water depth, soil stiffness and ground are analyzed. The influence of seismic wave strength and structural stiffness on the deformation and bending moment of underwater tunnel. The results show that under the influence of boundary effect, the displacements of the free site and the interaction finite element model are in good agreement except for a distance from the end point and the end point, which verifies the validity of the longitudinal integral response displacement method for underwater tunnels established in this paper. The stiffness of water depth and saturated soil shows both the interaction model and the bending moment of tunnel structure. The trend of monotonous change is related to the type of incident wave, and the displacement and bending moment of interaction model increase with the increase of incident intensity of seismic wave and stiffness of tunnel.

keywords: underwater site; underwater tunnel; equivalent linear method; integral response deformation method; longitudinal dynamic response

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基于不完全拱效应的隧道预处理机制与计算方法

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摘　要：隧道开挖中，掌子面-超前核心土的变形同样会使其周围产生拱效应，但该种拱效应不同于后方已开挖区域周围的拱效应，称之为不完全拱效应。不完全拱效应的发挥与预收敛变形和挤出变形有很大的关系，基于不完全拱效应提出了超前核心土周围围岩压力的计算公式，此公式与太沙基公式的不同在于考虑了预收敛变形对围岩压力的影响，并在黏性土的推导中考虑了非垂直滑移面效应，假定破裂面与垂直方向存在夹角 。算例分析显示，随着预收敛变形的增加拱顶土压力的变化可分为近线性快速下降、缓慢下降及稳定阶段，计算土压力随内摩擦角、埋深比及黏聚力的增大而减小，且在黏性土中随破裂面倾角的增大而增大。在此基础上，推导了计算基于新意法的超前核心土加固参数的理论计算公式，结合算例验证了理论公式的适用性，该公式计算简单，便于理解，可用于新意法的初步设计阶段。

关键词：隧道工程；不完全拱效应；超前核心土；新意法；理论分析

The Pretreatment Mechanism of Tunnels and Its Calculation Method Based on the Incomplete Arch Effect

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Abstract:

In the tunnel excavation，the deformation of the soil core in front of the surface of tunnel excavationmay stimulate the arch effect in the surrounding soil ahead of the tunnel face. This kind of arch effect is different from the one produced behind the tunnel face and is called the incomplete arch effect. The performance of the incomplete arch effect is closely related to the pre-convergence deformation and extrusion. The formulas for calculating the soil pressure around the front soil core considering the incomplete arch effect are proposed and are different from Terzaghi formula，because in the proposed method，an angle between the fracture face and vertical direction is assumed and the effect of the pre-convergence deformation on the surrounding soil pressure and the non-vertical sliding surface effect of cohesive soils are taken into consideration. The results show that as the increase of the pre-convergence deformation，the earth pressure exhibits three stages：the rapid near-linear decrease，the slow decrease and the stable ones. The earth pressure decreases with the increase of internal friction angle，thickness-span ratio and cohesion. However，the earth pressure increases with the increase of the angle of rupture surface. The formula for calculating the reinforcement parameters of the front soil core based on ADECO-RS is deduced and its applicability is verified in a case study.

keywords: tunnelling engineering; incomplete arch effect; the advanced core soil; analysis of

controlled deformation in rock and soils(ADECO-RS); theoretical analysis

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软弱破碎隧道围岩动态压力拱效应模型试验

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摘　要：为探讨围岩拱效应是否随隧道破坏而动态发展，以软弱破碎围岩为试验对象，在自行设计制作的试验平台上，以重晶石粉、河砂和洗洁精混合料模拟围岩材料，采用全断面隧道开挖法，测量并记录了隧道从开挖完成到塌方结束期间围岩应力的变化情况。试验结果表明：随着隧道开挖，拱腰处的水平应力与竖向应力成反比；距隧道最近围岩由于发生脆性破坏，径向应力和水平应力均减小；距隧道较近围岩由于发生塑性破坏，径向应力增大、水平应力减小；距隧道较远围岩径向应力减小、水平应力增大；隧道开挖后如不及时支护，塑性区将向围岩内部发展；根据隧道拱顶上方水平应力和拱腰处竖向应力峰值位置的变化，可判断拱效应随着隧道失稳而动态发展。

关键词：隧道工程；动态压力拱；模型试验；软弱破碎围岩

Model Test on Effect of Dynamic Pressure Tunnel in Soft Broken Surrounding Rock

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Abstract:

In order to explore whether arch effect to surrounding rock develops dynamically with the progressive failure of tunnel, taking soft broken surrounding rock as test object, using blanc fixe, river sand and cleanser essence to simulate the material of surrounding rock, full-face cut-and-cover tunnel method was used on test platform by self-design to measure and record the change of surrounding rock stress from tunnel excavation to the end of the collapse. The results show that with the tunnel excavation, the horizontal stress is in reverse proportion to the vertical stress on haunch. Due to the brittle failure, both the radial stress and horizontal stress of surrounding rock at the position nearest to the tunnel are decreased. Due to the plastic failure, the radial stress of surrounding rock near the tunnel is increased and the horizontal stress is decreased. At the relatively distant area, the radial stress is decreased and the horizontal stress is increased. The plastic zone would develop to the inner of surrounding rock if the tunnel is not supported in time after tunnel excavation. According to the position change of horizontal stress.

keywords: tunnel engineering; dynamic pressure arch; model test; soft broken surrounding rock

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软弱围岩隧道掌子面及超前核心土挤出位移特征研究

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摘　要：为研究软弱围岩隧道掌子面及超前核心土的挤出位移特征，用 Solexperts AG 公司生产的 GMD 滑动测微计对湄渝高速岐山隧道 F215 构造破碎带区域进行了挤出位移实测，通过有限差分程序进行系列数值试验，着重研究了隧道穿越软弱围岩期间挤出位移的变化特征，并分析了破碎带长度和硬软岩刚度比的影响。结果表明，(1) 挤出位移的大小可反映前方围岩质量，挤出位移在超前核心土内的分布可反映前方围岩的节理裂隙发育情况；(2) 隧道开挖在掌子面前方造成的扰动范围大致为 1.5 倍的隧道开挖跨度；(3) 隧道接近前方变化地质区域时，挤出位移的增大或减小具有超前性；(4) 软岩段长度在一定范围内会影响掌子面进入软岩区后挤出位移的大小和变化趋势；(5) 硬岩与软岩间的刚度比越大，挤出位移变化速率越大，且隧道由软岩区向硬岩区掘进时挤出位移的变化时机越早，而由硬岩区向软岩区掘进时的变化时机不受刚度比影响；(6) 可将对挤出位移的监测分析作为超前地质预报的补充手段判断掌子面前方围岩情况。

关键词：隧道；软弱围岩；岩土控制变形分析法；挤出位移；滑动测微计；现场实测

Research on Extrusion Displacement of Face and Advanced Core in Tunnel with Weak Surrounding Rock

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Abstract:

In order to investigate the characteristics of extrusion displacement in the tunnel face and advanced core in tunnel with weak surrounding rock, the extrusion displacement of the soft fault area F215 in the left line of Qishan tunnel in Fujian province is measured with the GMD sliding micrometers produced by Solexperts AG Company. A series of numerical simulations are carried out with finite difference program to study the characteristics of extrusion displacement during the time tunnel passes through the weak rock zone; and the influence of the length of weak rock zone and the stiffness ratio of hard rock to weak rock are analyzed. The results show that: (1) The magnitude of extrusion displacement can reflect the quality of the surrounding rock of the advanced core, while the distribution of extrusion displacement in advanced core can reflect the condition of joint crack ahead of the tunnel face. (2) The range of disturbance in front of the tunnel face caused by excavation are around 1.5 times as long as the excavation span of the tunnel. (3) The extrusion displacement is able to increase or decrease in advance before the tunnel face approaches the area where the surrounding rock is changed. (4) When the tunnel face enters into weak rock zone from hard rock zone, the length of weak rock zone can affect the magnitude and the change trend of extrusion displacement in some extent. (5) The bigger the stiffness ratio of hard rock to weak rock,

the faster the rate of extrusion displacement change increases; and the earlier the extrusion change occurs when the tunnel face approaches from hard rock zone to weak rock zone, while there is no difference when the tunnel face approaches from weak rock zone to hard rock zone. (6) The monitoring and analysis of extrusion displacement can be a supplementary method of advance geological forecast to distinguish the condition of surrounding rock ahead of the tunnel face.
keywords: tunnel; weak surrounding rock; analysis of controlled deformation in rocks and soils (ADECO-RS); extrusion displacement; sliding micrometers; field monitoring

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EPB 盾构开挖面稳定性的 PFC-FLAC 耦合分析

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摘　要：基于离散元-有限差分（PFC-FLAC）多尺度耦合分析方法模拟盾构掘进的动态过程，依据开挖面土体颗粒进入土舱的速度状态提出了一种土压平衡盾构（EPB）开挖面稳定性评价方法．通过建立刀盘切削和出渣过程的盾构隧道掘进耦合模型，分析了不同掘进模式、不同地层条件下开挖面的稳定性，并结合实际工程进行了验证．结果表明：离散元与有限元耦合方案可以有效模拟盾构渣土进出舱过程中的细观力学行为；地层因素对掘进模式选择影响较大，砂层或上软下硬地层中保持满舱或 3/4 舱模式掘进时能更好控制开挖面稳定；在全断面粉砂地层和上部中砂下部风化岩地层中，开挖面失稳的临界支护压力比分别为 0.41 与 0.29．

关键词：耦合分析；盾构隧道；掘进参数；掘进模式；开挖面稳定

PFC-FLAC Coupling Analysis of Face Stability for EPB Shield Tunneling

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Abstract:

A multi-scale coupling analysis scheme based on three-dimensional Particle Flow Code and Fast Lagrangian Analysis of Continua (PFC-FLAC) was used to simulate the Earth Pressure Balance (EPB) shield tunneling process and a method for evaluating the face stability was put forward according to the velocity state of the soil particles entering the soil tank. Considering the shield cutting and transporting slag process, a coupled model was established to analyze the excavation face stability under different tunneling modes and ground conditions. Results show the shield excavation face stability in different driving modes is greatly influenced by stratum factors. In the sand layer or the upper-soft-lower-hard strata, the face stable state can be reached more easily when full or 3/4 chamber of soil is kept. The critical support pressure ratio at the excavation face should be larger than 0.29 and 0.41 to keep stability in the sand layer and the upper- medium sand and lower- weathered rock strata, respectively. When discharging the soil constantly, the driving speed has a great influence on the stability of the excavation face.

keywords: coupled analysis; shield tunnelling; tunnelling parameters; tunnelling modes; face stability

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寒区隧道洞口段仰拱填充混凝土早期开裂机理及控制研究

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摘　要：针对寒区隧道洞口段仰拱填充混凝土早龄期易发生表面开裂问题，本文结合数值模拟与工程实测方法对温度与湿度变化耦合作用下混凝土早期变形与开裂特征进行了研究。基于 Abaqus 平台二次开发编写子程序反应寒区混凝土早期水化热、早期力学性能、温度与湿度变化收缩的动态变化过程，并采用扩展有限元方法模拟了混凝土多因素多场耦合作用下的裂缝萌生与扩展的过程。结合某寒区隧道工程仰拱填充层混凝土实际变形与开裂情况对本方法计算结果进行了对比验证。结果表明：本文提出的温度与湿度变化耦合作用数值模型可以较好的反映寒区混凝土早龄期芯部温度高、表面温度梯度变化大的温度变化趋势和表面裂缝分布范围较大、走向不规律的收缩开裂特征。负温环境和混凝土硬化过程中早龄期收缩是其表面开裂的主要原因，靠近既有混凝土和混凝土厚度较大处因其变形受到约束将产生更严重的开裂情况。基于此，本文结合寒区工程施工条件，提出降低砼出罐温度、提高混凝土养护温度的综合施工工艺，可避免仰拱填充混凝土早龄期表面开裂，具有一定的工程应用价值。

关键词：寒区隧道；仰拱填充混凝土；早龄期；开裂机理；开裂控制

Early Cracking Mechanism and Control of the Filled Concrete of Tunnel Invert at Entrance Section in Cold Region

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Abstract:

There are often surface cracking observed at the filled concrete of invert at tunnel entrance section in cold region. In this paper, the characteristics of deformation and cracking at early age under the coupled effects of temperature and moisture variation are studied by numerical simulation and engineering measurement. Based on the user development environment of ABAQUS, three subroutines were developed to reflect the dynamic changes of early hydration heat and early mechanical properties, and to ferret out the temperature and moisture vriation induced shrinkage of concrete in cold region. The crack initiation and propagation process of concrete were investigated by coupled multi-factor and multi-field analysis with the extended finite element method. Finally, the computed numerical results were validated by comparing with the actual obxerved deformation and cracking of the filled concrete of a tunnel invert in cold region. The results show that the presented coupled multi-factor and multi-field numerical model can reflect the variation of temperature distribution gradient in the concrete bodyat early age in cold region, which would results in a cracking characteristics that is widely but irregularly distributed. Low temperature environment and early age shrinkage during concrete hardening process are the main causes of surface cracking. Surface close to existing concrete and larger dimension area, cracking

performance will be more serious because of its deformation limitation. It is suggested that comprehensive construction process by reducing the temperature of the concrete mixing station and increasing the concrete curing temperature can effectively avoid the surface cracking of the tunnel invert filled concrete at early age, which can be regarded as reference for similar projects.

keywords: cold region tunnel; invert filled concrete; early age; cracking mechanism; cracking control

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在役隧道衬砌局部脱空的开裂力学行为研究

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（中南大学）

摘　要：由于不完善的施工或地下水侵蚀，隧道衬砌周围的局部脱空将导致局部接触损失和地下衬砌相互作用的不连续性。本文评价了局部脱空对隧道衬砌力学性能和开裂性能的影响。根据现场调查结果，确定了局部脱空的几何形状和位置。通过数值分析，研究了局部脱空对混凝土衬砌应力状态的影响，并对隧道的稳定性进行了检验。采用扩展有限元法（XFEM）分析了脱空附近既有隧道衬砌的开裂方向和开裂模式。通过与现场观测结果的对比，验证了上述结果。本文提出了一种模拟隧道衬砌裂缝的有效方法，并给出了一种系统的方法，初步评价了一种后置局部脱空的既有隧道衬砌的裂缝性能。

关键词：隧道衬砌；局部脱空；应力状态；裂缝；扩展有限元法

The Effects of Local Cavities on the Cracking Performance of an Existing Tunnel Lining

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Abstract:

Local cavities around the tunnel lining due to imperfect construction or ground water erosion will lead to local contact loss and discontinuity in the ground-lining interaction. This paper evaluated the effect of local cavities on the mechanical and cracking performance of an existing tunnel lining. The geometry and position of the local cavity were defined according to the results of field investigation. Numerical analyses were performed to investigate how the local cavities affect the stress state of the concrete lining and to check the stability of the tunnel. Extended Finite Element Method (XFEM) was used to illustrate the development of cracking directions and patterns on the existing tunnel lining in the vicinity of the cavity. The above results was then verified by comparing with field observations. The presented study suggested an effective way for modelling tunnel lining cracking, and shown a systematic method to preliminary evaluate the cracking performance of an existing tunneling lining with local cavities behind.

keywords: tunnel lining; local cavities; stress state; crack; XFEM

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盾构泡沫改良圆砾土流塑特性及综合评价新方法

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摘　要：为了验证坍落度试验评价改良渣土流塑性状态的合理性及探究改良参数对改良渣土流塑性状态的影响规律。本文采用改进型的坍落度试验装置，针对不同改良参数下的圆砾土进行坍落度试验，分析并探究了试样初始含水率及泡沫注入比对试样改良流塑性状态的影响规律。主要结论有：泡沫改良圆砾土（缺少细粒）仅适应于含水率较低的情况，且合适改良状态所需泡沫注入比随着试样含水率的增加逐渐减小；基于传统的坍落度值或延展度值来评价渣土改良流塑性状态不够准确；合适改良状态试样坍落后会在顶部形成一定直径的平台，且平台大小与延展度值、坍落度值三者之间存在一定联系；根据试验结果分析，提出了一种综合指标 F=(D-d)/h，并通过理论分析验证了该方法评价泡沫改良圆砾土流塑性状态的合理性及准确性。

关键词：盾构隧道；渣土改良；泡沫；坍落度试验；评价方法

Flow-Plastic Characteristics of Foam Conditioned Gravel and a New Evaluation Method

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Abstract:

In order to explore the rationality of evaluating the flow-plastic characteristics of conditioned soil based on slump test and variation of the flow-plastic characteristics of conditioned soil with conditioning parameters. In this paper, the improved slump test device was used to test the slump of the gravel soil under different conditioning parameters. The influence of initial water content and foam injection ratio on the flow-plastic of the soil was analyzed. The main results included: Foam-conditioned gravel soil (lacking fine grains) was only suitable for low water content and the foam injection ratio required for the suitable-conditioned state decreases with the increase of water content. The traditional evaluation methods based on the slump value or the extension value were not accurate. A certain diameter platform would be formed at the top of suitable-conditioned soil, and there was a certain relationship among the top-platform diameter, the slump value and the extension value. According to the results, a comprehensive index F=(D-d)/h was proposed, and the rationality and accuracy of this method to evaluate the flow-plastic of foam-conditioned gravel soil were verified by theoretical analysis.

keywords: shield tunnel; soil conditioning; foam; slump test; evaluation method

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级配影响下盾构隧道泡沫改良粗颗粒渣土渗流特性研究

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摘　要：为了防止 EPB 盾构掘进过程中螺机喷涌，往往采用泡沫对盾构渣土进行合理改良。泡沫能否有效提高渣土抗渗性依赖于粗颗粒土的级配特性。通过改变试验土的三大级配特征参数（即土的有效粒径（d10）、曲率系数（Cc）、不均匀系数（Cu）），对泡沫改良土开展了大型渗透试验。试验结果表明：级配特征参数的变化能够明显地影响改良土渗透系数时变曲线（包括初始稳定期、快速发展期和缓慢变化期三个阶段）。随着土有效粒径的增加，泡沫改良土的初始渗透系数大幅增加；随着土曲率系数、不均匀系数的增加，初始稳定渗透系数仅在一定范围内小幅波动。此外，当渗透系数进入缓慢变化期后，改良土的渗透系数距离为未加泡沫土渗透系数仍有较大差距。通过定义临界时间、流速安全时间、流量安全时间三个渗流特征时间，从流速和流量两个层面表征盾构掘进过程中泡沫改良土渗流的安全性，结果显示土曲率系数、不均匀系数发生变化对泡沫改良土渗流安全性影响较小，但随着土有效粒径的增加，渗流由安全变为不安全，表明土有效粒径的变化对改良土渗流安全性起到决定性作用。

关键词：泡沫；渣土改良；EPB 盾构；渗透性；级配特征

Effect of Grain Gradation on the Permeability Characteristics of Coarse-Grained Soil Conditioned with Foam for EPB Shield Tunneling

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Abstract:

To avoid water spewing out of the screw conveyor, foam is often used to condition the soil in shield chamber and to reduce its permeability during earth pressure balance (EPB) shield tunneling. Whether foam can effectively condition the soil or not strongly depends on soil gradation characteristics. A series of permeability tests were carried out on foam-conditioned soil with changing effective grain size (d10), curvature coefficient (Cc), and uniformity coefficient (Cu). The test results show that with an increase in d10, the initial permeability coefficient of the foam-conditioned soil increased greatly. However, with an increase respectively in Cc and Cu, the initial permeability coefficient fluctuated only slightly. In addition, when the permeability coefficient entered the slow growth period for a long time, it was still much lower than that of the unconditioned soil. To evaluate the anti-permeability for permeation safety during EPB shield tunneling, three characteristic times were defined, including critical time (tc), flow rate safety time (ta) and flow quantity safety time (ts). It was shown that the Cc and Cu had little effects on the permeation safety of the conditioned soil. However, as the d10 increased, the ta and ts obtained from the permeability tests decreased significantly, thereby inducing the permeability feature to change from a safe state

to an unsafe one for the soil discharging during EBP shield tunneling. Thus, the d10 played a decisive role in the permeation safety of foam-conditioned soil.

keywords: foam; soil conditioning; EPB shield; permeability; grain gradation

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基于关联分析和遗传算法优化 BP 神经网络的隧道围岩变形预测

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（石家庄铁道大学）

摘　要：隧道工程处于岩土介质中，岩体自然因素与隧道围岩变形的关系难以用确定的关系表述。因此，通过现场监测隧道变形情况，利用变形预测隧道围岩未来的变形具有重要意义。选取工程区地处我国地势第二阶梯的川陕鄂黔中、低山区，以吴家沟隧道为依托。首先基于灰色关联分析，选取影响隧道围岩变形的主要因素。接着，基于生物进化的思想，用遗传算法优化 BP 神经网络，分为三个部分，即 BP 神经网络结构确定、遗传算法优化和 BP 神经网络预测。最后，得到空间维预测结果，为工程实际应用提供借鉴。结果表明，在隧道围岩变形预测中，遗传算法优化神经网络精度高，满足隧道围岩变形预测精度的需要，对川陕鄂黔中、低山区复杂地质条件下长大高风险隧道围岩变形预测有一定的参考意义。

关键词：隧道工程；围岩变形；预测；灰色关联分析；遗传算法优化 BP 神经网络

Deformation Prediction of Tunnel Surrounding Rock Based on BP Neural Network Optimized by Correlation Analysis and Genetic Algorithm

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Abstract:

The tunnel engineering is in the geotechnical medium. The deformation of the surrounding rock of the tunnel shows complex mechanical properties. The relationship between the actual characteristics of the rock mass and the deformation of the surrounding rock of the tunnel is difficult to determine. Therefore, it is of great value to grasp the real-time deformation of the tunnel through on-site monitoring and use the deformation prediction to further judge the future deformation trend and stability of the surrounding rock. The project area is located in the middle and low mountainous areas of Sichuan, Shaanxi, Hubei and Guizhou in the second step of China's topography, relying on the Wujiagou Tunnel. Firstly, based on the grey relational analysis, the main factors affecting the deformation of the surrounding rock of the tunnel are selected. Then, based on the idea of biological evolution, BP neural network is optimized by genetic algorithm, which is divided into three parts: BP neural network structure determination, genetic algorithm optimization and BP neural network prediction. Finally, the spatial dimension prediction results are obtained to provide reference for the practical application of the project. The results show that in the prediction of tunnel surrounding rock deformation, the genetic algorithm optimizes the neural network with high precision and meets the needs of tunnel surrounding rock deformation prediction accuracy. The surrounding rock deformation of high and high risk tunnels under complex geological conditions in the middle and low mountainous areas of Sichuan, Shaanxi, Hubei and Guizhou The forecast has certain reference

significance.

keywords: tunnel engineering； surrounding rock deformation; prediction; grey relational analysis; genetic algorithm optimization BP neural network

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冲击与火载荷作用下隧道衬砌结构的响应分析

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摘　要：隧道内车祸及火灾是不仅阻碍交通，威胁人身物资安全，其冲击及温度效应往往也造成结构的破坏，影响结构工作性能和缩短结构服役年限。本文对隧道衬砌在车辆冲击和火荷载共同作用下的响应行为进行了数值模拟分析，以火与冲击载荷先后作用时衬砌拱顶沉降及边墙收敛位移作为其失效判据，系统比较了两种载荷的相互作用效应，即火载荷对衬砌抗冲击能力的影响，以及冲击载荷对其抗火性能的影响。研究结果表明：火载荷降低了衬砌的抗冲击能力，与初始静载荷相比，温度对其抗冲击能力的影响较为显著；冲击载荷对衬砌的抗火性能产生不利影响，当隧道衬砌先承受爆炸冲击载荷冲击后受火侵袭时，随着静载荷比和动载荷比的增加，衬砌的抗火性能也会显著降低。研究可为隧道支护结构的防火防爆参数设计提供借鉴。

关键词：隧道衬砌；火载荷；冲击载荷；相互影响

The Analysis on Responses of Tunnel Lining Under Fire and Impulsive Load

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Abstract:

Car accidents and fires in the tunnel could not only obstruct traffic and threaten human safety, but affect structural performance and shorten service life of the structure with impulsive load and temperature effects. In this study numerical simulation analysis on the response behavior of tunnel lining under interaction of vehicle impulsive load and fire load was carried out. Lining vault settlement and side wall displacement were taken as the failure criterion, the interaction effect of two kinds of load was systematically compared, i.e., the influence of fire load on lining impulsive resistance capability and influence of impulsive load on lining fire resistance capability. The results show: Firstly the fire load reduced lining impulsive resistance capability, and compared with the initial static load, the influence of temperature were more remarkable; Secondly, impulsive load on the lining also made adverse effects on the fire resistance capability. When the tunnel lining suffered impulse load before fire, fire resistance capability would also decrease remarkably along with the increase of dynamic and static load ratio. This study could provide reference for fireproof and explosion-proof parameters design of tunnel support structure.

keywords: tunnel lining; fire load; impact load; interaction

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富水地层浅埋隧道综合探测及处治对策

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摘　要：为保证富水地层浅埋隧道的施工安全，减少施工灾害发生的可能性，有必要对隧址地质异常体进行综合预报分析。本文依托成兰铁路金瓶岩隧道，通过地质分析研究了金瓶岩隧道的不良地质体赋存特征，利用 TSP 超前预报系统、地质雷达红外探水等物探手段对金瓶岩隧道的富水地层进行了探测，并结合短距离钻探进行对比分析，探测结果与现场实际揭露情况吻合较好。针对富水地层的围岩特点，制定针对性的施工处治方案，并通过全过程的监控量测结果，针对传统的曲线预测模型存在的不足和富水地层位移变形特点，提出含有四个参数的增长曲线模型—Richards 模型。通过对特殊地层拱顶沉降及周边收敛的动态过程进行分析，得出富水地层初期支护后的变形(拱顶沉降、周边收敛)—时间曲线的基本特征，验证了富水地层处置措施的优越性。这种综合预报优先-针对性处治-位移曲线验证的浅埋段富水地层治理模式可对今后类似工程的施工提供借鉴。

关键词：金瓶岩隧道；综合预报分析；TSP 超前预报系统；地质雷达

Optimization Scheme of Comprehensive Geological Prediction of Shallow Buried Tunnel in Water Stratum

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Abstract:

To ensure the construction safety of shallow buried tunnel in water stratum and reduce the possibility of hazards during construction, the comprehensive prediction analysis of the defective geological condition in tunnel area should be carried out. Taking the Jingpingyan Tunnel in Chengdu-Lanzhou Railway as background project, the developing characteristics of the defective geological bodies of Jingpingyan tunnel was analyzed using geological analysis, and then the geophysical prospecting methods such as TSP (tunnel seismic prediction) advanced prediction system and geological penetrating radar (GPR) were used to probe the water stratus of Jingpingyan tunnel. Moreover, the drilling and excavation results were adopted to verify the prediction results of TSP and GPR. The prediction results of TSP and GPR were consistent with actual excavation conditions. For the characteristics of the surrounding rock in water stratum, the targeted treatment schemes of construction were made for the surrounding rock in water stratum. The growth curve model with four parameters named Richards model is proposed aimed at the shortcomings of traditional exponential curve prediction models and the displacement deformation characteristics of water stratum by monitoring measurement results of whole process. The dynamic process of vault sedimentation and peripheral convergence of special stratum was analyzed to obtain the basic characteristics of deformations (vault sedimentation and peripheral convergence)—time curve of

water stratum after primary support verifying the advantages of disposal measures for water stratum. The treatment model mentioned in this paper can take some reference significance for the similar engineering in the future.

keywords: jingpingyan tunnel; comprehensive prediction analysis; TSP advanced prediction system; geological penetrating radar

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Numerical Analysis of Advanced Displacement in Construction Progress of Tunnel Excavation with Weak Surrounding Rock

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Abstract: Analysis of advanced displacement in construction progress of tunnel excavation with weak surrounding rock is carried out by numerical method and comparison of model test result. In allusion to the problems of regional landslides and extruded large-deformation seriously impacting the stability of rock mass in construction process of large-section tunnel with weak surrounding rock, the elastic-plastic numerical simulation relying on Liangshui tunnel of Lan-Yu railroad is conducted on mechanical behaviors and deformation steric effect of tunnel construction, and the calculation results are compared with the modeling data. The research results show that: the steric effect of excavation face is the dominant factor in the incidence of working face and the stress of surrounding rocks gradually releases from excavation face; the range of 0.5~1 times the cave diameter around rock mass in front of working face is the disturbance range and the key area of stabilization and reinforcement for wake surrounding rock. According to the analysis and construction practice, the supporting structure of large-section tunnel with weak surrounding rock should be established as soon as possible to control the displacement change of surrounding rock in the range of load-bearing ring, reduce disturbance and improve the self-bearing capability of surrounding rock. Because of the distinct excavation steric effect of weak surrounding rock, the secondary lining structure must be established in time to bear the later pressure and restrict the large displacement of surrounding rock. The research results can provide reliable basis for engineering stability control of analogous tunnels.

Key words: large section tunnel with weak surrounding rock; elastic-plasticadvanced displacement; numerical simulation; steric effect

地铁区间隧道与管廊开挖顺序优化分析

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摘　要：隧道开挖容易导致地表变形，严重情况下会产生安全事故，因此对于隧道开挖问题的研究尤为重要。为了研究不同开挖顺序对地表以及管廊影响、探索较为安全可靠的开挖方法，本文以北京某综合管廊工程为依托，利用 ABAQUS 软件建立模型并进行有限元分析，统计管廊及地铁隧道各个节点变形值，绘制折线图并进行分析比较。结果显示：8 种开挖方式对底层表面造成的影响均相差不多，管廊和地铁隧道同步开挖对管廊影响最小，对于地铁隧道影响相对较大；其他 7 种开挖方式均对管廊影响较大。就施工进度及安全可靠度方面来讲，管隧共建是较好的施工方案，而使用这种施工方式进行施工过程中，地铁隧道应加厚衬砌厚度。当下对管隧共建方案研究的学者越来越多，恰好证明管隧共建能更好的满足现场施工要求。

关键词：沉降

Optimization Analysis of Excavation Sequence of Urban Metro Section and Pipe Gallery

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Abstract:

The surface deformation caused by tunnel excavation cannot be ignored, this paper is based on a comprehensive pipe gallery project in Beijing, pipe gallery and double - line subway tunnels need to be built underground,there are many excavation sequences in the process of multiple tunnel construction.In order to study the effect of different excavation sequence on the surface and subsurface structure, Abaqus software is used to simulate the excavation process of subway tunnel and pipe gallery and do the finite element analysis in this paper, statistic the deformation value of each node of pipe gallery and subway tunnel, draw line charts and compare them. the results showed that: The influence of the eight excavation methods on the bottom surface is similar. The synchronous excavation of tube gallery and subway tunnel has the least influence on the tube gallery, and the influence on subway tunnel is relatively large.The other seven excavation methods have great influence on the pipe gallery.In terms of construction progress and safety reliability, co-construction of pipe and tunnel is a better construction plan. However, in the process of using this construction method, the lining thickness of subway tunnels should be increased.At present, more and more scholars are studying the joint construction of pipe and tunnel, which just proves that the joint construction of pipe and tunnel can better meet the requirements of site construction.

keywords: subsidence

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A Novel Method of Dynamic Monitoring and Parameters Estimation for Rockfall Based on Multichannel SAR

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Abstract： Rockfall influences the safety of infrastructure and transportation lines normal operation, the application of synthetic aperture radar (SAR) technology to monitor the rockfall is a new method to predict rockfall disaster.This paper proposes a new method of dynamic monitoring and parameters estimation for rockfall based on multichannel airborne SAR system.First,the signal model of multichannel airborne SAR system is derived.Then,for a better performance, the traditional Displaced Phase Center Antenna (DPCA) method is extended to three or more receive channels. This method can not only realize rockfall target detection effectively, but also estimate rockfall target parameters precisely and resolve the ambiguity during estimating rockfall targets parameters. Finally, the simulated data processing results validate the proposed approach.

Key words： rockfall target detection

Rockfall Monitoring Based on Multichannel Synthetic Aperture Radar

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Abstract: Rockfall influences the safety of infrastructure and transportation lines normal operation, application of SAR technology to monitor the rockfall could predict rockfall disaster. One of the most important factors in rockfall target detection is the signal-to-clutter-plus noise ratio (SCNR) after clutter suppression, which should be maximized before rockfall target detection. Through analyzing remainder rockfall target characteristic after clutter suppression, the method of removing quadratic FM component introduced by platform velocity and along track velocity of rockfall target is proposed. After removing quadratic FM component by dechirp technology, remainder rockfall target is focused in Doppler region image and the SCNR of remainder rockfall target is maximized. So it has a preferable result in rockfall target detection. To resolve the contradiction between calculated amount and the accuracy of along track velocity, this paper adopts the technology of gradual approach. Finally, by analyzing the focused signal characteristic, the method of rockfall target parameters estimation is proposed. The effectiveness of the presented method is demonstrated by both theoretic analysis and simulated data.

Key words: rockfall target detection.

穿越破碎带隧道掌子面力学模型及最小安全厚度研究

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摘　要：隧道穿越断层破碎带的稳定性及安全防护问题是目前隧道建设的难点。针对隧道掌子面前方存在破碎带松散岩土体的典型工况，综合采用理论计算、数值模拟、工程实践相结合的手段，基于隧道围岩以及掌子面的力学特性，提出了掌子面稳定岩体的最小安全厚度计算方法，并对隧道掌子面前方破碎带的预加固及处治方案进行了探讨。首先，建立了破碎带-岩板力学模型，将掌子面的岩体等效为受荷载作用的岩板，对受破碎带压力的岩板最小安全厚度展开计算分析，得到了岩板厚度与岩层倾角、破碎带有效高度的关系表达式，并对帷幕注浆处理参数进行了优化；随后基于理论计算结论，对某隧道穿越破碎带施工中因未控制掌子面岩体厚度而导致隧道失稳的典型案例展开对比分析；最后结合 Comsol Multiphysics 软件开展数值仿真模拟，分析了不同的岩层倾角、隧道埋深、注浆预处理参数等因素对掌子面岩板最小安全厚度的影响。理论计算、工程实际与数值模拟结果具有较好的一致性，结果显示：(1)正常施工时掌子面最小安全岩板厚度随破碎带有效高度的增大而增大，随岩层倾角增大而减小，故应在达到安全厚度之前对破碎带进行预支护；(2)在选用帷幕注浆方法对破碎带进行预处理时，最小安全岩板厚度随着岩层倾角的增大而减小，此时在注浆过程中需要保留较大的安全厚度，同时控制注浆压力。

关键词：层状岩体。

Study on the Mechanics Model and Minimum Safe Thickness of the Tunnel Face When Crossing a Fracture Zone

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Abstract:

The stability and safety protection of the tunnel through the fault fracture zone are the difficulties in the tunnel construction at present. Constraints on tunnel ahead is the typical working condition of the loose soil masses in broken zones, and integrated with the theoretical calculation, numerical simulation and engineering practice, the calculation method of proposed minimum safe thickness of the rock mass stability has been presented which is based on the mechanical properties of the surrounding rock and constraints. Meanwhile the fracture zone in front of the tunnel constraints pre-reinforcement and treatment scheme are discussed in this paper. First of all, the fracture zone - rock slab mechanics model is established, the constraints of the rock mass equivalent for the loads of rock slab, focused on the calculation analysis of pressure on the fracture zone of rock slab minimum safe thickness, which gave out the effectively expression of the relationship of the rock slab thickness, strata dip angle, and the fracture zone height. Besides the curtain grouting processing parameters are optimized. Then, based on the theoretical calculation conclusion, a

comparative analysis is made on the typical case of construction of a tunnel through the fracture zone instability, which is caused by failure to control the thickness of rock mass on the tunnel-face. Finally, Comsol Multiphysics software was used to carry out numerical simulation, and the effects of different rock dips, tunnel depth and grouting pretreatment parameters on the minimum safe thickness of the tunnel face rock slab were analyzed. The results of theoretical calculation, engineering practice and numerical simulation are in good agreement. The results show that: (1) during normal construction, the minimum safe rock slab thickness of the tunnel face increases with the increase of effective height of the crushing zone and decreases with the increase of the dip angle of the rock layer; (2) when the curtain grouting method is used for pretreatment of the broken zone, the minimum safe rock slab thickness decreases with the increase of rock dip angle. At this point, large safety thickness should be reserved in the grouting process and the grouting pressure should be controlled at the same time.

keywords: layered rock mass

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车公庙地铁站的现场检测与模型试验研究

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摘　要：本文对车公庙地铁站的开挖建造过程进行了研究，并在该车站基础上进行了盖挖逆作和明挖顺作的对比试验。该车站采用盖挖逆作的方法施工，通过记录现场监测数据，平均选取了数个测量点，对地表及建筑物的沉降进行数据分析，结合盖挖逆作和明挖顺作的对比试验，得出结论：①随着开挖深度的增加，明挖顺作段由于基坑开挖引起的邻近地铁车站变形要明显大于盖挖逆作段；②盖挖逆作段由于基坑开挖引起的地面沉降变形较小，而不同施作顺序下地表沉降值均在结构安全和正常使用要求的范围之内；③该研究成果可为邻近既有地铁车站深基坑设计与施工提供参考。

关键词：盖挖逆作；明挖顺作；模型试验；地表沉降

On-The-Spot Detection and Model Test of Che Gongmiao Subway Station

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Abstract:

This paper studies the excavation and construction process of Che Gongmiao subway station, and carries out comparative tests of top－down inverse construction method and bottom-up method on the basis of the station. The station was constructed by means of top－down inverse construction method. By recording the on-site monitoring data, several measurement points were selected on average, data analysis was carried out on the settlement of the surface and buildings, and combined with the top－down inverse construction method and the contrast-excavation test. It is concluded that: 1 With the increase of excavation depth, the deformation of the adjacent subway station caused by bottom-up method is obviously larger than that the zone using top－down inverse construction method; 2 The top－down inverse construction method is caused by the excavation of the foundation pit the ground settlement is less deformed, and the surface settlement values under different application sequences are within the scope of structural safety and normal use requirements. 3 The research results can provide reference for the design and construction of deep foundation pits adjacent to existing metro stations.

keywords: top－down inverse construction method; bottom-up method; model test; surface settlement

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公路隧道环境感知系统的设计与实现

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摘　要：基于物联网和云计算技术设计并开发了一套公路隧道环境感知系统。采用 STM32 微处理器实时采集隧道内污染物浓度、温度气压、能见度和风速风向等环境信息，应用 4G 移动通信网络进行数据的远程传输，部署云服务器实现监测数据云端存储与共享。实验结果表明该系统集成度高、布设简单、运行稳定，弥补了便携式监测设备和传统隧道监测设施的技术缺陷，可为综合评判隧道空气质量和动态调节风机运行提供实测数据支撑。

关键词：隧道通风；空气质量；通风控制

Design and Implementation of Environment Perception System for Highway Tunnel

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Abstract:

Based on the Internet of things and cloud computing, an environment perception system for highway tunnel was designed and developed. The STM32 microprocessor was applied in the real-time acquisition of in-tunnel pollutant concentration, temperature, air pressure, visibility, wind speed, and direction. 4G mobile networks were used for remote data transmission, and the cloud server was deployed to implement cloud storage and data sharing for the in-tunnel environment monitoring data. The experiment results indicated that the developed system has advantages of high integration level, simplified structure, and stable performance, which make up the technical defects of the portable emissions measurement system (PEMS) and traditional tunnel monitoring facilities. The application of this system can provide situ data support for the comprehensive evaluation of the in-tunnel air quality and dynamically adjustment of the fan operation.

keywords: tunnel ventilation; air quality; ventilation control

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公路隧道入口段自然采光的结构类型研究

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摘　要：自然采光技术是基于确保行车安全性前提下改善入口段光环境并降低照明能耗为目的提出来的，具体技术手段是将隧道入口段前半段延伸出隧道外。为此，提出了两种采光结构形式，针对不同的洞口朝向和六个典型时间特征点，采用 DIALux 软件中的室内场景和日光场景进行了模拟计算分析。从平均亮度、亮度均匀度等方面，对比研究了两种结构方案的采光效果，并推荐采用类型 2（采光天窗等间距、等尺寸设置）。于是，入口段 1 的加强照明完全取消，仅保留夜间基本照明，最不利情况下的最大节能率为 44%，节能效果可观。

关键词：隧道；照明；入口段；自然采光；DIALux

Study on Structural Types of Natural Lighting Within Tunnel Entrance Section

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Abstract:

Based on the premise of ensuring the safety of traffic, the natural lighting technology is adopted to improve the light environment within the entrance section and reduce lighting energy consumption. The technical means is to extend the first half of the tunnel entrance section out of the tunnel. For this purpose, two kinds of lighting structure are proposed. In view of different orientation and six typical time feature points, the indoor scene and daylight scene in DIALux software are simulated and analyzed. From the aspects of average brightness and brightness uniformity, the lighting effects of two structural schemes are compared and studied. As a result, the 2nd type is recommended finally. Therefore, the enhanced lighting of the entrance section 1 is completely abolished with the basic lighting maintained. A considerable energy saving effect occurs with an energy-saving rate of 44% under the most unfavorable conditions.

keywords: road tunnel; lighting system; entrance section; natural lighting; DIALux

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隧道拱墙装饰方案对照明效果的影响研究

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摘　要：为了定量分析隧道侧墙和拱顶的装饰方案对照明效果的影响，采用能够考虑侧墙和拱顶的二次反射光的 DIALux 软件，分析了相同的灯具配置、不同的隧道装饰方案时隧道路面的亮度情况。结果表明：隧道装饰方案对照明质量的影响是存在的，建议在通风条件良好的短隧道中，应积极推荐采用拱顶为浅灰色，侧墙为纯白色的装饰方案，在隧道进洞口，甚至建议拱顶也采用白色，进一步提高洞口入口段的亮度，缓解黑洞效应。

关键词：公路隧道；装饰方案；照明；协调性；DIALux

Study on Influence on Lighting Effect Resulted from Decoration Scheme

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Abstract:

In order to quantitatively analyze the influence on the lighting effect resulted from different decorative schemes of the side wall and the vault in tunnels, DIALux software which can consider the reflection light is adopted to illustrate the brightness situation of the tunnel pavement with same luminaire configuration and different tunnel decoration schemes. The result proves the supposed influence. The decoration scheme with light grey vault and pure white side wall is recommended for short tunnel with good ventilation. As for the tunnel entrance, even a white vault is recommended to improve the brightness of the entrance section of the tunnel entrance in order to lessen the black hole effect.

keywords: road tunnel; decoration scheme; lighting; coordination; DIALux

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基于光环境室内仿真和视觉功效实验的公路隧道照明评价方法研究

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摘　要：结合当前公路隧道照明设计和运营现状，本文从“静态视觉感知”和“动态亮度适应”两个角度开展隧道静、动态照明模拟环境下多样本视觉功效响应实验。研究表明：在公路隧道（尤其是长、特长隧道）中间段，被测人员的视觉功效随视觉环境视野感知域内相对光谱能量分布和相对色温的变化而变化；动态暗适应下被测人员的视觉功效受亮度梯度降低值的影响较大，在公路隧道照明亮度梯度降低引起的动态暗适应视觉背景下，在照明过渡段被测人员视野光谱灵敏度逐渐向短波方向过渡，在照明中间段呈现典型中间视觉亮度特征。最后，本文结合相对光谱能量分布、相对色温值的影响进一步分析了公路隧道照明的评价方法和指标。

关键词：公路隧道；静、动态照明环境；视觉功效；视觉响应；评价指标

Research on Evaluation Method of Highway Tunnel Lighting Based on Indoor Simulation of Light Environment and Visual Performance Experiment

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Abstract:

According to the design and operation status of the highway tunnel lighting, this paper did a variety of visual performance experiments in tunnel static and dynamic lighting simulation environment from "static visual perception" and "dynamic luminance adaptation". The results show that in the interior zone of highway tunnels (especially the long and extra-long ones), the visual performance varies with the spectral power distribution(SPD) and the correlated colour temperature(CCT) in the visual field; the visual performance under dynamic temporal adaptation is greatly affected by the decrease of luminance gradient, the sensitivity of vision spectrum gradually transits to the short-wave direction in the lighting transition zone, and the mesopic vision features are presented in the interior zone under this background. Therefore, from the perspective of human-vehicle-tunnel lighting environment, it is necessary to optimize the evaluation index of highway tunnel lighting, such as the luminance evolution curve of each tunnel zones, SPD & CCT, and the lighting environment parameters. Finally, the evaluation methods of highway tunnel lighting are further analyzed from the visual performance experiment on SPD and CCT.

keywords: highway tunnel; static and dynamic lighting environment; visual performance; visual response; evaluation indexes

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大断面沉管隧道火灾人员疏散及应急救援仿真分析

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摘　要：为了更好地规划设计隧道内发生火灾时人员疏散及救援路线，针对深中通道超大断面沉管隧道的疏散救援设施的实际工程状况，采用 FDS、Pathfinder 以及 Vissim 软件对隧道火灾工况下人员疏散以及救援技术进行分析和验证。仿真计算结果表明，本项目隧道的人员疏散安全门的尺寸和间距设置满足隧道内发生火灾时人员疏散要求，东人工岛、西人工岛以及三围互通收费广场 3 处分别设置的消防救援点可满足应急救援的时间要求，此结论可为设计人员提供参考。

关键词：沉管隧道;火灾；安全疏散；应急救援；交通仿真

Simulated Analysis of Evacuation and Emergency Rescue in Extra-Wide Immersed Tunnel Fire

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Abstract:

In order to better plan the evacuation and rescue the route of fire in the tunnel, the actual engineering conditions of the evacuation and rescue facilities for the deep-span mega-section immersed tunnels, personnel evacuation and rescue techniques under circumstance of fire in the tunnel by FDS, Pathfinder and Vissim Perform are verified and analyzed. The results of simulation show that the distance and size of the evacuation safety door of the tunnel of the project meet the evacuation requirements of fires in the tunnel. The fire rescue points can be set up in the east artificial island, the west artificial island and three surrounding toll plazas to meet the requirement of emergency rescue time and it provides designers with the design basis as well.

keywords: immersed tunnel; fire; evacuation; emergency rescue; traffic simulated

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基于发光反光高性能涂料的隧道照明安全与节能技术应用研究

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摘　要：本文针对公路隧道照明节能压力和品质提升之间的矛盾，提出利用发光反光高性能涂料的优点进行隧道应用的方案设计。通过理论分析、模拟仿真和工程应用得出所提出的应用方案不仅可有效提高隧道照明安全性，并可通过亮度提升降低隧道照明能耗。根据实际工程应用效果测试，所采用的方案可降低隧道照明年运营能耗在 20%以上，对提升隧道照明安全和节能水平，推动隧道提质升级和公路交通绿色低碳具有积极的促进作用。

关键词：公路隧道；安全；节能；发光反光；涂料

Application Research of Tunnel Lighting Safety and Energy Saving Technology Based on Luminescent Reflective High Performance Coatings

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Abstract:

View of the contradiction between energy saving pressure and quality improvement of highway tunnel lighting, this paper proposes the design of tunnel application by utilizing the advantages of luminescent reflective high performance coating. Through theoretical analysis, simulation and engineering application, the proposed application scheme can not only effectively improve the tunnel lighting safety, but also reduce the tunnel lighting energy consumption through brightness improvement. According to the actual engineering application effect test, the adopted scheme can reduce the annual energy consumption of tunnel lighting by more than 20%, and it can promote the tunnel lighting safety and energy saving level, promote quality upgrading of tunnels and green low carbon highway traffic.

keywords: highway tunnel; security; energy conservation; luminous reflection; coating

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低交通量下“与车随行”隧道照明节能控制技术应用研究

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摘　要：本文针对公路隧道照明安全与节能之间的矛盾，提出在低交通量下实施“车来灯亮、车走灯暗”的“与车随行”智能控制技术。通过方案制定和工程实施得出所提出的应用方案不仅可保证隧道照明安全性，并可通过与交通流实时相关的照明控制降低隧道照明能耗。根据实际工程应用效果测试，所采用的方案可降低隧道照明年运营费用达 72%，对提升隧道照明安全和节能水平，推动隧道提质升级和公路交通绿色低碳具有积极的促进作用。

关键词：公路隧道；安全；节能；低交通量；智能控制

Application Research on Energy-Saving Control Technology of "With Vehicles" Tunnel Lighting Under Low Traffic Volume

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Abstract:

In view of the contradiction between lighting safety and energy saving in highway tunnels, this paper proposes to implement the " With Vehicles " intelligent control technology with " When the car comes, the light is on;When the car leaves, the light dims" under low traffic volume. Through the scheme formulation and engineering implementation, the proposed application scheme can not only ensure the tunnel lighting safety, but also reduce the tunnel lighting energy consumption through the lighting control related to real-time traffic flow. According to the actual engineering application effect test, the adopted scheme can reduce the annual operating cost of tunnel lighting by 72%, which has a positive role in promoting the level of tunnel lighting safety and energy saving, promoting the upgrading of tunnel quality and green low-carbon highway traffic.

keywords: highway tunnel; safety; energy conservation; low traffic volume; intelligent control technology

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新型太阳能烟囱在隧道通风中的应用研究

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摘　要：目前，公路隧道运营中采用的竖（斜）井纵向式机械通风方式，普遍存在着耗电量巨大的问题，给隧道运营带来了沉重的经济负担。太阳能烟囱作为一种热压作用下的自然通风设备，利用太阳辐射，将热能转化为空气的动能，从而起到通风换气的作用。本文首先分析了公路隧道中需要注意的通风阻力和超静压差对太阳能烟囱的影响；其次对利用太阳能烟囱的公路隧道通风系统的效果进行了研究；最后对太阳能烟囱装置进行定量的数值模拟，模拟结果与未建成时的实测数据进行对比，发现太阳能烟囱能将纯自然通风条件下原有的通风量提升约一倍。太阳能烟囱装置能够最大限度地利用自然风，解决公路隧道在运营和管理中成本过大、维护费用过高的问题，对创建节能环保型隧道通风运营具有较好的理论意义与工程应用价值。

关键词：公路隧道；太阳能烟囱；数值模拟；自然通风

Application Research of the New Solar Chimney in Tunnel Ventilation

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Abstract:

At present, the vertical (inclined) well vertical mechanical ventilation used in the operation of highway tunnels exists huge electricity consumption, which brings heavy economic burden to the tunnel operation. As a kind of natural ventilation device, solar chimney transform thermal energy into kinetic energy of air, producing a chimney effect, thus plays the role of ventilation. But there is little research about solar chimney used in tunnel ventilation. Analyze the influence of parameters which solar chimney is used in tunnel ventilation., As the supplement of research in the field of tunnel ventilation based on solar chimney .Comparing the simulation results with the measured data, it is found that the solar chimney can increase the original ventilation volume by about twice under the condition of pure natural ventilation. And the experiment and the numerical simulation with real examples were carried on, and provide an effective reference for the application of solar energy chimney. Contribute to the further implementation of energy-saving, emission reduction of tunnel.

keywords: highway tunnel; solar chimney; numerical simulation; natural ventilation

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匝道通风模式对合流分岔上游主隧道烟气控制的影响研究

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摘　要：本文借助通风模拟软件 IDA RTV，对火源位于 Y 形合流分岔路段上游时不同匝道通风模式对主隧道烟气控制的影响进行了模拟分析。研究结果表明：当火灾发生在合流分岔路段上游，主隧道以临界风速送风时，匝道送风对合流分岔路段上游烟气往下游流动起抑制作用，送风量越大，抑制作用越强，此时，火源上游的烟气回流得不到抑制；而匝道排风时则起促进作用，并且随着排风量增加，促进作用增强，主隧道烟气控制效果增强，但匝道较长时，需考虑匝道内车辆和人员的安全。

关键词：临界风速

Study on the Impacts of the Ventilation Mode in Ramp Tunnel on the Smoke Control in the Main Tunnel with Converging Intersections

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Abstract:

By using the software IDA RTV, smoke spread in the main tunnel under different ventilation mode in ramp tunnel was studied when the fire occurs at the upstream of the intersection. The results show that the ventilation mode in ramp tunnel would have large effects on the smoke control effect in main tunnel. When the ventilation mode in the ramp tunnel is the air supply mode, the supply air from the ramp tunnel would decrease the ventilation speed at the upstream of the fire source. The smoke backlayer would not be prevented. The exhaust mode in the ramp tunnel would increase the ventilation speed at the upstream of the fire source, and the smoke control effects would be enhanced. The safety of the vehicle and occupants in the ramp tunnel would be considered carefully when the ramp tunnel is relatively long under this condition.

keywords: critical velocity

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隧道通风阻力格栅局部阻力试验研究

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摘　要：根据等效设计理论，在隧道通风模型试验中安装阻力格栅可有效缩短隧道模型的长度。为了研究阻力格栅在通风模型中所造成的局部阻力影响，通过建立物理模型来分别观测不同的阻力格栅串联间距、串联数量以及格栅类型的变化对通风试验局部阻力的影响。结果表明：加入阻力格栅后通风模型仍存在自模区，且对模型进入自模区的的临界风速影响很小；阻力格栅的串联间距、组数、规格对模型进入自模区的临界风速几乎没有影响；当格栅间距大于三倍断面当量直径时，格栅之间的相互影响可以忽略不计，故阻力格栅串联间距应不小于三倍模型当量直径；每组格栅局部阻力损失系数随格栅组数的增多而降低，降低的速率随着格栅组数的增多而减小。

关键词：隧道通风；阻力格栅；等效设计理论；模型试验

Experimental Research on the Local Resistant of Grid in Tunnel Ventilation Model Test

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Abstract:

According to the equivalent design theory, the resistant grids can effectively reduce the length of the tunnel ventilation system model in tunnel ventilation model test. In order to study the influence of local resistance in ventilation model caused by the resistance grid, through the physical model to observe the influence of local resistance in different resistance grid series spacing, the number of series and the type of grid. The results show that adding resistance rack in the model, the automatic zone still exists, its critical speed of the wind is almost equal to the wind speed of the model; when the grid spacing is greater than three times of the model section, the interaction between the grid can be neglected, so the gap of the resistance rack should be longer than triple equivalent diameter of the section of the model; every rack of the part of the resistance loss factor is getting lower with the rising of the rack number, the lowing speed is getting smaller with the rising of the rack number.

keywords: tunnel ventilation；the resistant grids；the equivalent design theory；mode1 test

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Numerical Investigation of Particle Concentration Distribution Characteristics in Twin-Tunnel Complementary Ventilation System

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Abstract: Longitudinal ventilation systems are commonly installed in new tunnels. In this paper, based on the similarity law, the scale model with a view to different conditions are carried out to study the effectiveness of twin-tunnel complementary ventilation system. The system can offer enough amount of fresh air to meet requirement of driving safety by using longitudinal ventilation without ventilation shaft. Field measurements were also performed to validate the numerical model. Results reveal that particle concentration distribution is influenced by the distance from air interchange cross passages to uphill tunnel inlet () and the flow volume of air interchange cross() passage and jet fan thrust() in tunnel. And the is the most important factors about influencing the ventilation efficiency.

Key words: tunnel ventilation; twin-tunnel complementary; particle concentration; CFD; field measurement; large single-sloped

A Computational Study on Effects of Fire Location on Smoke Movement in a Road Tunnel

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Abstract : In this work, a numerical model of tunnel fire is developed and aimed to investigate the influence of cross-sectional fire locations on critical velocity and smoke flow characteristic. It is shown that the critical velocity for a fire next to the wall is obviously higher than that for a fire in the middle or on the left/right lane. The ratio is estimated to be 1.12. The predictions of critical velocity from ‘small-fire’ models show a good agreement with that for a fire in the middle or on the left/right lane from CFD. The tunnel height at the fire location is proposed to be instead of the hydraulic tunnel height in the ‘big-fire’ model of Wu and Bakar for a fire next to the wall. The smoke moves backward in a tongue like form as the ventilation velocity is lower than the critical velocity. The back-layering length of a fire in the middle is shown to be approximate twice than that on the left/right lane under the same ventilation velocity, although they share the same critical velocity. Whereas a relatively short back-layering length for a fire next to the wall under the velocity of 2.6 and 2.7 m/s. In addition, a snaky high-temperature profile on the top wall at the initial downstream is observed for a fire on the left lane and next to the wall, and finally a steady and layered smoke flow. The likely cause of this phenomenon is subsequently explained in this study.

Key words: tunnel fire; fire location; critical velocity

Experimental Investigation on Evacuation Performance of Pedestrians in Large-Long UrbanTunnel with the Natural Ventilation in Fire

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Abstract: This paper presented a field experimental study recording several participants' evacuation in smoke from a bidirectional large-long urban tunnel with openings on the ceiling. Openings on the ceiling with vertical shafts are applied as natural ventilation and provide large amount of sunlight into the tunnel in the daytime, serving as an extremely beneficial way in people's emergency evacuation. Route choice, movement time, physical condition and reaction to technical installations were recorded and discussed considering human factors, including pedestrians' genders, ages and emotional state. The influence of openings on the ceiling is analyzed both on people and setting of related evacuation system. This study leads to guidance on evacuation planning and procedures on tunnels with natural ventilation and suggestions regarding to corresponding technical installations in the tunnel, such as way-finding signs, loudspeakers, and continuous light.

Key words: evacuation performance;tunnel fire and smoke;large-long urban tunnel; openings on the ceiling; natural ventilation

隧道中泡沫混凝土抗震性能的研究

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摘　要：在过去的 20 年里，泡沫混凝土因其独有的性质，越来越多的应用于地下工程中。为促进泡沫混凝土在隧道工程中的发展与应用，首先对泡沫混凝土的发展与抗震机理进行了探讨，然后，分析了泡沫混凝土的物理力学特性，并总结了影响泡沫混凝土抗震性能的主要因素：水灰比、外加剂和泡沫混凝土的孔隙状态。最后，提出了提高泡沫混凝土抗震性能的建议，为进一步提高泡沫混凝土抗震性能，加强隧道稳定性提供参考和借鉴。

关键词：地下工程；隧道工程；泡沫混凝土；抗震性能

Research on Aseismic Behavior of Foam Concrete in Tunnel

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Abstract:

In the past 20 years, foam concrete has been applied to underground engineering more and more because of its unique properties. In order to promote the development and application of foam concrete in tunnel engineering, the development and anti-seismic mechanism of foam concrete are discussed first. Then, the physical and mechanical properties of foam concrete are analyzed, and the main factors affecting the aseismic performance of foam concrete are summarized: water cement ratio, admixture and the pore of foam concrete. State. Finally, suggestions for improving the performance of foamed concrete are put forward, so as to provide references for further improving the seismic performance of foam concrete and strengthening tunnel stability.

keywords: underground engineering; tunnel engineering; foam concrete; seismic performance

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地震荷载作用下地铁车站变形缝动力响应分析

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摘　要：为探究不同震级强度作用下地铁车站设置变形缝后的结构抗震性能，采用三维有限元方法，对地铁车站设置变形缝与未设置变形缝的结构体系位移变化规律及受力特征进行了对比分析。结果表明：变形缝设置使车站结构受力状态得到改善，大震、中震和小震作用下最大应力值与未设置变形缝时相比减小系数分别为 13.5%、21.3%和 40.2%。变形缝对车站结构的影响与不同震级强度有关，小震下，变形缝对车站结构位移和受力的影响基本可以忽略；中震和大震下，顶点有无变形缝对结构位移影响差异明显，设置变形缝时顶点各个方向的位移明显比无变形缝大，其中 Y 方向的位移值比 X 和 Z 方向的位移相对较大；随着震级强度的增加，变形缝的影响作用越明显。

关键词：变形缝

Ynamic Response Analysis of Deformation Joints of Subway Station Under Seismic Loading

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（Chang'an University　China University of Mining and Technology）

Abstract:

To investigate the performance of subway station structure on different seismic after set deformation joint, a study on structural system displacement and stress characteristics of the deformation joint model and the non-deformation joint model was performed by three dimensional finite element method in Xi'an subway station. The results shows that the stress state of the station structure is improved by setting deformation joints. The reduction coefficients of the maximum stress under large, moderate and small earthquakes are 13.5%, 21.3% and 40.2% respectively compared with those without deformation joints. The influence of deformation joints on the displacement and stress of the station can be ignored at small earthquake. Under the moderate earthquake and the large earthquake, the influence of deformation joints on the displacement of the structure is obvious. Moreover, when set deformation joints the displacement of each direction of the vertex is obviously larger than that without deformation joints. Compared with the non-deformation joint, the displacement value of each direction of the station is increased.The displacement value in the Y direction is larger than that of X and Z. Moreover, the effect of the deformation is more obvious with the earthquake amplitude increasing.

keywords: deformation joint

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地下工程抗震研究方法及现阶段发展综述

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摘　要：地下结构抗震研究是当今的一个热点问题，在国家不断的加大地下交通设施建设的力度之下，作为生命线工程的地下结构，对其进行抗震分析至关重要。由于受到周围岩土体的约束作用，使得地下结构的分析方法与地上结构截然不同。针对此问题，国内外的相关学者开展了一系列的研究工作。在前人研究的基础之上，详细总结目前地下结构抗震分析方法，并对各方法的优缺点进行简要介绍，以期为相关研究工作提供有益的参考。

关键词：地下结构 抗震 分析方法 研究现状

Seismic Research Method of Underground Engineering and Its Current Development

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Abstract:

the aseismic research of underground structure is a hot issue at present. Under the continuous strengthening of the construction of underground transportation facilities, the seismic analysis of the lifeline engineering is very important. Due to the constraint of surrounding rock and soil, the method of underground structure analysis is quite different from the ground structure. In view of this problem, scholars at home and abroad have carried out a series of research work. On the basis of previous research, the seismic analysis methods of underground structures are summarized in detail, and the advantages and disadvantages of various methods are briefly introduced in order to provide useful reference for the relevant research work.

keywords: underground structure; anti-seismic; analysis method; research status

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Study on Wavelet Method of Work-Velocity Ratio Curve for Demarcating Surrounding Rock

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Abstract: It is convenient and important to introduce the work-velocity ratio[1] into the prediction of advanced borehole parameters for the demarcation of surrounding rock sections, but there are some difficulties in accurate classification of surrounding rock lithology and structure. In this paper, the wavelet analysis method is introduced to study the work-velocity ratio curve. The results show that through wavelet transform analysis of the work-velocity ratio curve by using the Mexihat wavelet basis, primary demarcation of surrounding rock determined based on the time-frequency chromatogram and zero-crossing point of wavelet coefficient achieves better classification of surrounding rock lithology and structure, and is superior over borehole coring and TSP regarding the classification accuracy.

Key words: advanced horizontal drilling;work-velocity ratio;wavelet transform; wavelet coefficient

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TST 超前地质预报方法及其在黄猄岭隧道中的应用

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摘　要：TST 技术是一种较为先进的隧道超前地质预报方法，首先详细介绍了其原理，进而将这种技术应用于黄猄岭隧道左线进口 ZK155+969～ZK156+069 段。根据隧道超前地质预报结果，掌子面后方的岩体波速图像与地质构造图像有很好的对应性，掌子面后预报段地质类型情况可细分为 3 段，这与后期隧道开挖的实际地质情况吻合良好，是 TST 技术的一次成功应用。

关键词：TST 技术；黄猄岭隧道；超前地质预报

TST Advanced Geological Forecast Method and Its Application in Huang Jing Ling Tunnel

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Abstract:

TST Technology is one of the relatively advanced Comprehensive Advanced Geological Forecasts; firstly we introduces the detailed principle of TST Technology, and then TST Technology was applied to the ZK155+969～ZK156+069 of Huang Jing Ling Tunnel left-hand lane. According to the results of Huang Jing Ling Tunnel Comprehensive Advanced Geological Forecast, rock mass velocity and geological structure after tunnel face have good parallelism, and geological type after tunnel face was divided into three parts which is completely consistent with actual geology of the subsequently excavated tunnel, so it is a successful application of TST technology.

keywords: TST Technology;Huang Jing Ling Tunnel;Advanced Geological Forecast

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基于理想点法的岩溶隧道突涌水灾害风险辨识 及其工程应用

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摘　要：岩溶隧道突涌水灾害已成为我国岩溶地区隧道建设过程中最严重、最常见的地质灾害之一。基于理想点法的基本原理，综合分析岩溶隧道突涌水灾害影响因素的基础上，选取地层岩性、不良地质、地下水位、地形地貌、岩层产状、围岩级别、层面与层间裂隙、可溶岩与非可溶岩接触带等 8 个关键致灾因子建立评价指标体系，采用频数统计法与层次分析法对各评价指标进行综合赋权，建立突涌水风险等级及基于理想点法的风险辨识模型。最后，将其应用于渝怀线圆梁山隧道 PDK354+220～PDK354+245 段及翻坝高速公路鸡公岭隧道 ZK19+500～ZK19+539 段的突涌水风险辨识。研究表明，预测结果与实际情况相吻合，证明应用理想点法进行突涌水风险辨识具有一定价值。

关键词：岩溶隧道，突涌水灾害，理想点法，风险辨识。

Risk Differentiation of Water Inrush in Karst Tunnels Based on Ideal Point Method and Engineering Application

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Abstract:

The water inrush has become one of the most serious and common disasters in the construction of karst tunnel. Based on the ideal point method, a model for risk differentiation and classifying of water inrush was established. Considering the key affecting factors of water inrush comprehensively, 8 key factors were selected as evaluation indexes including formation lithology, unfavorable geology, groundwater level, topography and geomorphology, contact zone of dissolvable and insoluble rocks, layer and interlayer fissures whose weights determined by frequency statistic method and AHP. Finally, the model was applied to Yuanliangshan Tunnel of Yuhuai railway and the Jigongling Tunnel of the Fanba expressway. The research shows that the prediction results are in good agreement with practical situation of risk level and the prediction model is reliable.

keywords: karst tunnel, water inrush, ideal point method, risk differention

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基于 BP 神经网络的溶洞规模预测及应用

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摘　要：复杂岩溶地区的溶洞发育规模受地质构造、地区岩性、地下水动力系统等多种因素的影响，具有高度复杂性和非线性的特征。通过对岩溶区溶洞的赋存规律研究，确定影响溶洞发育规模的控制因素进行定量处理，收集已探明溶洞的样本数据。为克服已有研究对溶洞发育规模定性描述的模糊性，本文利用 BP（Back Propagation）神经网络对自组织、自适应特性对数据样本的非线性关系揭示的能力，实现对溶洞发育规模的预测。并基于 MATLAB 实现 BP 神经网络结构的设计、训练、预测。结果表明：BP 神经网络模型对溶洞规模预测的精度高、收敛性能好。

关键词：溶洞、赋存规律、BP 神经网络、规模预测

Forecasting Model for the Scale of Karst Cave Based on the Back Propagation Artificial Neural Network

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Abstract:

In complex karst region, the scale of karst caves is affected by the characteristics of geological, properties of soluble rock and groundwater hydrodynamic. This influencing factors presented high complexity and nonlinearity. Thought by studying the karst caves occurrence regularity, the controllable factors have been defined. And, a lot of samples date have been collected for studying. In order to overcome the fuzziness qualitative description for the formation of karst cave, this paper adopts Back Propagation (BP) Artificial neural network to realize the forecasting for the scale of karst caves. The features of the BP neural network are self-organization and self-adaptive, which is able to handle the nonlinearity samples date. The BP neural network is designed, trained, and forecast based on the MATLAB R2012a software. The results show that BP artificial neural network forecasting model for the scale of karst cave is high accuracy and good convergence.

keywords: karst cave; occurrence regularity; BP neural network; scale forecast

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Research on Application of Dynamic Weight on the Evaluation of Rock Quality

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Abstract: Due to weaknesses from traditional grading system, the evaluation ignores the impact of uncertainty, complexity and ambiguity on the classification of rock mass surrounding tunnels. The calculation of traditional weight is only interested in the selection of evaluation index rather than expert on the self-adjustment with changes in weight in total. As consequences, results from the traditional grading system behave inconsistent with the actual results of the assessment. To solve this issue, the dynamic weight and extension methodology are introduced to improve the evaluation of rock quality. To cooperate with the variation in weight, the standard evaluation index needs to be dealt to avoid the subjectivity of the evaluation process. Meanwhile, evaluation object is enabled to actively participate the comprehensive assessment. The sample level could be evaluated by the calculation results of variable eigenvalue of the object class. The method can avoid the disadvantages during the calculation of weight. Also, it can fully reflect the impact on rock mass when the same factor has different data for the evaluation results more reasonable. Therefore, the evaluation results are more reasonable. Finally, result from studies of tunneling projects shows that factors affecting the weight have a dynamic property. Even if evaluation factors are same, the values of weight will also alter with the different value of factors. Then the evaluation results of rock mass must be different.

Key words: factors; dynamic weight; extension theory; tunnels; classification of surrounding rock

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基于激光点云的隧道危石识别与稳定性判识方法及工程应用

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摘　要：三维激光扫描技术在工程危石识别中的作用日趋明显，为提高识别效率和准确率，提出一种与点云技术相配套危石分析方法显得尤为重要。本文基于三维激光扫描技术在岩体结构面识别领域的研究基础，提出一种依靠激光点云技术的危石识别与稳定性分析方法。该方法首先提出了封闭性危石体的计算方法，随后将块体理论与点云技术相结合，利用点云的高密度特征，将传统危石的矢量分析方法转换到三维点云空间坐标中，直接利用三维激光扫描系统内置坐标系，提取危石各角点 X，Y，Z 坐标值，进行空间量化比较分析，进行关键危石判定及其相应的失稳方式的判识，实现危石在几何尺度上的可动性识别与稳定性分析。主要概述了封闭危石体的识别、关键危石的可动性识别以及坠落型、单面滑移型、双面滑移型三种危石失稳模式的判定方法，并运用 C++及 OpenGL 语言编程，实现该方法的可视化分析过程。最终将该方法用于实际工程中，获得了良好效果，证实了该方法的有效性，对于以后工程应用具有重要意义。

关键词：隧道工程；危石识别；稳定性分析；激光点云；块体理论。

Identification and Stability Identification of Tunnel Dangerous Stone Based on Laser Point CloudMethod

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Abstract:

The role of 3D laser scanning technology in the identification of dangerous rock in engineering is becoming more and more obvious. In order to improve the recognition efficiency and accuracy, it is particularly important to propose a method of matching dangerous stones with point cloud technology. Based on the research foundation of 3D laser scanning technology in the field of rock mass structural surface identification, this paper proposes a dangerous stone identification and stability analysis method based on laser point cloud technology. This method first proposes a calculation method for closed dangerous rock bodies and combine the block theory with the point cloud technology and use the high-density features of the point cloud to transform the traditional vector analysis method of dangerous stone into the 3D point cloud space coordinates. The method utilizes a built-in coordinate system of the three-dimensional laser scanning system to extract X, Y and Z coordinate values of each corner point of the dangerous stone. Then it carries out spatial quantitative comparison analysis to identify key critical stones and identifies the corresponding instability methods. Finally it realizes the mobility identification and stability analysis of dangerous stone on the geometric scale. It mainly summarizes the identification of closed dangerous stone bodies, the movable identification of key dangerous stones, and the determination methods of three

types of dangerous rock instability modes: falling type, single-sided sliding type and double-sided sliding type. Using C++ and OpenGL language programming realize the visual analysis process of this method. Finally, the method is applied to practical engineering, and good results are obtained, which proves the effectiveness of the method and is of great significance for future engineering applications..

keywords: tunnel Engineering; Rockfall identification; Stability analysis; Laser point cloud; Block theory

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Intelligent Evaluation System of Water Inrush in Roadway (Tunnel) and its Application

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Abstract: Risk assessment of mine water inrush is a complicated theoretical and technical problem that is concerned with hydrogeology conditions, engineering geology, mining conditions, rock mechanics, etc. To address this problem, a software system for risk assessment of mine water inrush was established. From the matter - element extension theory, combined with the entropy - weight method, a matter - element extension entropy - weight model was constructed to evaluate mine safety. Eleven indices were determined based on the principles of science, rationality, operability, and representation, and each index was quantitatively graded. This system had built-in abundant cases of typical mine water inrush, so users could determine the value of the parameter according to the analogy of water inrush cases with similar conditions. Combined with analysis of typical water inrush cases, a database of water control measures with a strong advisory function was established. Finally, through the case study of a typical mine, it was found that the results of this study agreed with the practical ones, indicating that this system can improve the accuracy and availability of risk assessment of mine water inrush.

Key words: roadway (tunnel) water inrush;matter-element extension entropy-weight model; risk assessment; software design; engineering application

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Improved Attribute Interval Evaluation Theory for Risk Assessment of an Underground Geological Disaster and Its Engineering Application

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Abstract: Based on the theory of attribute mathematics, this paper improves on the attribute interval evaluationtheory. The main feature is that the evaluation index is an intervalrather than a certain value.Usingsingle index attributeanalysis of the upper and lower limits of the interval, the paper proposes two calculation methods for the multiple indexsynthetic attribute measure. Based on the original AIET software, we develop a new set of software packages (NEWAIET) that can automatically complete a large number of calculations in a few seconds. Via engineering application,the accuracy and feasibility ofgeological disaster risk assessment are verified and can be used to better evaluateengineering disaster risk.

Key words: risk

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考虑岩体环向作用的浅埋隧道压力拱极限平衡高度公式改进及应用

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摘　要：基于普氏压力拱理论，对传统的地层应力分布方式进行改进，采用环形分布方式施加地层应力，构建力的平衡方程，揭示了浅埋隧道压力拱极限平衡高度与和隧道开挖高度、跨度等参数的关系，得到了考虑岩体环向作用的浅埋隧道形成压力拱极限平衡高度计算公式。基于有限差分软件Flac 3D，建立了Ⅴ级围岩地质条件下的浅埋隧道三维计算模型并模拟隧道开挖，得到地层竖向应力、最大主应力与隧道埋深的关系曲线，确定了压力拱极限平衡高度，分析了计算误差，验证了计算公式的准确性。

关键词：压力拱；极限平衡高度；浅埋隧道；有限差分。

Improvement and Application of Limit Equilibrium Height Formula of Shallow Buried Tunnel Pressure Arch Considering Hoop Direction of Rock Mass

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Abstract:

Based on the Platts pressure arch theory, the traditional formation stress distribution method is improved, the formation stress is applied by the annular distribution method, and the balance equation of the force is constructed. The limit equilibrium height of the shallow tunnel pressure arch and the tunnel excavation height and span are revealed. According to the relationship of the parameters, the formula for calculating the limit equilibrium height of the pressure arch formed by the shallow tunnel considering the circumferential action of the rock mass is obtained. Based on the finite difference software Flac 3D, a three-dimensional calculation model of shallow buried tunnel under V-level surrounding rock geological conditions was established and the tunnel excavation was simulated. The relationship between vertical stress, maximum principal stress and tunnel depth was obtained, and the pressure arch was determined. The limit equilibrium height is analyzed, and the calculation error is analyzed to verify the accuracy of the calculation formula. Based on the improved pressure arch limit equilibrium height formula, the pressure arch limit equilibrium height of the shallow tunnel section of the Lunan high-speed railway is calculated. The essential reason for the phenomenon of “sag and collapse” during tunnel excavation is analyzed. Buried tunnel construction provides an effective reference.

keywords: Pressure arch; limit equilibrium height; shallow tunnel; finite difference

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Study on the Contributory Factors of Asymmetric Deformation in deep Roadway

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Abstract: According to the asymmetric deformation of the surrounding rock in the deep roadway, five kinds of contributory factors were selected, and the varying levels of each factor were set up respectively, the surrounding rock deformation of the deep roadway under different levels of each factor was studied through the orthogonal test method. In accordance with the orthogonal design scheme, twenty-five tunnel tests were numerical simulated and analysed. Three kinds of indexes were specified to weigh the effect of various factors on asymmetric deformation of the roadway, the Extreme Difference analysis and F Statistics were built to investigate indexes' contribution of the asymmetric deformation. Besides, the asymmetry of the surrounding rock deformation was analysed. Finally, we concluded that the deformation of the surrounding rock mainly influenced by the bury depth of the roadway, and the asymmetry of the deformation was affected by the dip angle of the strata and the section height-width ratio of the roadway. The results in this paper can provide a theory basis for maintaining stability of surrounding rock in the deep roadway.

Key words: asymmetric deformation; deep roadway; contributory factors; orthogonal design

隧道岩面三维模型构建及偏差分析

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摘　要：针对传统方法测量岩体结构信息工作效率低、危险系数高且精度稳定性差的现状，对基于机器视觉的隧道岩体信息测量方法进行了研究。通过量化分析和对比试验，对测量环境和数据采集环节进行分析，研究了在隧道复杂环境下，隧道围岩三维建模的误差来源，并提出了相应的修正方法。采用修正后的测量方法，对滨莱高速工程姚家峪隧道进行了隧道岩体信息采集和稳定性分析，并取得了良好的效果。

关键词：隧道；三维模型；误差修正。

Establishiment and Error Analysis of 3D Model of Tunnel Working Face

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Abstract:

In view of the low the efficiency, high risk factor, and poor accuracy of traditional methods to measure the structural information of rock mass, a method for measuring tunnel rock mass information based on machine vision was studied. Through quantitative analysis and comparative experiments, the environment factors and work process were analyzed, the error sources of 3D model of tunnel surrounding rock under the complex tunnel environment were studied, and corresponding correction methods were proposed. Using the revised measurement method, the tunnel rock mass information acquisition and stability analysis was carried out in Yaojiayu tunnel of Bin Lai high-speed project, and good results were obtained.

keywords: tunnel; 3D model; error correction

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Model test and Numerical Simulation Research of Water Leakage in Operational Tunnels Passed Through Intersecting Faults

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Abstract: During the operation of Kaiyuan Tunnel, water leakage from the lining frequently occurs in the rainy season, and this has a serious impact on the safety of the tunnel structure. To study the occurrence mechanism and evolution law of water leakage in operational tunnels caused by intersecting faults under different burial depth, both large-scale 3D physical model test and numerical simulation were carried out. The results of the water leakage volume, vertical displacement and hydraulic pressure of the monitoring sections in the physical model and numerical model were analyzed. It is shown that the vertical displacement and hydraulic pressure in the model increase with the increase of the applied load and water pressure. Because the better water conductivity and lower strength of the intersecting faults, the influence of intersecting faults on tunnel water leakage is higher than that of surrounding rock. The intersecting faults have a hydraulic connection, and the main fault plays a major role in the seepage of groundwater. The results show that the internal defects of lining and quality defects of tunnel construction are the main factors leading to the water leakage in operational tunnels, and the uneven settlement is another important factor affecting the crack and leakage of lining in operational tunnels. Finally, some useful suggestions and conclusions for tunnel construction and operation were obtained from the test results.

Key words: water leakage; operational tunnel; model test; numerical simulation

青岛地铁工程渗漏水处置关键技术

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摘　要：青岛具有典型的岩土二元复合地层结构，地铁线路广泛穿越第四系砂土层、强风化花岗岩等不良地质体，地下水较为丰富，地铁建设深受涌水溃砂、裂隙涌水及衬砌渗漏水等水害威胁！在施工过程中，采用劈裂—压密注浆技术、模袋桩技术、钢花管注浆技术等技术，并将自动化实时监测技术应用到地铁隧道的开挖建设中，有效的治理富水砂层涌水流砂灾害。运用地质雷达及钻孔影像技术全方位的探明了裂隙富水区域，在裂隙深部涌水点进行环形注浆，针对围岩裂隙采用径向群孔注浆，对浅层裂隙及初期支护背后实施充填注浆，针对难以根治的滴水点，使用环氧树脂进行针对性治理，有效的解决了地层裂隙水及衬砌渗漏水问题。

关键词：富水砂层；裂隙涌水；衬砌渗漏水；地下水；固结注浆。

Key Technology of Seepage and Leakage Disposal in Qingdao Metro Project

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Abstract:

Qingdao has a typical dual stratigraphic structure of soil and rock. The subway line passes through the fourth series sand and soil layer, strong weathering granite and other bad geological bodies. Groundwater is abundant and subway construction is threatened by water hazards such as sand erosion, water bursting in cracks and seepage in lining. In the construction process, the technology of split compaction grouting is adopted, such as die bag pile technology, steel tube grouting technology, etc., and the technology of automatic real-time monitoring is applied to the excavation construction of subway tunnel. Effective control of water - rich sand - bearing sand - bearing sand disaster. The water - rich area of fissures was found by using geological radar and borehole imaging technology. Using geological radar and all-round exploration borehole imaging techniques, at deep fissure water ring grouting, in view of the surrounding rock fracture by the radial hole grouting, the shallow fissure filling grouting behind and initial support, in view of the drop point is difficult to cure, using epoxy resin for targeted treatment, and effectively solve the ground fissure water water leakage, lining fissure water rich area.

keywords: water-rich sand stratum;fracture water gushing;lining Leakage; groundwater; consolidation grouting

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一种新型大流量注浆泵送装备的试验研究

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摘　要：注浆泵送装备输浆流量小、效率低是目前岩溶地区大流量突涌水治理面临的重大难题之一。基于已成功研发的新型大流量注浆泵送装备，研制了一套适用于测试分析该装备性能参数和工程适用性的室内试验系统，该系统由多元信息参数采集装置、大型制浆储浆设备和循环耐压输浆管路等组成，可实现大流量、多参数下持续性测试，获取流量、压力、不均匀系数、容积效率及机械效率等关键指标参数及其影响因素。依托试验测试系统开展充填注浆模拟试验，试验结果表明：该新型注浆装备可实现 0~35 m3/h 内流量无级调节，最佳输出转速 780 r/min。相较现有三缸往复式注浆泵，其流量不均匀系数降低 60%，机械效率提高 22%，具有流量大、脉冲小、能耗低及重量轻等显著特点。在室内试验基础上，通过现场试验进一步验证了该新型注浆装备的可靠性和适用性。研究成果对隧道与地下工程灾害处治注浆装备的研究与发展具有一定借鉴意义。

关键词：灾害治理；注浆装备

Experimental Research on a New Large Flow Grouting Pumping Equipment

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（Shandong University）

Abstract:

The small flow and low efficiency of the current grouting pumping equipment is the major problems of the water inrush grouting engineering in karst areas. Based on the new large flow grouting pumping equipment which has been developed successfully, an indoor auxiliary test system for analyzing the new equipment was developed. The system includes real time multi-parameters monitoring device, large slurry-making and storage device, and cyclic withstand slurry pipeline. It can satisfy the test demand of large flow, multi-parameters and circulation. The key parameters of discharge, pressure, uneven coefficient, volumetric efficiency and mechanical efficiency were obtained. The simulation experiment of filling grouting was developed by this test system. Test results show that: the new grouting equipment has a output flow within 0~35 m3/h, which can be stepless adjustment; its best output speed is 780 r/min; Compared with the existing three cylinder reciprocating grouting pump, the flow unevenness coefficient of the new pump reduced by 60%, the mechanical efficiency increased by 22%.

keywords: disaster control; grouting equipment

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一种新型综合注浆加固试验系统的研制及应用

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摘　要：针对现有注浆加固试验装置难以平衡高压注浆所需密封效果和多功能试验所需空间结构的缺点，研制了一套新型多功能综合注浆加固试验系统。该试验系统的优点为：1）尺寸适中、结构合理，既具有布设监测元件的试验空间又具有良好的密封效果；2）适用范围广，可针对不同岩土体介质开展多类注浆加固试验；3）具备多元物理信息并行采集功能；4）可同时满足加固体宏观物理力学性质测试及浆-岩界面微观耦合机制的研究需求。该系统成功应用于断层角砾岩体注浆加固室内模拟试验，分别从应力响应-传递特征、加固体强度增长规律及加固模式等方面探究了断层角砾岩体的注浆加固机理，提出了角砾岩体强度增长的经验公式，揭示了加固过程中注浆压力的传递分配机制。

关键词：断层角砾；注浆加固

Development of New Comprehensive Grouting Reinforcement Test System and Its Application

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Abstract:

The existing grouting test devices hardly satisfy the need of the sealing effect or experimental space for multifunctional test at the same time. Based on the weakness of current devices, a new comprehensive grouting reinforcement test system was developed. The major advantages of this system include: 1) The device has the characteristics of moderate size and reasonable structure which can realize the properties of large experimental space and good sealing property; 2) The device can realize the simulation of different groundwater environment and grouting conditions for different rock soil medium; 3) Multiple physical information can be obtained for researching the space-time response law of reinforcement parameters; 4) The test of compressive strength and shear strength of grouting solid and microscopic coupling mechanism of slurry-rock interface can be studied simultaneously. The orthogonal test of grouting reinforcement for fault breccia was designed using the device. The grouting reinforcement mechanism of fault breccia was studied from the aspects of the stress response-transfer characteristics, the growth law of solid strength and the reinforcement mode. The test results show that the fault breccia is mainly reinforced by permeation grouting, and the grouting reinforcement model was divided into three types including substrate type, micro-splitting type and significant splitting type.

keywords: fault breccia; grouting reinforcement

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一种均匀粘性土粘聚力计算方法

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摘　要：粘聚力是粘性土的重要力学性能参数，土的密度、孔隙比是影响粘聚力的重要因素，而密度、孔隙比变化时土的粘聚力变化难以估算，本文依据固体颗粒分子吸引力理论，研究了均匀粘性土粘聚力随孔隙比及干密度的变化规律。以颗粒均匀的粘性土为研究对象，将土体简化为由土颗粒与粒间孔隙两部分、依靠土颗粒间吸引力连接而成的整体，粘聚力被简化为单位面积上土颗粒间吸引力的合力；在此基础上，提出了均匀粘性土孔隙结构模型，推导了土颗粒净距与土体孔隙比的函数关系，分析了土颗粒净距随孔隙比的变化规律。根据 Lifshitz 固体颗粒分子吸引力理论，建立了均匀粘性土粘聚力与干密度、孔隙比之间的函数关系，据此提出了一种考虑密度、孔隙比变化的均匀粘性土粘聚力计算方法。通过均匀细粒土的直剪试验测得了不同含水量下的粘聚力，将理论计算结果与直剪试验结果相对比，验证了提出的粘聚力计算方法的合理性。研究结果表明：均匀粘性土颗粒净距与孔隙比正相关，但随孔隙比增大，其对土颗粒净距的影响逐渐减小；粘聚力与干密度正相关，与孔隙比负相关；且随干密度的增大，其对粘聚力的影响更加显著。

关键词：孔隙比；直剪试验

A Method for Calculating the Cohesive Force of Uniform Cohesion Soil

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Abstract:

Cohesive force is an important mechanical parameter of cohesive soil, and density and void ratio of soil are important factors affecting its cohesion, but the cohesion force of cohesive soil is difficult to estimate, while its density and void ratio have changed. With the theory of molecular attractive forces between solids, the functional relationship between soil cohesion and its dry density or void ration is analyzed. To establish the conceptual model of pore structure in cohesion soil, the uniform cohesive soil is simplified into a combination of soil particles and pores, in which the soil particles are connected into a whole by molecular attractive forces; and the soil cohesion is simplified into the resultant force of molecular attractive forces per unit area. On the base of the conceptual model, the relationship between soil particle spacing and soil void ratio is built, and the influence of void ratio on soil particle spacing is analyzed. According to the theory of molecular attractive forces between solids established by lifshitz, the functional relationship between soil cohesion and its dry density or void ration is established, and a mathematic method for calculating the cohesive force of uniform soil is derived. The calculation results of the cohesive force are compared with that of the direct shear test, and the rationality of the proposed method is verified. The results show that, the soil particle spacing is positively correlated to void ratio, as the void ratio

increasing, its influence on soil particle spacing gradually decrease; the cohesion force of uniform soil is positively correlated to dry density, and negatively correlated to void ratio. At the same time, the effect of dry density on cohesive force is more significant with its increase.disaster treatment.
keywords: void ratio; soil particle spacing

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Detection and Treatment of Water Inflow in Karst Tunnel: A Case Study

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Abstract: In karst tunnel, fissures or cracks filling with weathered materials are a kind of potential water outlets for they are easy to be triggered and converted into groundwater outlets under the influence of high groundwater pressure. Terrible water inrush caused by potential water outlets can seriously hinder the construction of project. For the treatment of water inflow, potential water outlets and water sources surrounding the tunnel must be detected first. This paper provides a successful case of detection and treatment of water inflow in a karst tunnel and a potential water outlet detection (PWOD) method is proposed in which a heavy rain (>50mm/d) is considered as the trigger for potential water outlet. The Daba tunnel located in hunan province, China, is constructed in karst stratum, the rockmass is weathered intensely by the influence of two faults. After a heavy rain, some potential water outlets were triggered, as a result a serious water inrush occurred. For the treatment of water inflow, the PWOD method was applied to this project, and a total of 6 potential water outlets were identified through 3 heavy rains. At the same time, geophysical prospecting technique was also used for detection of water sources. With a 3-D graphic including all water outlets and sources, connections between them were identified. According to the distribution of water outlets and sources, the detection area were divided into 3 sections and separately treated by curtain grouting.

Key words: Karst tunnel; potential water outlet detection

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非开挖施工引起地表沉降及影响因素定量研究——以北京市为例

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摘　要：道路非开挖施工会引起路基沉降不均，产生路面病害，影响行车安全以及交通畅通等问题。基于随机介质理论和 peck 经验公式，本文从地层条件和施工方法两个维度探索影响地表沉降的主要因素，采用 2012－2018 年朝阳、密云、怀柔和昌平 4 个区、122 个样本非开挖工程的跟踪监测数据。该数据集详细记录了沉降监测值、施工方法、覆土深度、管径大小、移动荷载和管内注浆等数据。对该数据集运用多元线性回归模型，分析影响地表沉降的主要因素。研究结果显示：内摩擦角、人工顶管和移动荷载对地表沉降产生正向显著影响；管道覆土深度和管内注浆对地表沉降具有负向显著作用。因此，采用掘进速度快的机械顶管法、增加管线埋深、导改分流移动荷载和及时管内注浆能有效减小非开挖施工引起的地表沉降。

关键词：隧道工程；非开挖技术；实证研究；地表沉降；随机介质理论；peck 经验公式

The Effect of Trenchless Construction on Surface Subsidence-A case Study of Beijing

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Abstract:

The trenchless construction of road will cause uneven settlement of subgrade to appear the pavement distress, which affects the traffic safety and the traffic flow. Based on the stochastic medium theory and the Peck Formula, combing stratum condition and construction method, this paper analyzes the main factors that lead to ground subsidence with a dataset from 122 trenchless construction samples in four districts of Beijing (Chaoyang, Miyun, Huairou, and Changping). The dataset observes ground subsidence, construction method, overburden layer depth, pipe diameter, moving load and grouting, etc. Multiple linear regression model was built to analyze the factors influencing ground subsidence. From statistics of the regression model, there is significant evidence that the angle of internal friction, pipe-jacking technique and moving load are positively correlated with ground subsidence. On the other hand, the depth of overburden layer and grouting have negative correlation with the settlement. Therefore, applying high-speed mechanical pipe jacking, deep pipeline burying, moving load diverting, and timely pipe grouting can effectively reduce the ground subsidence due to trenchless construction..

keywords: tunnel engineering; trenchless technology; empirical research; surface subsidence; stochastic medium theory; peck empirical formula

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径向非均匀脉冲荷载作用下隧道衬砌的动力响应

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摘　要：基于弹性动力学-Flügge 薄壳理论，采用解析法研究了径向非均匀瞬态脉冲荷载下全空间隧道衬砌的动力响应。衬砌采用 Flügge 薄壳理论模拟，土体采用弹性介质动力学理论模拟，通过波函数展开法与 Laplace 变换法及数值逆变换，结合土体-衬砌应力协调条件以及衬砌内表面应力边界非均匀条件，得到隧道在二维空间中应力和位移场在时域内的数值解。并通过算例，分析了衬砌与土体相对刚度、衬砌厚度、不同角度等对径向和环向上应力位移场的动力特性影响以及不同径向位置随时间的波动特性。研究结果表明：随着衬砌与土体的相对刚度增大，位移与应力响应幅值逐渐减小，当相对刚度 I*从 10-100 ，位移与应力的瞬态响应降低近 50%；在非均匀瞬态荷载作用时，衬砌外径与内径比对位移响应有显著影响，且随衬砌厚度增大，不同角度上位移响应衰减存在差异；当无量纲时间 t*>8 时，环向与径向应力几乎衰减至 0，应力响应峰值在 1 至 2 倍洞径位置急速衰减，随时间与土中径向位置改变，应力拉压状态发生变化。

关键词：瞬态荷载

Dynamic Response of Tunnel Lining UnderRadial Non-Uniform Impulse load

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Abstract:

Based on the elastic dynamics-Flügge thin shell theory, the dynamic response of tunnel lining in full space under radial non-uniform transient impulse loading is studied by analytical method. The lining is simulated by Flügge thin shell theory, the soil is simulated by elastic medium dynamics theory, and the stress and displacement fields of tunnel in two-dimensional space are obtained in time domain through wave function expansion method, Laplace transform method and numerical inverse transformation, combined with soil-lining stress coordination conditions and non-uniform stress boundary conditions on lining inner surface. Numerical solution within. The effects of relative stiffness of lining and soil, thickness of lining and different angles on the dynamic characteristics of radial and annular stress and displacement fields and the fluctuation characteristics of different radial positions with time are analyzed through an example. The results show that with the increase of the relative stiffness of lining and soil, the amplitude of displacement and stress response decreases gradually. When the relative stiffness is from 10 to 100, the transient response of displacement and stress decreases by nearly 50%. Under the action of non-uniform transient load, the ratio of outer diameter to inner diameter of lining has a significant influence on displacement response, and increases with the thickness of lining. When the dimensionless time , the

circumferential and radial stresses almost decay to 0, and the peak stress response decreases rapidly from 1 to 2 times the diameter of the hole. With the change of time and the radial position of the soil, the stress tension and compression state changes.

keywords: transient response

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Estimation of the Ground Settlement Induced by the Tunnel Excavation in Changchun, China

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Abstract : This study investigates an estimation model of ground settlement caused by excavation of tunnels with a horseshoe-shaped cross section. The ground settlement data of the construction of section 4 of the first subway line in Changchun were analyzed, and obtain the characteristics of the ground settlement caused by the double line tunnels with a horseshoe-shaped cross section. A model based on the simplified equation of the stochastic medium theory is established. The formula for parameter r(H) was derived. The parameters of the model are obtained by linear regression analysis of the ground settlement data. Based on the linear regression analysis results of the monitoring data, the distribution laws of the parameters in the model are obtained. The primary distribution range for tan β in the Changchun area is 0.9 - 1.6, and the recommended value for △A is 8—22 mm (β is the angle between the slip surface and horizontal plane and △A is the uniform convergence value of the tunnel cross section). Further analysis of the proposed model indicates that with a good choice of parameters, a good estimate of the ground settlement can be obtained.

Key words: tunnel excavation, ground settlement,stochastic medium theory,estimation model, calculation parameters

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断层破碎带隧道围岩稳定性的离散元模拟研究

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摘　要：断层破碎带是隧道施工中常见的不良地质体之一，容易导致隧道围岩失稳甚至塌方等问题，为了分析其对隧道围岩稳定性的影响规律，本文依托港珠澳大桥连接线南湾隧道，利用离散元软件 PFC2D 建立二维分析模型，结合施工监控量测结果，得出了以下结论：（1）断层破碎带作用下隧道围岩应力呈非对称性，当断层位于受拉一侧时，断层对隧道水平位移的影响更为明显。（2）当断层穿越隧道轮廓面时，断层对隧道围岩竖直方向位移的影响比水平方向位移更加显著。（3）对比断层比邻与穿越隧道两种情况，断层与隧道相交时的最大潜在松动破坏区是未相交时的最大坍塌区域的 2 倍以上。（4）现场监测结果表明，当断层与隧道边墙位置相交时，该断面的位移最大且相比其他断面位移值明显增大，几乎是其他断面相同位置位移的 2.5 倍。

关键词：松动破坏区

Study on Discrete Element Simulation of Tunnel Surrounding Rock Stability with Fault Fracture Zone

Huang Feng, Li Tianyong
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Abstract:

The fault fracture zone has obvious anisotropy and heterogeneity, which leads to the instability and even collapse of surrounding rock. By taking the Nan-wan tunnel along the connecting line of Hong Kong-Zhuhai-Macao bridge as the background , analyzed the influence law of the fault fracture zone on the stability of tunnel surrounding rock. Research shows that: (1) The stress of tunnel surrounding rock is asymmetrical，When the fault is on the pulled side, the effect of the fault is more obvious on the horizontal direction displacement of the tunnel.(2) The influence of fault on the vertical displacement of tunnel surrounding rock is more obvious than that of horizontal direction displacement when the fault passes through the contour surface of the tunnel. (3) Contrasting the two conditions of fault drawing near and crossing tunnel，The maximum potential loosening failure area of the intersection of fault and tunnel is more than twice collapse area of the non-intersection of fault and tunnel.（4）Field monitoring results show that the largest displacement of the section with the obvious increase of displacement is almost 2.5 times of that of other sections when the fault intersects the tunnel side wall , which has the same results using PFC2D analysis that the collapse area area of the section with the obvious increase of collapse area is almost 2 times of that of other sections when the fault intersects the tunnel side wall.

keywords: loosening failure area

Analysis of the Causes of Forming the Confined Water Channel Under the Metro Passing Through Reinforced Structures

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Abstract: Underground water gushing is an important problem affecting the safety of tunnel excavation and operation. This paper analyzes the problem of "water bladder" encountered in Hangzhou metro after the reinforcement of the structure under the railway station, and studies the cause and formation mechanism of the problem. According to the field investigation and geological conditions, the theoretical grouting pressure was calculated. The possibility of problems caused by phreatic water was excluded after the comparison with the actual grouting pressure. Based on the analysis of the mechanism of confined water, combined with the failure mode of water seepage in the pipe segment, the confined water was confirmed to be the cause of the problem. On this basis, the reason for the formulation of confined water channel is put forward. The difference of settlement between the reinforced structure and the soft stratum is the reason for the formation of confined water channel. This hypothesis is mainly verified by comparing the numerical simulation with the field measured data. According to the analysis of the causes and action mechanism of the engineering problems, the relevant treatment scheme is put forward. The research results can be reference to the prevention of similar engineering problems.

Key words: Metro tunnels;Water bladder;Reinforced structures;Confined water channel; Numerical simulation; Case analysis

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Arching Effect and Collapse Evolution Law of Tunnel in Boulder-Cobble Mixed Formation

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Abstract: As the geological conditions encountered in tunnel construction become more and more complicated, especially in the boulder-cobble mixed (BCM) formation commonly found in river terraces. Large area collapse is easily occurred in the surrounding rock above the vault during excavation, so the tunnelling in BCM formation is very difficult. In this paper, a similar simulation test in 1g was carried out to study on the evolution of collapse during tunnel excavation and the influence of rainfall on the stability of tunnel surrounding rock. The results showed that after the tunnel was excavated, the surrounding rock had good self-stabilization ability; after adding water, the self-supporting capacity of surrounding rock decreased sharply but does not collapse immediately; in the process of collapse, the loosening zone of surrounding rock above the vault expand outward remarkably, while the loosening area of side wall basically do not expand.

Key words: Tunnel engineering;Boulder-Cobble Mixed formation;Progressive destruction; Pressure arch; Model test

黄土地区地下管廊地震横波动力响应分析

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摘　要：为了研究地震横波作用下地下管廊结构的动力响应特征，以黄土地层条件下的某双层地下管廊为背景，采用Midas软件建立了地下管廊有限元动力学模型，分析了地下管廊结构的动力响应规律。结果表明：在地震横波的作用下，地下管廊结构的相对位移、相对加速度随着埋深的减小而增大，增幅受地震波影响较大，前期剧烈，后期缓和。薄弱部位主要为管廊节点处，在地震横波作用下，发生较大应力集中现象，因此应重点进行抗震设计。

关键词：地下管廊；地震；动力响应；Midas

Seismic Shear Wave Dynamic Analysis of Underground Pipe Corridor in Loess Area

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（Chang'an University）

Abstract:

In order to study the dynamic response characteristics of the underground pipe corridor under the action of seismic shear wave, the finite element dynamic model of the underground pipe corridor was established by using Midas, and the response law of the underground pipe corridor structure was analyzed. The results show that the relative displacement and relative acceleration of the underground tube corridor structure increase with the decrease of buried depth under the action of seismic shear wave. The weak part is mainly the joints of the pipe corridor. Under the action of the seismic shear wave, there is a large stress concentration phenomenon. Therefore, seismic design should be emphasized.

keywords: Underground pipe gallery; Earthquake; Dynamic response; Midas

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裂缝长度对盾构隧道管片结构破坏模式模型试验研究

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摘　要：盾构隧道在施工或运营期间常会出现不同程度的裂缝问题，导致部分盾构隧道在建成初期即处于带裂缝工作状态，裂缝长度是评价裂缝的一个重要指标，不同长度的裂缝对结构将产生不同的影响。依托国内某地铁区间盾构隧道工程，采用相似模型试验的方法，通过对盾构隧道管片的声发射数据、管片衬砌位移及破坏过程素描等数据的分析，探明了不同裂缝长度条件下管片衬砌在外荷载作用下的力学响应及其承载性能。研究结果表明：裂缝的存在降低了结构整体刚度，裂缝长度对管片衬砌结构的力学特性具有显著影响，1/3 幅宽是裂缝长度对管片衬砌结构力学性能影响的分界点；当裂缝长度大于 1/3 幅宽时，随裂缝长度增加，相同荷载条件下管片椭圆扁平率急剧增大，结构的极限承载力逐渐降低，结构的失稳破坏趋于突发性破坏。

关键词：盾构隧道；既有裂缝；相似模型；声发射；破坏模式

Model Test Study on Failure Mode of Segment Structure of Shield Tunnel with Crack Length

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Abstract:

Various degrees of cracks often occur during construction or operation period of shield tunnels which leads to some shield tunnels operate with cracks at the early stage. Cracks with different length will have different effects on the tunnel structure. Therefore, crack length can be regarded as an important criterion for crack evaluation. Based on a domestic metro shield tunnel section project, this paper studies the mechanical response and bearing capacity of lining segments with different crack length under external loads by conducting a series of model tests and analyzing acoustic emission data, values of displacement and failure process sketch of lining segments. The results indicate that the existence of cracks reduces the overall stiffness of structure. The length of cracks has a significant impact on the mechanical properties of lining segments. The turning point for the influence of the crack length on the mechanical properties of the lining structure occurs at the 1/3 of the segment width. If the crack length is greater than 1/3 of the segment width, with the increase of the crack length, the elliptical flattening rate of the segment gains sharply under the same load. This phenomenon results in the gradual decline of the ultimate bearing capacity and the increase of the chances of sudden failure.

keywords: shield tunnel; existing crack; similar model; acoustic emission; failure mode

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水力耦合作用下含双裂隙岩体破裂行为研究

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摘　要：为研究水力耦合作用下裂隙岩体的破坏行为，基于水泥砂浆类岩石材料开展了室内水力耦合试验，并借助声发射技术，研究了水压和双裂隙空间分布特征对裂隙岩体破坏模式及力学特性的影响。研究结果表明：水力耦合作用下，随水压增大，裂隙岩体破坏模式由滑移破坏转向为劈裂破坏，最后过渡为拉剪破坏。裂隙岩体受力变形特征呈现阶段性，并且应力、水压、声发射特征数的变化规律具有相关性，可依据三者变化规律及相关性推断裂隙岩体起裂应力。裂隙间距对裂隙岩桥的贯通特征和力学特性的影响程度存在临界值。当裂隙间距 d 与预制裂隙长半轴 a 之比 d/a 在 0.25~0.75 范围内，岩桥区域内部破坏，起裂应力和峰值强度随 d/a 增大而升高；而当 d/a 在 0.75~1.25 范围内，岩桥区域外围形成贯通面，起裂应力和峰值强度随 d/a 变化不明显。岩桥角改变双裂隙岩桥重叠区域及其长轴端外围承载面积，进而分别影响岩桥贯通特征、起裂应力与峰值强度。

关键词：水力耦合；双裂隙岩体；破坏模式；岩桥贯通特征；力学特性

Research on Fracture Behavior of Rock Mass with Double 3-D Cracks Under Hydro-Mechanical Coupling

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Abstract:

In order to study the failure behavior of double fractured rock mass under hydraulic coupling, with the aid of acoustic emission technology, the laboratory tests were carried out with cement mortar rock materials. The effects of the geometric form of water pressure and fracture on the failure modes and mechanical properties of rock mass with double cracks were analyzed. The results showed that the hydraulic coupling was coupled to the hydraulic coupling. With the increase of water pressure, the failure mode of fractured rock mass is converted from sliding failure to splitting failure with the increase of water pressure. The stress and deformation of fractured rock mass presents a phase characteristic, and the variation of the stress, water pressure and acoustic emission characteristics presents a correlation. The fracture stress of fractured rock mass can be deducted according to the three law of change. There is a critical value in the influence of the distance to the length of the long semi shaft of the prefabricated fissure d/a on the connecting characteristics and mechanical properties of the rock bridge. When d/a is damaged within the bridge area within the 0.25~0.75 range, the crack stress and peak strength increase with the increase of d/a; when d/a is within the range of 0.75~1.25, the perforation surface is formed along the bridge area, and the crack stress and peak strength follow the d/a. The change is not obvious. The overlap area and the bearing area of the long axis are changed along the angle of the bridge, and then the fracture stress and the

peak strength are affected respectively.

keywords: Hydraulic coupling;Double fractured rock mass;Failure mode;Rock bridge transfixion characteristics;Mechanical properties

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某浅埋箱型地铁隧道病害成因分析及治理

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摘　要：研究目的：受侧方深基坑施工扰动影响，某浅埋明挖箱型地铁隧道出现了变形缝部位漏水漏砂、道床脱空与横向开裂、道床冒水涌砂等严重病害。本文详细描述了该地铁隧道病害的事故概况，归纳整理了主要的隧道病害及分布情况，分析探讨了病害产生的原因，为其后的病害治理提供了依据。
研究结论：隧道纵向不均匀沉降是导致漏水漏砂的主要原因，也是造成道床底部与隧道结构底板脱空、道床横向开裂及道床冒水涌砂的重要原因；水位下降诱发隧道下方地层压缩是导致隧道过大沉降和不均匀沉降的主要原因；隧道浅埋敷设与两侧回填处理不利于抵抗侧方基坑施工扰动，基坑施工诱发的地层侧移与隧道结构的侧移不协调导致隧道上方地面出现一条纵向大裂缝，为地面降水入渗提供了途径，加剧了隧道渗漏等病害。

关键词：病害治理

Causes Analysis and Treatment of Damage in a Shallow Buried Box Metro Tunnel

Liu Tingjin
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Abstract:
Research purposes: Some damages such as leakage in deformation joint, disengaging and transverse cracks in ballast, in ballast etc. have been found in the shallow buried box metro tunnel, which caused by excavation of adjacent deep foundation pit. In this paper, overview of the metro tunnel disease accident are detailed described, and then the distribution of main disease are sorted, at last, causes of tunnel disease are deeply investigated which provide reference for damage treatment.
Research conclusions: The structural differential settlement of tunnel is the main reason of leakage in deformation joint, disengaging, transverse cracks and seepage in ballast. Furthermore, the compression of layer leads to huge and uneven settlement of tunnel structure which caused by the decrease of groundwater level. As the shallow buried tunnel and its refilling treatment is weak to resist the excavation disturbance of adjacent foundation pit, a large longitudinal ground crack occurred above the metro tunnel caused by uncoordinated horizontal deformation between ground and tunnel structure, which provide penetration path for ground rainfall and aggravate the tunnel leakage.
keywords: damage treatment

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湛江湾跨海盾构隧道管片变形与受力分析

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摘　要：以湛江湾跨海盾构隧道工程为背景，应用数值分析方法，建立了单环衬砌结构的三维有限元精细模型，研究了在不同水头作用下单环管片结构以及接缝部位的变形情况。采用修正惯用法得出在最大水头作用下管片结构的内力分布，由此推出管片内、外侧的环向钢筋应力，并与现场的应力监测数据进行了对比。研究表明：（1）高水压作用下，单环管片衬砌的变形呈现“横鸭蛋形”，且管片结构变形和接缝张开量均与外水压力变化呈线性关系；（2）作用水头每增加 10m，衬砌结构中各接缝张开量绝对值约增加 0.5mm；（3）采用修正惯用法计算得到的钢筋应力与实测结果较为吻合，较好地反映了隧道管片的实际受力状态。

关键词：管片变形

Analysis on Deformation and Stress of Sea-Crossing Shield Tunnel Segment in Zhanjiang Bay

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Abstract:

Based on Zhanjiang bay tunnel project, three-dimensional finite element model of single segment structure is established to study the deformation of segment structure and joint in different water head. Then, modified routine method is adopted to analyze the stress distribution of segment structure on the maximum water head. Circumferential reinforcement stress which is calculated is compared with monitoring data. The result shows that: (1) On the force of high water head, the deformation of single segment present “horizontal oval shape”. The deformation of segment structure and the value of joint open are linear relation with change of water stress. (2) The absolute value of joint open increases 0.5mm when the water head increases 10m. (3) Reinforcement stress calculated by the modified routine method agrees with the monitoring data, this method can reflect the real stress state of tunnel segment well.

keywords: deformation of the segment

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桩锚深基坑诱发地铁盾构隧道病害的成因分析及治理

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（华南理工大学）

摘　要：研究目的：受侧方桩锚支护深基坑施工扰动影响，某地铁盾构隧道出现了严重病害，主要包括管片破损掉块、开裂、接缝渗漏、道床边沟裂开等，严重危及地铁运营与结构安全。本文详细描述了该地铁盾构隧道病害的事故概况，对隧道病害现状进行了归纳整理与分析；基于隧道周边施工历程、病害现状与相关监测数据，从桩锚支护下基坑施工扰动影响与隧道变形特性两方面初步分析了该地铁盾构隧道严重病害的成因；采用有限元数值模拟方法计算分析了该病害隧道的结构安全状况；提出了相应的隧道病害治理措施。
研究结论：邻近桩锚支护深基坑的施工扰动下锚索锚固端会形成土层松动区，降低隧道侧方的地层约束能力，诱发隧道断面呈横椭圆变形的趋势；上部荷载的增加也是导致隧道发生横椭圆变形的一个诱因。原因分析结果认为，隧道横椭圆形状的变形特性是造成拱腰处管片角部破损掉块、接缝渗漏与拱顶管片纵向开裂等病害的主要原因。隧道结构安全计算分析表明，该盾构隧道周边地层因扰动影响已进入松散状态，管片环结构趋向横椭圆变形；管片环中部分连接螺栓有可能已进入屈服状态。

关键词：横椭圆变形

Cause Analysis and Treatment on Damage of Adjacent Metro Shield Tunnel Due to Deep Pit Excavation with Pile-Anchor Retaining

Liu Tingjin
（South China University of Technology）

Abstract:

Research purposes: Some damages such as segment breakage, segment cracks, leakage in joints, side ditch cracking in ballast etc. have been found in the metro shield tunnel, which caused by excavation of adjacent deep foundation pit with pile-anchor retaining. In this paper, overview of the metro shield tunnel disease accident are detailed described, and then disease status are sorted and simply analyzed, causes of tunnel disease are deeply investigated from the two aspects of excavation disturbance of adjacent foundation pit and the property of tunnel deformation according to surrounding construction process, damage status and relative monitoring data. At last, safety condition of the shield tunnel is calculated and analyzed by method of finite element numerical simulation. All former works provide reference for damage treatment.
Research conclusions: Soil loosing region will occur in the end of anchor owing to excavation disturbance of adjacent foundation pit with pile-anchor retaining, which could decrease the restriction ability of lateral soil and induce the deformation trend of transverse ellipse of the tunnel. Meanwhile, the increase of upper load is another reason of the trend. The results of cause analysis show that the deformation property of transverse ellipse is the main reason of segment breakage,

joints leakage in the waist of tunnel, segment longitudinal cracks in the vault of tunnel. The results of calculation and analysis of tunnel structural safety condition show that adjacent layer of the tunnel is in the status of loose caused by the excavation of adjacent pit. The segment ring deforms according to transverse ellipse, and some of connecting bolt may be in the state of yield.
keywords: transverse elliptical deformation

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考虑重力影响的含空洞地层浅埋隧道围岩应力及位移解析解

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摘　要：地层空洞对浅埋隧道施工引起的地层应力和变形影响显著，这可能会危及地面建筑物和地下构筑物的安全。为此，本文建立了含空洞地层浅埋圆形隧道开挖引起的地层应力和位移解析模型，通过该模型既可以考虑隧道与空洞的相互作用也可以考虑重力影响。采用复变函数法和 Schwarz 交替法对该模型进行了求解，并从复势解析函数包含的项数、附加面力的逼近精度和迭代次数三个方面对计算精度做了讨论。将理论解与数值解相比较，发现两者吻合较好。基于所建立的解析模型，分析了应力释放系数、空洞位置及尺寸对地层应力和变形的影响规律。研究成果对含空洞地层浅埋隧道施工引起的地层变形和应力预测具有重要的理论意义和应用价值。

关键词：浅埋隧道；地层空洞；应力和位移；复变函数法；Schwarz 交替法

An Analytical Solution of the Stress and Displacement of the Surrounding Rock for a Shallow Tunnel with a Cavity in the Strata Considering the Gravity Condition

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Abstract:

For a shallow tunnel, the influence of the cavity on the ground stresses and deformations induced by the tunneling construction cannot be ignored, which may endanger the surrounding understructures and nearby superstructures. In order to achieve the stresses and deformations of the surrounding rock for a shallow circular tunnel with a cavity in the strata, an analytical model is proposed, in which the interaction between the tunnel and the cavity can be considered as well as the influence of gravity. The Schwarz alternating method and the complex variable method are applied in the solving process， and the calculation precision is discussed from the three aspects: the non-zero terms contained in the analytic function, the approximation precision of the additional surface force and the iteration times. By comparing the theoretical solution with the numerical solution, it is found that they are in good agreement. Based on the analytical model, the effects of stress release coefficient, position and size of the cavity on the stresses and deformations are analyzed. The research has important theoretical significances and application values for the prediction of deformations and stresses caused by shallow tunnel with a cavity in the stratum.

keywords: shallow tunnel;cavity;stress and displacement;complex variable method;Schwarz alternating method

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基于正交试验的隧道近接施工隔离桩优化设计

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摘　要：隔离桩作为一种主要的施工控制措施广泛应用于隧道近接敏感建(构)筑物施工中，但目前尚未有规范对隔离桩的设计做出规定，现行隔离桩设计主要依据经验进行。本文针对这一现状，采用数值方法对影响隔离桩隔离效果的桩长、距隧道距离、桩径和桩弹模四个主要因素安排了正交试验，定义了隔离系数并以此作为试验指标表征隔离桩隔离效果，分析评价了各因素对隔离桩隔离效果的影响程度。结果表明：桩长是影响隔离桩隔离效果的最主要因素。

关键词：隔离桩；正交设计；优化设计；合理桩长。

Optimum Design of Isolation Pile in Tunnel Close-Spaced Construction Based on Orthogonal Test

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Abstract:

As a main construction control measure, isolation piles are widely used in the construction of tunnel adjacent sensitive buildings. However, there is no specification for the design of isolation piles. The current design of isolation piles is mainly based on experience. In view of this situation, the orthogonal test is arranged for the four main factors affecting the isolation effect of isolation piles: the length of piles, the distance from tunnels, the diameter of piles and the elastic modulus of piles. The isolation coefficient is defined as an experimental index to characterize the isolation effect of isolation piles, and the influence degree of each factor on the isolation effect of isolation piles is analyzed and evaluated. The test results are analyzed by variance analysis and significance test. The results show that the length of the pile is the most important factor affecting the isolation effect of the isolation pile, while the other three factors have no significant impact on the isolation effect of the isolation pile. Then, based on the evaluation of the influencing factors of isolation piles, the design of isolation piles is optimized from two aspects: the selection of isolation piles and the determination of reasonable length of piles. It is pointed out that the relatively low-cost rotary jet grouting piles should be selected as isolation piles in engineering practice, and it is suggested that the isolation effect of isolation piles should be better when the length of isolation piles is 1.2 times of tunnel depth.

keywords: isolation pile; orthogonal design; optimum design; reasonable pile length

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超大直径盾构下穿既有铁路群安全性评估研究

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摘　要：以武汉市两湖隧道工程下穿既有武黄城际线、南环线和大花岭疏解线等铁路为背景，对隧道施工中的重大风险源——区间下穿武黄城际铁路等 6 条铁路线的施工过程进行了三维仿真数值模拟。武汉两湖隧道盾构直径达 15.5m，两轨面间的差异沉降不得大于 5 mm，对地铁下穿段的施工提出了较高要求。数值模拟的计算结果表明：（1）超大直径盾构下穿铁路路基主要引起的是路基沉降，地层损失率是控制沉降的关键因素。（2）盾构下穿的铁路接触网立柱，沉降及位移明显，以沉降为主，水平向偏移主要表现为向盾构轴线侧倾斜。（3）在隧道开挖面通过路基下方前已发生沉降变形，穿过路基时轨道变形较大，完全穿越路基后轨道沉降几乎不发展。

关键词：大直径盾构；铁路群；交叉下穿；沉降控制。

Study on Safety Assessment of Ultra-Large Diameter Shield Tunnel Crossing Existing Railway Groups

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Abstract:

Based on the background of Wuhan Lianghu Tunnel project crossing the existing Wuhuang Intercity Line, South Ring Line and Dahualing Intercity Line, three-dimensional numerical simulation was carried out to simulate the construction process of six railway lines crossing the Wuhuang Intercity Railway，which is the major risk sources in tunnel construction. The shield diameter of Wuhan Lianghu Tunnel is 15.5m, and the differential settlement between the two rail surfaces should not be greater than 5 mm, which puts forward higher requirements for the construction of subway underpass section. The results of numerical simulation show that: (1) The ground subsidence is the main cause of the ultra-large diameter shield tunneling through the railway subgrade, and the stratum loss rate is the key factor to control the subsidence. (2) The settlement and displacement of the railway catenary column under the shield are obvious, and the settlement is dominant. The horizontal deviation is mainly inclined to the axis of the shield. (3) Settlement deformation has occurred before the tunnel excavation surface passes under the roadbed. The track deformation is larger when the tunnel passes through the roadbed, and the track settlement hardly develops after crossing the roadbed completely.

keywords: Large diameter shield;Railway group;Cross underpass;Settlement control

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隧道工程地震易损性分析研究综述与展望

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摘　要：易损性分析是隧道工程区域防灾减灾重要的基础工程之一。首先，详细综述了国内外隧道地震易损性研究历史与现状；其次，归纳了国内外隧道地震易损性分析主要方法，并总结了各种方法的实际适用性；接着，提出了隧道地震易损性评估步骤，并且讨论了以数值模拟为主要手段的理论易损性曲线建立中的三个关键内容：(1)输入参数确定；(2)破坏状态分级；(3)相关不确定性参数计算；最后，指出该领域一些亟待解决的问题和未来研究发展的方向。结果表明：隧道地震易损性分析能通过考虑相关不确定性因素，反映了隧道在地震荷载作用下的性能，有利于未来的风险评估和损失估算，对基于性能隧道抗震设计的发展具有重要的意义。

关键词：隧道工程；地震；易损性分析；不确定性；数值模拟

Research Review and Future Prospect of the Seismic Fragility Analysis for Tunnel Engineering

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（Chang'an University）

Abstract:

Fragility analysis is an important basic work of regional disaster prevention and reduction in tunnel engineering. Firstly, the history and status of the fragility analysis of tunnels at home and abroad are reviewed in detail; Secondly, the main methods of seismic vulnerability analysis of tunnels at home and abroad are summarized, and the practical applicability of various methods is summarized; Then, the steps of seismic vulnerability assessment for tunnels are proposed, and three key points in the establishment of theoretical vulnerability curve by numerical simulation are discussed: (1) Determination of input parameters; (2) Classification of failure state; (3) Calculation of related uncertain parameters; Finally, Some problems to be solved urgently in this field and the direction of future research and development are pointed out. The results show that the seismic vulnerability analysis of tunnels can reflect the performance of tunnels under seismic loads by considering relevant uncertainties, which is conducive to future risk assessment and loss estimation, and is of great significance to the development of performance-based seismic design of tunnels.

keywords: tunnel engineering; earthquake; vulnerability analysis; uncertainty; numerical simulation

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盾构近接塔式高层建筑变形及其受力特性数值分析

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摘　要：基于西安地铁 2 号线盾构侧穿塔式高层建筑泛美大厦，建立有限元模型探究盾构推进盾构近接塔式高层建筑物变形及其受力特性。结果表明：泛美大厦沉降量 13.9mm，倾斜度为 0.0005，盾构过程安全，但由于此高层建筑中钢塔的存在，其形变和受力特征规律有所不同，对于整体的沉降量、倾斜度有所增大，且自身的变形大，易倾斜，也属于泛美大厦变形及其受力较为不利的一部分。盾构过程中塔式高层建筑结构受力更大，钢塔的存在对于高层建筑有所影响，且钢塔与主体结构连接处的受力特别大，为盾构工程中高层建筑的不利荷载处。今后类似工况，应该加强监控量测，以及注意钢塔与主体连接部位的受力状况。

关键词：盾构施工

Numerical Analysis of Deformation and Stress Characteristics of Tower High-Rise Building Under Shield Tunneling

Lu Yuquan
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Abstract:

Based on the shield tunneling of Xi'an Metro Line 2 side-through tower high-rise Fan-Mei Building, a finite element model was established to investigate the deformation and stress characteristics of the shield tunneling near the tower high-rise building. The results show that the settlement of Fan-Mei building is 13.9 mm, the inclination is 0.0005, and the shield process is safe. However, due to the existence of steel towers in the high-rise building, the deformation and stress characteristics are different. The overall settlement and inclination are increased, and the deformation of Fan-Mei building is large and inclined easily. A more unfavorable part of the force. In the process of shield tunneling, the force of tower high-rise building structure is greater, the existence of steel tower has an impact on high-rise building, and the stress of the connection between steel tower and main structure is especially large, which is the disadvantageous load of high-rise building in shield tunneling project. In the future, the monitoring and measurement should be strengthened and the stress condition of the connection between the steel tower and the main body should be paid attention to.

keywords: shield construction

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千枚岩隧道浅埋偏压段监控量测与有限元模拟

钟宇健
（长安大学）

摘　要：对安康白河红石河隧道浅埋偏压段施工过程现场监控量测数据以及有限元分析结果进行对比研究，揭示了隧道浅埋偏压状况下由于围岩积水局部沉降导致的监控量测数据非正常规律。结果表明：隧道拱顶-右拱腰部位由于围岩失稳导致初支钢拱架形变，拱顶沉降数值出现“反常”“跳跃”“剧变”现象，周边收敛数值出现“剧变”现象；该特殊围岩形变规律可对类似工程提供参考，同时有限元模拟结果能准确反映隧道支护的不利位置。可见现场监控量测与有限元仿真模拟相结合的方法对隧道浅埋偏压段施工施工工艺调整，支护参数优化，围岩变形监测提供了依据。

关键词：隧道工程

Monitoring and Finite Element Simulation of the Shallow Buried Bias Section of Phyllite Tunnel

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Abstract:

the field monitoring data and the finite element analysis results of the construction process of the shallow buried partial pressure section of the Hongshi River Tunnel in the Baihe River are compared, and the abnormal regularity of the monitoring data caused by the local settlement of the surrounding rock under the shallow buried tunnel pressure is revealed. The results show that the deformation of the initial support steel arch is caused by the instability of the tunnel vault and right arch, and the value of the settlement of the vault appears "anomalous", "jumping" and "upheaval". The surrounding convergence value appears "upheaval", and the special surrounding rock deformation law can be referred to similar projects, and the finite element simulation results can be obtained. It does reflect the unfavorable position of the tunnel support. It can be seen that the method combined with the field monitoring and the finite element simulation can provide the basis for the construction technology adjustment of the tunnel shallow buried partial pressure section, the optimization of support parameters and the monitoring of the deformation of the surrounding rock.

keywords: tunnel engineering

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地铁暗挖隧道二衬水头控制值及影响因素研究

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摘　要：深埋全封堵方式的城市地铁暗挖隧道二衬常面临高水压力作用的威胁，可能诱发二衬结构安全和耐久性问题。目前，针对如何计算确定暗挖隧道二衬的水头控制值尚没有统一的标准。应用三维数值模拟分析方法，采用混凝土损伤塑性模型，结合广州地铁暗挖隧道二衬结构设计，研究了外水压力作用下隧道二衬的渐近性破坏全过程，获得了混凝土起始开裂、裂缝深度达到钢筋保护层厚度、混凝土压碎、受力钢筋屈服、裂缝贯通截面五个受力阶段对应的二衬水头控制值；针对影响二衬水头控制值的相关因素如二衬厚度、配筋量、混凝土强度等级等进行了参数敏感性分析；根据现场检测结果，分析论证了某暗挖隧道二衬结构出现局部垮塌事故的主要原因。研究结果表明：广州地铁常规单线暗挖隧道二衬的起裂开裂水头为 30m，水头大于 47m 后裂缝深度将超过钢筋保护层厚度，大于 74m 后二衬混凝土压碎，大于 90m 后受力钢筋开始屈服，大于 95m 后二衬裂缝贯通截面；为满足二衬的耐久性设计要求，水头控制值应设定为 47m；对二衬进行合理配筋并确保二衬厚度，可有效提高满足二衬耐久性要求的水头控制值；某隧道二衬出现局部垮塌事故的主要原因为较高外水压力作用下二衬厚度严重不足所致。

关键词：损伤塑性

Study on Control Values and Influence factors of Water Head on Secondary Lining in Mined Subway Tunnel

Liu Tingjin, Yang Xiaoping
（South China University of Technology）

Abstract:

Still threatened by the high water pressure, the secondary lining of deeply buried whole water plugging type of mined subway tunnel may induce trouble in safety and permanence. However, there had no consolidated standard for calculating and determining the control value of water head height of the secondary lining. Based on the three dimensional numerical simulation, plastic damage model of concrete and structure of secondary lining of mined subway tunnel in Guangzhou metro, we studied the whole process of asymptotic destruction of secondary lining under the external water pressure and acquire the control values of water head height of five specific force states of secondary lining, including the parameters of crack initiation of lining, cracking depth reaching cover thickness, concrete crushing, reinforcement yielding and crack cutting through section. The sensitivity of parameters of relevant factors affecting the control values of water head height of secondary lining such as thickness of secondary lining, quantity of reinforcement, and concrete strength grade was analyzed. According to the field measuring results, we analyzed and demonstrated the major reasons responsible for a partial collapse accident of secondary lining of mined subway tunnel. The results

showed that in the secondary lining of Guangzhou routine single-line mined metro tunnel, the control values of water head height of crack initiation, cracking depth reaching cover thickness, concrete crushing, reinforcement yielding and crack cutting through section were 30, 47, 74, 90 and 95 meters, respectively. Therefore, to assure the durability of secondary lining, the control value of water head height should be set to 47 meters, also it could be effectively improved by reasonable reinforcement and ensuring the thickness of secondary lining. The primary cause for the partial collapse accident of secondary lining of mined subway tunnel was that the gravely insufficient thickness of secondary lining under the relatively high external water pressure.

keywords: plastic damage

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冻结降温导致地铁盾构隧道漏水的数值与理论分析

刘庭金，杨小平
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摘　要：针对地铁盾构隧道正上方基坑冻结开挖诱发隧道环缝渗漏水现象，采用数值分析方法建立三环管片衬砌结构的三维精细有限元模型，主要研究了冻结降温作用对盾构隧道环缝、纵缝张开量的影响，并结合接缝处细部构造的特点对隧道环缝出现漏水的原因进行了理论分析。结果表明：1）盾构隧道管片纵缝、环缝张开量和螺栓应力随着冻结温度降低而增大；2）在地层荷载与冻结温度共同作用下，盾构隧道环缝张开量为纵缝张开量的 4.2 倍；3）环缝张开使得接缝处管片与橡胶密封垫接触不紧密，进而导致橡胶垫与接缝槽接触产生的摩擦力小于水压力，是隧道漏水的主要原因。

关键词：管片接缝

Numerical and Theoretical Analysis of the Water Leakage in the Metro Shield Tunnel Caused by Freezing Method

Liu Tingjin, Yang Xiaoxing
（South China University of Technology）

Abstract:

To study the influence of foundation pit excavation by freezing method on the longitudinal and circumferential joint opening of a metro shield tunnel, a three-dimensional detailed finite element model is established. The reasons of the water leakage through the circumferential joint are discussed. The results show that: 1) the longitudinal and circumferential joint openings, and the bolt stresses increase with the decrease of freezing temperature; 2) the value of the circumferential joint opening is 4.2 times larger than the longitudinal one under composite effect of water-earth pressure and freezing temperature; 3) the loss of the compaction between segment and rubber sealing gasket caused by circumferential joint opening, is the main reason that results in the subsequent water leakage.

keywords: joint of segment

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隧道突涌水防突结构微震信号 P 波初至拾取方法

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摘　要：隧道突涌水灾害是隧道工程建设遇到的重大难题，微震监测技术可以通过对防突结构微震事件活动的监测来实现突涌水灾害时空演化过程的评价。为了实现突涌水过程中微震信号 P 波初至的精确拾取，不同于预设阈值的常规初至检测方式，本文基于单自由度振动体系（SDOF），将微震引起的质点加速度运动记录进行能量域转化，使得时间序列中的波至特征在体系输入能、阻尼耗能及弹性动能序列上得到凸显，以此实现 P 波初至的精准识别，提高定位精度。通过对不同信噪比的微震信号进行对比分析，本文方法对于低信噪比的信号仍然有明显的特征响应。拾取结果与长短时窗比方法（STA/LTA）进行了比较，结果表明本文提出的拾取方法优于常规预设阈值的检测方式，能够在无预设阈值的情况下完成波动初至的拾取，避免了预设阈值的人为误差，具有更好的误差控制，一定程度上提升了隧道突涌水灾害微震监测技术事件信号的 P 波初至拾取精度，为后续的微震定位计算和分析提供了依据。

关键词：单自由度体系；能量分析；微震初至拾取；误差控制

The Picking Method of P-Wave Arrival for Micro-Seismic Signal of Prevention Structure of Tunnel Inrush Water

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Abstract:

Water-inrush disaster is a difficult problem in Tunnel Construction.Micro-seismic monitoring technology can be used to evaluate the temporal and spatial evolution characteristics of water-inrush disasters by monitoring the activities of microseismic events in preventing structures. In order to realize the accurate pick-up of P-wave initial arrival of micro-seismic signal in the process of water inrush, the motion records of particle acceleration caused by microseismic are transformed into energy domain based on the single-degree-of-freedom vibration system (SDOF) which is different from conventional method with preset threshold.The characteristics of P-wave arrival in time series are highlighted in the input energy, damping energy dissipation and elastic kinetic energy series, so as to realize the accurate identification of the first arrival of P-wave and improve the accuracy of positioning.Through the comparison and analysis of the micro-seismic signals with different signal-to-noise ratio, there is still obvious characteristic response for the low signal-to-noise ratio.The pick-up results of the method are compared with the STA/LTA method. The results show that the method proposed in this paper is superior to the conventional pre-threshold detection method and can complete the pick-up of the first arrival of fluctuation without the preset threshold.the pick-up accuracy of P-wave of the event signal of tunnel water inrush disaster is improved to a certain extent, which provides the basis for the calculation and analysis of micro-earthquake location.

keywords: single-degree-of-freedom system; energy analysis; p-wave initial arrival of microseismic; error control

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基于压水试验的地层渗流场反分析研究

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摘　要：地下工程建设过程中，地下水分布以及岩体渗透参数确定是至关重要。基于对解决欠定反分析问题的目标函数分析，通过利用适应度函数、地质统计原理和变差函数等优化，得到了解决地层渗透系数一类水文地质问题的罚函数，为解决欠定的反分析问题提供了一个优化评判准则，并结合粒子群算法建立优化反分析数学模型；提出利用压水试验钻孔水头变化反分析得到地层渗透系数的新方法，针对南京地铁上元门车站，进行现场压水试验得到钻孔水头高度，利用经过罚函数优化的反分析数值计算获得地层渗透系数，对压水试验区域的电阻率跨孔 CT 探测验证了该方法区域上的正确性，该区域的钻孔原位渗透系数测试验证了该方法在数值上的准确性，结果表明，经过罚函数优化的反分析计算的准确率达到 90%，说明该方法有助于得到全面的地层水文地质信息，对后续的治理具有指导作用，希望对类似工程具有一定的借鉴意义。

关键词：罚函数；粒子群算法；评判准则；压水试验；反分析；渗流场

Inverse Analysis of Seepage Field Based on the Pressure Water Test

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Abstract:

Groundwater distribution and determination of permeability of rock mass parameters are very important in the process of underground engineering construction. Based on analysis on the objective function of underdetermined problem, and through the use of fitness function and the principle of geological statistics and variation function optimization, we obtained a class of hydrogeological problems penalty function for solving formation permeability coefficient, which provides an optimized evaluation criterion to solve the problem of inverse analysis of underdetermined problem Also, a mathematical model of optimized back analysis combined with particle swarm optimization (pso) algorithm is established, and a new method of formation permeability coefficient is proposed using back analysis of the pressure water test drilling head change. In view of the Nanjing Shang Yuanmen subway station, we processed pressure water test to get drilling head height on-site, and obtained the coefficient of permeability of the layer by using back analysis numerical calculation which the penalty function have optimized. Detection of the resistivity cross hole CT were conducted to verify the accuracy of the method on the regional results, and drilling in situ permeability tests verified the accuracy of the method on the numerical results. The results show that calculation accuracy reached 90%after a penalty function optimizing the analysis, which proves that the method helps to get comprehensive formation hydrogeological information, and is important for the follow-up governance, which is expected to have certain

reference significance for similar projects.

keywords: Penalty function; Particle swarm optimization (pso); Evaluation criterion; Pressure water test; Back analysis; Seepage field

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平板裂隙注浆渗滤机制研究

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摘　要：水泥基浆液是一种悬浊液，在裂隙内扩散通过裂隙局部收缩位置处存在明显渗滤效应，而浆液在光滑平行裂隙内扩散是否存在渗滤效应尚不明确。为了探究浆液在光滑平行裂隙内扩散是否存在渗滤效应，以提高对裂隙注浆工程的认识。本文以平板裂隙作为研究对象，基于非牛顿流体力学理论分析了浆液在平板裂隙扩散中的渗滤机制，并阐述了平板裂隙渗滤发生过程。利用自主研发的裂隙模型注浆模拟实验系统，开展了平板裂隙注浆渗滤试验，获取表征平板裂隙渗滤效应的固相体积比变化的规律，验证了浆液渗滤发生结果。分析了裂隙开度与水灰比对裂隙渗滤过程的影响程度。讨论了裂隙渗滤效应对于裂隙注浆工程的影响。研究结果表明，恒定流道的平板裂隙存在渗滤效应。裂隙开度与浆液的水灰比影响着裂隙注浆中渗滤效应的强弱。相较于 1mm 开度裂隙，3mm 裂隙开度沿扩散路径上固相体积比明显较低，其渗滤效应尤为明显。在裂隙开度一定的条件下，浆液水灰比越小，浆液沿扩散方向上固相体积比越高，裂隙渗滤效应越不显著。究结果希望对于裂隙渗滤效应的理论研究提供一定借鉴意义。

关键词：平板裂隙；渗滤；裂隙注浆

Study on the Mechanism of Filtration in Fracture Grouting

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（Shandong University）

Abstract:

As a suspended liquid, cement based slurry has filtration effect in fracture grouting engineering. However, the problem of filtration effect seriously affects the sealing and grouting design of fracture rock mass. In order to explore the filtration effect of slurry in fracture grouting, based on the theory of non Newtonian fluid mechanics, the filtration mechanism of slurry in plate fracture diffusion is analyzed in this paper. The process of plate fracture infiltration is described. Using the self-developed fracture model grouting simulation experimental system, the test of fracture grouting for filtration was carried out. The influence of filtration effect on fracture grouting engineering is discussed. The results show that fracture aperture influences the degree of filtration. The bigger the fracture aperture is, the less obvious the filtration effect is. The smaller the water-cement ratio of the slurry is, the more obvious the filtration effect is. It is hoped that the results can be used for reference in the theoretical study of fracture filtration effect.

keywords: Plate fracture; Filtration; Fracture grouting

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基于双重介质的浆岩耦合作用机制研究

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（山东大学）

摘　要：在裂隙岩体注浆工程，浆液与岩体的相互作用影响着浆液的扩散过程，而工程中岩体裂隙多以成组发育，相较于单一裂隙岩体的浆液-岩体的相互作用机制，多裂岩体的浆液-岩体相互作用机制更为复杂。本文以含有多个裂隙组的岩体作为研究对象，研究浆液在裂隙扩散时与岩体的耦合效应。通过 Monte-Carlo 方法，生成了服从一定概率分布的裂隙组来表征岩体内的随机裂隙，将裂隙岩体简化为孔隙裂隙介质模型，推导了浆液在孔隙裂隙介质模型内的连续性方程，基于修改后的界面层理论描述浆液岩体单向耦合机制。分析了不同注浆压力对于岩体内各条裂隙开度的影响规律。研究结果表明，浆液在含多条裂隙的岩体内扩散时，裂隙开度变化主要与裂隙分布位置及裂隙倾向有关。在相同注浆压力条件下，裂隙开度主要存在四种变化形式，即沿裂隙展布逐渐增大、缓慢减小、先增大后减小、基本不变。当注浆压力提高时，具有相同分布形式的裂隙组其开度变化规律相似，但变化幅度有所差异。相同注浆压力下，随着岩体内裂隙数量的增加岩体受浆岩耦合效应更为明显。

关键词：水力耦合；注浆扩散；孔隙裂隙介质；数值模拟

Title Study on Coupling Mechanism of Grout-Rock Based on Fractured Porous Medium Model

Wang Xiaochen, Liu Rentai, Li Xiuhao
（Shandong University）

Abstract:

In the engineering of fracture grouting, the effect of hydraulic coupling is important for the process of penetration. However, the fracture of rock mass is mostly developed in groups, so the coupling effect of grout and rock mass is more complex. Based on the Monte-Carlo method, a fracture group with a certain probability distributions is generated to characterize the random fractures in the rock mass. The fracture rock mass is simplified into a fractured porous medium model, and the continuity equation of slurry in the porous fissure medium model is derived. The unidirectional coupling mechanism of grout-rock is described based on the modified interfacial layer theory. Analyze the influence of different grouting pressure on the variation of fracture aperture in rock. The results show that when the grouting fluid is injected from the grouting hole to a certain position, the variation of the fracture aperture is mainly related to the distribution of the fracture and the angle of the fracture inclination.

keywords: Hydromechanical coupling;Grout penetration;Fractured porous media;Numerical simulation

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Influence of Grouting Pressure on Bearing Capacity of Pile Foundation Under the Sandy Soil

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Abstract: The aim of the paper is to investigate the increase of bearing capacity of pile after grouting. In this paper, through the soil grouting reinforcement experiment and the numerical simulation of the bearing capacity of the pile, the increase of pile bearing capacity was investigated and compared with the standard method. Thus The relationship between grouting pressure, cohesion force and internal friction angle was obtained through grouting test. Grouting pressure has a great influence on cohesion force and a slight influence on internal friction angle. The lifting capacity of pile foundation obtained by numerical simulation is close to that of pile foundation obtained by formula. It is feasible to calculate the lifting range of bearing capacity of pile foundation by standard method.

Key words: Grouting

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粒径组合对煤矸石基充填材料影响机制研究

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（山东大学）

摘　要：实验室制备出了以粉煤灰-脱硫石膏-水泥熟料复合材料为胶凝材料，并利用粉煤灰作为细集料，破碎粉磨后的煤矸石为充填骨料的胶结充填材料。根据不同胶凝材料的水化特性，选取高活性辅助胶凝材料和低活性辅助胶凝材料的颗粒级配。通过组分筛选、配比优化、力学性能测试分析，获取了材料的抗压强度、流动度、泌水率等宏观性能；采用扫描电镜 SEM 微观分析手段研究了结石体的微观结构，采用压汞仪测定了结石体孔径分布，以便反馈充填材料的组分设计，调整各组分之间的最优配比。结果表明：煤矸石、粉煤灰和脱硫石膏三者存在最优粒径布置，当煤矸石粒径为[0.075,0.106] mm，粉煤灰和脱硫石膏粒径为[0.053,0.075] mm 时，材料的 28 d 强度达到最大值 12.1 Mpa，并且泌水率较低，流动度较好。

关键词：充填材料

Influence of Grain Size Combination on Gangue-Based Filling Material

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Abstract:

Fly ash was used as fine aggregate, coal gangue after crushing and grinding was used as filling aggregate. According to the hydration characteristics of different cementitious materials, the granule gradation of high activity auxiliary cementitious materials and low activity auxiliary cementitious materials was optimized. The macroscopic properties such as compressive strength, fluidity and bleeding rate were obtained through the experiments of component selection, proportion optimization and mechanical property test and analysis. The microstructure of the stone body was analyzed by SEM microanalysis. The pore structure of the material was determined by mercury injection instrument, so as to feedback the component design of the filling material and adjust the optimal proportion of each component. The results show that the optimal particle size distribution exists in coal gangue, fly ash and desulfurized gypsum. When the grain size of gangue is between [0.075,0.106] mm and the grain size of fly ash and desulfurized gypsum is between [0.053,0.075] mm, the 28 d strength of the material reaches the maximum value of 12.1 Mpa, and the bleeding rate is low, and the fluidity is good.

keywords: cemented filling material

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上方开挖时压顶梁对箱形地铁隧道区间 纵向变形的控制效果

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摘　要：依托白云公园-飞翔公园站明挖箱形地铁隧道区间，基于荷载-结构法，运用Midas FEA有限元软件建立三维数值模型，分析上方连接通道开挖时箱形地铁隧道的纵向变形规律，从而解释了目前既有箱形隧道出现病害的原因。针对该类病害问题，建立相应的数值模型，研究压顶梁对箱形隧道纵向变形的控制效果。结果表明:若不采取抗隆起措施，隧道上方开挖深度较大时变形缝两侧箱体的差异沉降较大，易造成隧道结构开裂，发生渗漏水等病害；设置压顶梁后，箱形隧道最大隆起量为无压顶梁时的11%；压顶梁对限制箱形隧道底板脱空范围较有效。

关键词：纵向变形控制

Control Effect of the Capping Beam on the Metro Box Tunnel Structure′s Longitudinal Deformation Induced by Above Unloading

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Abstract:

According to a project case, a three-dimensional detailed finite element model was proposed to simulate the box tunnel structure, especially the deformation joint by Load-Structure Method. The longitudinal deformations of the box tunnel under different above unloading conditions were studied, and the reasons of the defects arisen in the existing box tunnel were analyzed. For this reason, the control effect of capping beam in box tunnel’s longitudinal deformation and the disengagement of tunnel bottom were studied. The results show that: (1)When the unloading depth is deep, the differential deformation between the two adjacent boxes in the joint is large without capping beam. (2)The maximum deformation of box tunnel with capping beam is about 11 percent of the deformation of box tunnel without capping beam.(3)Setting capping beam can increase the effectiveness of anti-uplift. This research can provide reference for the optimization of the box tunnel design and construction.

keywords: longitudinal deformation

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不同温度花岗岩热处理力学特性研究

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摘　要：通过颗粒流程序(particle flow code,PFC)对鲁灰花岗岩进行参数标定，获取一组能够真实反映鲁灰花岗岩宏观力学行为的细观参数。进而对鲁灰花岗岩进行升温及快速冷却模拟，分析在升温和快速冷却过程中裂纹演化和应力场变化规律。结果表明：在高温下，花岗岩内部热应力空间分布不均。随温度升高，花岗岩内部热应力逐渐积累并产生热裂纹，造成花岗岩峰值强度降低,峰值应变减小,使得花岗岩在高温下力学性质劣化;在高温冷却后，花岗岩内部热应力逐渐消散。造成花岗岩内部结构出现大面积破坏，导致峰值强度降低，使得花岗岩在高温快速冷却后力学性质进一步劣化。

关键词：细观参数；高温；水冷却；裂纹；力学性质劣化

Research on Mechanical Properties of Granite Heat Treatment at Different Temperatures

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（Shandong University）

Abstract:

The parameters of Luhui granite are calibrated by PFC, and a group of meso-parameters are obtained which can truly reflect the macro-mechanical behavior of Luhui granite. On this basis, the temperature-rise and water-cooling simulation of Luhui granite are carried out. The evolution of cracks and the variation of stress field in the process of temperature-rise and water-cooling are analyzed, and the deterioration mechanism of mechanical properties of high-temperature granite after water-cooling is revealed. At high temperature, the spatial distribution of thermal stress in granite is uneven. With the increase of temperature, the thermal stress in granite gradually accumulates and produces thermal cracks, which results in the decrease of peak strength and peak strain of granite, and deteriorates the mechanical properties of granite at high temperature. After cooling at high temperature, the spatial distribution of thermal stress in granite changes obviously, and the internal thermal stress dissipates gradually. With the increase of heat treatment temperature difference, the number of thermal shock cracks increases gradually and long cracks extend inward on the surface.

keywords: Meso-parameters;High temperature;Water cooling;Crack; Degradation of mechanical properties

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时间序列分析在地下工程中的应用

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摘　要：时间序列分析在地下工程中监测数据处理与预测方面的应用越来越多，鉴于此，从线性模型和非线性模型两方面总结了一些当前在应用在地下工程中较为广泛的时间序列分析预测模型和方法，同时对比分析了这些方法的特点和不足，并介绍了当前时间序列预测技术所面临的问题，探讨了该技术在今后的发展中需要重点解决的关键问题和未来发展趋势。

关键词：地下工程；时间序列；综述

Review of the Application of Time Series Analysis in Underground Engineering

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（Chang'an University）

Abstract:

Time series analysis has been applied more and more in underground engineering monitoring data processing and prediction. In view of this, this paper summarizes some time series analysis and prediction models and methods which are widely used in underground engineering from two aspects of linear model and non-linear model. At the same time, the characteristics and shortcomings of these methods are compared and analyzed, and the current time series prediction is introduced. The problems faced by the measurement technology are discussed, and the key problems to be solved in the future development of the technology and the future development trend are discussed.

keywords: underground engineering; time series; review

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地铁车站混凝土裂缝渗漏水注浆修复研究

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（重庆交通大学）

摘　要：地铁车站新旧混凝土裂缝渗漏水，会影响列车运行安全。采用 C-S 材料进行注浆修复时，常规 C-S 注浆材料有凝胶时间过快，浆液容易堵塞注浆管，且抗水溶蚀差等缺点，需要对 C-S 注浆材料进行改进。本文采用超细粉煤灰、Na2HPO4 对 C-S 注浆材料性能进行改性试验研究，获得了合理的最佳配合比，并提出了混凝土斜缝注浆修复工艺。通过地铁车站新旧混凝土裂缝渗漏水处治的应用，证明其修复效果良好，研究成果可为混凝土裂缝修复提供理论支持和经验借鉴。

关键词：混凝土裂缝；渗漏水；修复；C-S 材料；改进

Study on the Grouting Repair for Water Leakage Cracks of Concrete in Subway Station

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Abstract:

The water leakage of old and new concrete cracks will affects the safety of train operation in subway stations. The concrete cracks used Cement-Sodium silicate(C-S) grouting material for repair has drawbacks. One is that the gelation time is so short that the grouted slurry likely to plug the grouting pipe; the other is that the C-S material has low corrosion resistance against water. Therefore, the C-S material needs to be improved. In this paper, the properties of the C-S material were studied by ultrafine fly ash (UFA) and Na2HPO4, and obtains its proper proportion by testing. In addition, the inclined slot grouting repair technology is proposed for concrete cracks. The modified material and the repair technology have been applied in a typical subway station suffering from serious water leakage, and it shows excellent repair effect. This results can provide theoretical and empirical reference for similar engineering.

keywords: concrete cracks, water leakage , repair, C-S material, improve, application

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Stochastic Damage Model of the Concrete Structure of the High-Speed Railway Tunnel Base

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Abstract: Based on thermodynamic and energy dissipation principles, and directed towards the repeated "tensile - compressive - tensile - compressive" stress of the concrete structure of the high-speed railway tunnel base, double scalar damage variables are defined, the hardening function is introduced, the elastoplastic Helmholtz free energy is amended, and the non-linear stochastic damage constitutive model that describes strain-softening of the concrete under tensile and compressive conditions is derived. In the effective stress space, the evolution rule of the damage variables is derived based on the normality rule of the plastic mechanics, and, based on the solution of the probability density evolution equation, the numerical analysis solving algorithm of "elastic prediction — plastic amendment — damage amendment" is established. Further, secondary development of the program is performed, which realizes the numerical computation of the stochastic damage constitutive model. By comparison with the indoor uniaxial tensile and uniaxial compressive test results obtained in previous studies, the accuracy and the adaptability of the derived stochastic damage constitutive model is verified. This model not only reflects the stress - strain relationship of the concrete when in tension or compression in terms of the mean value but also simulates the discrete range in terms of probability, which closely reflect the non-linearity and randomness of the loading behavior of the concrete. Through algorithm analysis, this model can be adopted to calculate the damage evolution rules and fatigue damage life of the tunnel base concrete.

Key words: high-speed railway;tunnel base;concrete structure;damage variable;stochastic damage constitutive model

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Damaging Behaviors and Maintenance Design of Tunnel Lining: A Case Study

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Abstract : The lining cracking and spalling have adverse impacts on serviceability and durability of the tunnel, and the corresponding maintenance work against certain damage in tunnel structure is vital. In this paper, a particular case study of an operational tunnel structure is presented for the serious lining cracking and spalling behaviors that induce lining failure. An integrated field investigation is implemented to characterize the spatial distribution of damages with site situation, and the construction deficiency is speculated as inducement of lining failure. To further understanding of the lining structure performance influenced by construction deficiency, a reliable numerical simulation is conducted by using the finite-element software. The simulation responses are essentially in accordance with the actual lining damaging forms, especially including an assessment of lining safety under realistic condition according to safety factors. This work demonstrates that the serious lining damaging behaviors are directly caused by insufficient lining thickness. Ultimately, a specific maintenance work is developed and simulated based on the construction deficiency, which is confirmed as an efficient, time-saving and safe maintaining method in the operational railway tunnel.

Key words: Construction deficiency;Lining failure;Field investigation;Numerical simulation; Safety factors

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小净距隧道浅埋偏压段洞口施工对临近房屋安全影响分析

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摘　要：为了研究浅埋偏压隧道洞口段施工时地表的沉降及对临近房屋的影响，基于云南省昭通市宜昭高速段彝良 2 号隧道工程，采用有限元软件建立三维模型进行动态数值分析，得到洞口段采用环形开挖预留核心土法进行隧道施工时的地表及建筑物沉降曲线，并结合现场实测数据，对比分析隧道开挖过程中，地表及建筑物沉降规律。结果表明：隧道洞口在浅埋偏压段施工影响的隧道地表范围在-2D~2D 之间，总体沉降呈“W”形分布；建筑物的变形经历了微小沉降、急剧沉降、沉降稳定、沉降回弹四个阶段，其中急剧沉降阶段建筑物沉降约占总沉降的 85%；沉降稳定阶段及沉降回弹阶段变形值只有总沉降的 5%左右。

关键词：隧道工程；地表沉降；数值模拟；房屋沉降

Analysis on the Influence of Tunnel Entrance Construction in Shallow and Eccentric Section of Small Clear Distance Tunnel on the Safety of Nearby Buildings

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Abstract:

In order to study the surface subsidence and its influence on adjacent buildings during the construction of shallow-buried eccentric pressure tunnel entrance section, based on the Yiliang No.2 tunnel project of Yizhao high-speed section in Zhaotong City, Yunnan Province. A three-dimensional dynamic numerical analysis model was established by using finite element software, and the surface and building subsidence curves of tunnel construction were obtained by using ring excavation reserved core soil method. Based on the measured data, the law of ground surface and building settlement during tunnel excavation is compared and analyzed. The results show that the surface area of the tunnel affected by the construction of the tunnel entrance in the Shallow-buried eccentric section ranges from -2D to 2D, and the total settlement presents a "W" shape distribution; the deformation of the building undergoes four stages: micro-settlement, rapid settlement, settlement stability and settlement rebound, of which the settlement of the building in the rapid settlement stage accounts for about 85% of the total settlement. The deformation value in the stable stage and the rebound stage is only about 5% of the total settlement.

keywords: Tunnel Engineering;Surface Settlement;Numerical Simulation;Housing Settlement

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列车振动荷载作用下重载铁路岩溶隧道稳定性分析研究

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摘　要：以岩溶区修建的重载铁路隧道为研究对象，对处于隧道围岩背后侧方溶洞进行分析研究。采用数值分析方法，对隧道与侧方溶洞之间的安全距离进行分析，考虑列车振动荷载作用下，分析隧道衬砌结构动力响应及隧道围岩稳定性，研究表明列车振动荷载对隧道衬砌结构影响不明显，但对隧道围岩和侧方溶洞的塑性区分布有明显影响，可造成塑性区贯通，导致隧道失稳破坏，因此在施工期间对一定范围内的侧方溶洞进行注浆加固处理。

关键词：重载铁路隧道；列车动荷载；侧方溶洞；数值分析

Study on Stability Analysis of Heavy-Haul Railway Karst Tunnel Under Train Vibration Load

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Abstract:

Taking the Heavy-haul Railway Tunnel Constructed in karst area as the research object, the karst caves located behind the surrounding rock of the tunnel are analyzed and studied. The safe distance between tunnel and lateral karst cave is analyzed by numerical analysis method. Considering the train vibration load, the dynamic response of tunnel lining structure and the stability of tunnel surrounding rock are analyzed. The research shows that the influence of train vibration load on tunnel lining structure is not obvious, but it has obvious influence on the plastic zone distribution of tunnel surrounding rock and lateral karst cave, which can lead to the penetration of plastic zone. The tunnel is destroyed by instability, so the lateral karst caves within a certain range are reinforced by grouting during construction.

keywords: heavy-haul railway tunnel; train dynamic load;　lateral karst cave;　numerical analysis

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微膨胀混凝土衬砌结构模型试验相似比研究

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摘　要：混凝土结构裂缝及渗漏水是公路隧道衬砌结构的通病，采用微膨胀混凝土可以增加地层弹性抗力，并提高衬砌结构的压应力，改善衬砌抗拉、抗裂性能。为了定量化分析衬砌结构采用微膨胀混凝土后的地层弹性抗力提高幅度，采用了缩尺寸模型试验的方法，通过测试模型隧道衬砌结构所受地层弹性抗力可以推算原型隧道所受地层弹性抗力，为此首先需要弄清两者之间的相似比。根据地层弹性抗力及其与衬砌结构膨胀力的相互作用机理，推导出了地层弹性抗力相似比理论公式，影响相似比大小的因素包括原型隧道与模型隧道之间的半径、厚度、弹性抗力系数、弹性模量等比例关系。最后，采用有限元软件建立了弹性支点法数值计算模型，通过对比地层弹簧的轴力及折算地层弹性抗力，进一步验证了地层弹性抗力相似比解析公式的正确性。

关键词：隧道衬砌；微膨胀混凝土；模型试验；弹性抗力；相似比

Study on Similarity Ratio of Model Test of Micro Expansive Concrete Lining Structure

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Abstract:

Concrete structure cracks and leakage of water are two common diseases in highway tunnel lining structures. Micro expansive concrete can increase the elastic resistance and pressure stress, which result in improving the anti-tensile and anti-crack performance. In order to evaluate the effect of expansive concrete, a test model is adopted and the elastic resistance pressure is measured to estimate the real pressure in prototype tunnel. Therefore, the first thing is to ascertain the similarity ratio between prototype and model. According to the interaction mechanism between elastic resistance and the lining expansion force, similarity ratio formula of elastic resistance was theoretically derivated, which is relative with radius and thickness, and elastic resistant coefficient, elastic modulus. Finally, a numerical calculation model of elastic fulcrum method is established by using finite element software. By comparing the axial force of formation spring and the elastic resistance of stratum, the correctness of analytic formula for elastic resistance of stratum is furtherly verified.

keywords: road tunnel lining; expansive concrete; model test; Elastic resistant coefficient; similarity ratio.

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公路隧道二次衬砌加固与排水系统恢复技术研究

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摘　要：目前，大量公路隧道已经进入“养护”阶段 ，部分早期建设的公路隧道，施工质量不高，在长期运营过程中，出现了衬砌开裂、衬砌厚度不足、隧道渗漏水、材料劣化等病害，危及行车安全，急需进行维修加固。本文通过大量的文献调研和工程实践应用，筛选出针对不同衬砌裂损等级的简单易行的加固治理措施，并根据隧道堵塞或渗水部位，提出了整套方便适用的排水系统恢复技术。基于本文所提出的公路隧道衬砌裂损及水害处治技术，可显著改善隧道结构服役状态，提高隧道的整体运营安全。

关键词：公路隧道；衬砌裂损；排水管道；处治技术

Research on Secondary Lining Reinforcement and Drainage System Restoration Technology of Highway Tunnel

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（Chongqing Jiaotong University）

Abstract:

A large number of highway tunnels have entered the "maintenance" stage at present. Highway Tunnel Construction in Early Stage ,Construction quality is low,In the long-term operation of highway tunnels,Lining cracking, insufficient lining thickness, tunnel leakage and material degradation have occurred. It endangers the traffic safety and urgently needs maintenance and reinforcement. Through a large number of literature research and engineering practice applications, this paper screens out simple and easy reinforcement measures for different lining cracking grades, and proposes a convenient and applicable drainage system recovery technology according to the tunnel blockage or water seepage location. Based on the road tunnel lining cracking and water damage treatment technology proposed in this paper, the service state of the tunnel structure can be significantly improved and the overall operation safety of the tunnel can be improved.

keywords: Highway tunnel; lining split;drainage pipelines;treatment technique

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基于扩展有限元的隧道偏载致裂机理及对策措施研究

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摘　要：偏压是导致隧道衬砌裂缝的原因之一，为了研究隧道衬砌在偏压作用的开裂机理，采用扩展有限元方法，模拟了偏压地形情况下的破坏模式，在局部偏压下的衬砌裂缝分布、位移收敛、内表面裂缝扩展以及界面偏心距特征。最后提出了针对性措施，即针对偏压地形的偏压挡墙明洞、反压护拱，以及针对局部偏压的加大截面厚度和不对称配筋措施。

关键词：公路隧道；衬砌；裂缝；偏压；扩展有限元分析

Study on the Mechanism and Countermeasures of Bias Load Cracking of Tunnel Based on Extended Finite Element Method

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Abstract:

The bias load is one of the leading causes of tunnel lining cracks, in order to study the mechanism of cracking of tunnel lining in the bias load effect, using extended finite element method, simulate the failure mode under the condition of bias, bias in the local lining crack distribution, displacement convergence and inner surface crack extension and interface characteristics of eccentricity. Finally, some countermeasures are put forward, namely open cut tunnel with retain wall and loading umbrella arch for bias terrain, as well as increasing section thickness and asymmetric reinforcement for the local bias.

keywords: Road Tunnel;Lining;Cracks; Bias load;Extended Finite Element Method

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掺再生微粉水泥基渗透结晶型浓缩剂的制备与性能研究

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摘　要：水泥基渗透结晶型防水材料具有很多优点，已经在工程中得到广泛应用，但其原料成本高、力学性能不尽人意以及不能够作为浇筑混凝土和灌浆材料使用等诸多缺陷也逐渐显现。因此，作者利用建筑垃圾中的废混凝土经破碎、筛分和球磨获得再生微粉，将其作为浓缩剂主要的活性化学物质之一，通过试验及其结果的分析确定了浓缩剂配方中活性物质的最佳值，同时反映出再生微粉对水泥基材料强度影响显著。此外，作者对浓缩剂关键性能指标进行了试验研究。结果表明：所制备的浓缩剂与市售产品性能相当、稳定性好，弥补了现有水泥基渗透结晶型防水材料的技术缺陷，可推广应用于防水、灌浆材料、浇筑建筑体以及库岸软弱夹层固结材料掺料使用。

关键词：水泥基；渗透结晶；浓缩剂；配方设计；性能研究

Preparation and Properties of Cement-Based Permeate Crystalline Concentrates Containing Regenerated Powder

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Abstract:

Cement-based Permeate Crystalline Waterproof Material has many advantages. It has been widely used in engineering., but the high cost of raw materials, unsatisfactory mechanical properties, and the inability to be used as cast concrete and grouting materials have gradually appeared. Therefore, the author used the waste concrete to obtain the regenerated micropowder by crushing, sieving and ball milling, and used it as one of the main active chemicals of the concentrate. The optimum value of active substance in concentrator formulation was determined by experiment and analysis of results, and the analysis results indicate the significant effect of the recycled fine powder on the strength of the cement-based material. In addition, The key performance indexes of concentration agent were tested by the author. The test results show that the prepared concentrate has the same performance and good stability as the commercially available products. Some defects of the existing cement-based permeable crystalline waterproof materials can be widely applied to waterproofing, grouting materials, pouring construction bodies and the use of solid intercalation materials for storage of weak interlayers.

keywords: Cement-based;capillary crystalline;concentration agent;formulation design; performance research

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粘贴钢板加固地铁盾构隧道承载性能研究

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摘　要：遭遇结构整体过大变形的地铁盾构隧道常采用粘贴钢板工法进行加固。为探究粘钢加固盾构隧道衬砌的承载性能和破坏机理，本文基于上海内张钢圈加固管片衬砌结构试验，建立三维实体精细有限元模型，讨论了通缝隧道衬砌粘钢加固后的力学行为、变形特性和破坏模式，验证了数值仿真手段的可靠性。在此基础上，对某地铁错缝盾构隧道钢板加固案例展开模拟，评价加固效果。研究表明：(1)精细有限元模型能较好模拟钢板与管片衬砌的共同承载特性，真实反映接头等细部构造的变形及力学指标；(2)粘钢加固后衬砌结构破坏的直接原因是钢板与管片混凝土间环氧树脂黏结失效，呈现明显的脆性特征，常规变形监测难以起到预警作用，应着重关注钢圈与混凝土间黏结状态。

关键词：粘贴钢板

Study on the Load-Bearing Capacity of Metro Shield Tunnel Lining Strengthened by Bonded Steel Plates

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Abstract:

The solution of bonding steel plates to the metro shield tunnel lining which already with excessive overall deformation had been widely applied for reinforcement. To investigate the load-bearing behavior and failure mechanism of lining structure after bonded steel plate reinforcement, a detailed three-dimensional finite element modeling approach was proposed, on the basis of a full-scale structural test of single lining ring reinforced by steel plates. By comparison with the test observations, the reliability and feasibility of the proposed single-ring model were validated. Subsequently, another detailed “1/2+1+1/2”-ring model based on stagger-jointed lining structure was developed to evaluate the strengthening effect of a diseased tunnel case after reinforcement. The results show that: (a)Three-dimensional detailed model can capture the composite effect of steel plates and segmental lining and reflect the deformation and mechanical indices in detailed configuration of the joints. (b)The bond failure between the steel plates and the segments leads to the failure of the strengthened structure. Conventional displacement monitoring is no longer appropriate for safety assessment and the separation phenomenon in the bond interface should be concerned to prevent brittle destruction.

keywords: bonded steel plate

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公路隧道设计阶段风险评估中存在的问题与对策

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摘　要：初步设计阶段对特殊隧道开展安全风险评估有利于强化公路隧道设计和建设过程中的安全风险意识，降低事故概率，减少经济损失。针对目前安全风险等级判断标准宽松和简单化，未重视数值分析，缺乏模糊综合评价指标体系、交通事故和火灾事件量化标准，以及评估单位和专家对评估结论的贡献度欠明确的问题，提出了针对性措施建议，包括：（1）提高事故等级判断标准、综合考虑各类事故后果；（2）在洞口稳定、塌方、岩爆、结构风险评估中发挥数值分析作用；（3）细化和完善模糊综合评价法的评价指标体系；（4）将交通事故和火灾发生率，以及运行速度差作为评价交通事故和火灾风险的依据；（5）评估单位和专家分别按 60%、40%的权重比例来汇总成最终的风险等级值。这些对策措施将有助于提高评估结论的客观性和背靠背评估时结论的一致性。

关键词：公路隧道；设计阶段；风险评估；问题；对策

Problems of and Countermeasures for Risk Assessment in the Preliminary Design Phase of Road Tunnels

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Abstract:

In preliminary design phase, risk assessments for special tunnels help enhance the awareness of risks in highway tunnel design and construction process, and reduce the probability of accident and economic losses. However, there were some problems occurring in the process of risk assessment, including adoption of the loose and simplified risk rating criteria, the neglect of numerical analysis, the lack of fine rating system for fuzzy comprehensive method, the hazy quantitative criteria for traffic and fire incident, and the uncertain influence factor of the assessment group and experts. Some countermeasures were put forward in the article, including: (1) adjusting the accident rating criteria, and including all kinds of accidents; (2) adopting the numerical method to analyzing portal stability, collapse, rock burst, structure calculation; (3) refining rating system for fuzzy comprehensive method; (4) taking traffic accidents and fires frequency, actual speed difference into account; (5) setting the assessment group and experts with weight ratio of 60% and 40% respectively, then aggregating into a final level of risk rate. These measures could improve the objectivity of the assessment conclusions and the consistency under situation of back to back assessments.

keywords: road tunnel; design phase; risk assessment; problem; countermeasure

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公路隧道衬砌防裂钢筋网作用机理研究

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摘　要：为了定量分析防裂钢筋网提高隧道衬砌结构抗裂性能的机理和幅度，以双车道隧道Ⅲ级和Ⅴ级围岩衬砌结构为研究对象，采用荷载结构法和杆系有限元数值模拟，获得了素混凝土结构开裂的临界荷载、进而获得了配置钢筋网的衬砌结构达到 0.2mm 裂缝宽度时的临界荷载。分析表明，配置防裂钢筋网后，Ⅲ级和Ⅴ级围岩衬砌结构的抗裂性能分别提高 22.4% 和 15.2%。可见，抗裂效果明显。

关键词：隧道衬砌；防裂钢筋网；数值分析；机理

Study on Mechanism of Anti-Crack Reinforcement Mesh for Road Tunnel Lining

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Abstract:

In order to quantitatively analyze the mechanism and extent of anti-crack reinforcement mesh improving the crack resistance of tunnel lining structure, taking the surrounding rock lining structure of grade III and V of double-lane tunnel as the research object, the critical load of cracking of plain concrete structure is obtained by using load structure method and finite element numerical simulation, and then the critical load of lining structure with reinforcement mesh when the crack width reaches 0.2 mm is obtained. The analysis shows that the crack resistance of lining structure in grade III and V surrounding rock increases by 22.4% and 15.2% respectively after the anti-crack reinforcement mesh is deployed. It can be seen that the crack resistance effect is obvious.

keywords: tunnel lining;anti-crack reinforcement mesh;numerical analysis;mechanism

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补偿收缩混凝土隧道衬砌结构模型试验研究

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摘　要：裂缝与混凝土材料如影随形，公路隧道衬砌亦如此，采用补偿收缩混凝土是改善衬砌抗裂性能的一种尝试。为此，按 1:10 的比例制作了 V 级围岩中的两车道隧道衬砌结构缩尺寸模型，并推导了模型隧道和实际隧道地层弹性抗力强度的相似比解析公式，其主要影响因素包括半径、厚度、弹性抗力系数、弹性模量。最后，根据实测值，并采用弹性支点法估算了衬砌结构预压应力的提高值约为 480kPa。

关键词：补偿收缩混凝土；衬砌；模型试验；相似比

Model Test Study on Lining Structure of Compensatory Shrinkage Concrete Tunnel

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Abstract:

Crack is one of the common diseases in concrete structure, and the lining of the highway tunnel is also the same. The use of compensated shrinkage concrete is an attempt to improve the anti-crack performance of the lining. For this reason, the shrinkage model of lining structure is made with a similarity ratio of 1:10, and the analytical formula of the similarity ratio between the model tunnel and the actual tunnel stratum's elastic resistance is derived. The main influencing factors include radius, thickness, elastic resistance coefficient and elastic modulus. Finally, according to the measured values, the increase of 480kPa-pre pressure stress of the lining structure is estimated by using elastic fulcrum method.

keywords: Compensatory Shrinkage Concrete;Lining;Model Test; Similarity Ratio

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三车道公路隧道衬砌防裂钢筋网作用机理研究

胡坚，汪洋
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摘　要：为了定量分析防裂钢筋网提高隧道衬砌结构抗裂性能的机理和幅度，以三车道隧道Ⅲ级和Ⅴ级围岩衬砌结构为研究对象，采用荷载结构法和杆系有限元数值模拟，获得了素混凝土衬砌结构开裂的临界荷载、进而获得了配置钢筋网的衬砌结构达到 0.2mm 裂缝宽度时的临界荷载。分析表明，配置防裂钢筋网后，Ⅲ级和Ⅴ级围岩衬砌结构的抗裂性能分别提高 22.4%和 15.2%。可见，抗裂效果明显。

关键词：隧道衬砌；防裂钢筋网；数值分析；机理

Study on Mechanism of Anti-Crack Reinforcement Mesh for Road Tunnel Lining with Three lanes

Hu Jian ,Wang Yang
（Zhejiang University of Technology）

Abstract:

In order to quantitatively analyze the mechanism and extent of anti-crack reinforcement mesh improving the crack resistance of tunnel lining structure, taking the surrounding rock lining structure of grade III and V of three-lane tunnel as the research object, the critical load of cracking of plain concrete structure is obtained by using load structure method and finite element numerical simulation, and then the critical load of lining structure with reinforcement mesh when the crack width reaches 0.2 mm is obtained. The analysis shows that the crack resistance of lining structure in grade III and V surrounding rock increases by 22.4% and 15.2% respectively after the anti-crack reinforcement mesh is deployed. It can be seen that the crack resistance effect is obvious.

keywords: tunnel lining; anti-crack reinforcement mesh; numerical analysis; mechanism

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基于 K-S 检验方法的公路隧道裂缝分布特征研究

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摘　要：裂缝是运营期隧道衬砌结构的主要病害。为了有效地开展衬砌裂缝的预防及修复工作，首先使用人工检测和自动化检测两种方法，对浙江 48 座隧道的衬砌裂缝病害进行了调查，并结合文献查阅，统计了境内外 109 条含有裂缝的隧道实例。随后，运用 K-S 检验方法，分析了衬砌裂缝各种特征分布规律。

关键词：衬砌裂缝；自动化检测；K-S 检验方法；特征分布规律

Research on Fracture Distribution Characteristics of Highway Tunnel Based on K-S Test Method

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Abstract:

Crack is the main disease in tunnel lining structure during operation. In order to effectively carry out the prevention and repair work of the lining cracks, both manual testing and automated detection methods are firstly adopted to investigate lining cracks in Zhejiang 48 tunnels. Combining with literature review, other 109 tunnels are taken as statistics examples. Lastly, K-S test method is used to analyze the various characteristics of lining crack distribution.

keywords: Lining Cracks;Automatic Testing;K-S Test Method;Characteristic Distribution Law

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隧道二次衬砌早期裂缝成因及防治对策研究

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摘　要：为解决隧道衬砌结构裂缝和渗漏水问题，通过对不同配合比混凝土早期力学性能的对比试验，证明了掺加粉煤灰、矿渣和微膨胀剂对改善早期收缩变形是有效的。采用荷载-结构法定量分析了不同配合比和不同拆模时间衬砌结构的内力和应变，结果显示掺加粉煤灰、矿渣和 UEA 微膨胀剂的二次衬砌最大拉应变远小于混凝土极限拉应变，从而为二次衬砌拆模时机的确定提供了理论依据。

关键词：二次衬砌；早期裂缝；早期收缩；防治对策

Study on the Causes and Prevention Countermeasures of the Early Cracks in Second Tunnel Lining

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Abstract:

To solve the problem of tunnel lining crack and water leakage, the early mechanical properties of concrete with different mix ratio are studied, which shows that the mix of fly ash, slag and expansive agent can improve the early shrinkage deformation effectively. Load structure method is used to quantitatively analyze the lining structure stress and strain with different mix ratio and different removal time. The result shows that secondary lining with fly ash, slag and UEA expansive agent has a much smaller tensile strain than the concrete ultimate tensile strain, which provides theoretical basis for determining the time of lining template removal..

keywords: second lining; early crack; early shrinkage; prevention countermeasures

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Preliminary Study on Prevention and Control Technology of Crystallization Blockage in Tunnel Drainage System

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Abstract:With the construction of a large number of tunnel engineering, the problem of tunnel diseases gradually prominent, especially the tunnel drainage system crystallization blockage, new tunnel and operation tunnel have appeared drainage system crystallization blockage phenomenon.When the tunnel drain pipe is blocked by crystallization, the pressure of tunnel lining structure increases, and a series of diseases such as cracks and leakage of tunnel lining occur subsequently.In view of the problem of crystallization blockage in tunnel drainage system, a large number of field investigations were carried out to analyze the crystallinity and groundwater, and five prevention and control technologies of crystallization of drainage pipes were put forward, including new coating drainage pipes, new electric field drainage pipes, new magnetic field drainage pipes, new flocking drainage pipes and new deformable drainage pipes.New electric field drainage technology, for example, on the basis of theoretical analysis for the indoor experiment study, the results show that the new type of electric field drainage pipe has good crystallization, the voltage value is 5 v, and prevent crystallization of strong electric field effect is best, the electric field can inhibit the calcite crystal shape the formation of calcium carbonate, drain the crystallization treatment can be used in the tunnel.

Key words: tunnel engineering; crystallization blockage; coating; electric field; magnetic field; flocking; variable drainage pipe; SEM

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地表超载下含环缝凹凸榫错缝拼装管片接头劣化机理

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摘　要：针对地表超载导致盾构隧道接头破坏的问题，以含环缝凹凸榫（不含纵缝凹凸榫）的错缝拼装管片为研究对象，建立了精细化盾构隧道有限元模型。通过施加 1：10 盾构隧道-土相互作用模型试验验证的水土荷载，对超载作用下管片接头的变形及破坏进行了研究，得出；（1）靠近隧道拱腰部位的接头张开量大于靠近拱底及拱顶的接头张开量，接头环缝错台主要是由纵缝接头张开导致，且接头的张开量与错台量呈近线性关系；（2）隧道拱腰部位环缝凹凸榫出现裂损的时机比拱底部位早；（3）管片接头劣化过程可分为四个阶段，分别为接头张开及错台发展缓慢，接头张开及错台发展加快，环缝凹凸榫及管片表面出现损伤，接头处混凝土裂缝和管片表面裂缝贯通（接头发生完全破坏）。

关键词：地表超载；盾构隧道；错缝拼装；凹凸榫；接头破坏

Deterioration Mechanism of Staggered Jointed Segment Joint with Circumferential Tenon Under Surface Surcharge

Shuo Yu, Jin Hao
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Abstract:

Aiming at the problem of shield tunnel joint failure due to surface surcharge， a finite element model of shield tunnel is established that based on the segment with circumferential tenon and without longitudinal tenon.Though applied the soil load that is verified by 1:10 scale model test of tunnel and soil interaction, the deformation and failure process of segment joints under surface surcharge is analyzed. The results showed that:(1) the joint open near the arch waist position is bigger than the joint open near the arch bottom and arch open, the ring dislocation of joint is mainly caused by the open of joint longitudinal seam, and joints open and the dislocation is near linear relation;(2) the crack moment of segmental circumferential tenon near the arch waist parts is earlier than the arch bottom parts; (3)the deterioration process of the staggered jointed segment joints can be divided into four stages: joint open and dislocation slow development—joint open and dislocation fast development—the circumferential tenon and segment surface appear damage—concrete crack near the joint and segment surface is linked up, the joint is completely failure.

keywords: surface surcharge;shield tunnel;staggered jointed;tenon;joint failure

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衬砌背后空洞对隧道结构安全影响的模型试验研究

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摘　要：隧道衬砌背后脱空现象是隧道建设与运营中的主要病害之一，会改变隧道衬砌与围岩的相互作用关系，引起隧道结构应力集中而破坏。论文采用物理模型试验的方法，模拟了隧道衬砌背后无空洞、存在单空洞、存在组合空洞的三种工况。通过对比分析三种工况在表面加载的作用下围岩压力、衬砌轴力及弯矩变化规律，获得了以下主要结论：（1）隧道无空洞时，衬砌与围岩接触良好，围岩压力、衬砌轴力及弯矩均随上覆荷载的增加而增大；（2）隧道衬砌背后存在空洞时，空洞范围内围岩压力也无法传递到衬砌结构上，导致围岩压力、衬砌轴力及弯矩均随上覆荷载增加而减小，但衬砌结构偏心距增大容易发生开裂破坏。

关键词：模型试验。

The Influence of Cavities Behind Lining on the Safety of Tunnel Studied by Model Test

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（Chongqing Jiaotong University）

Abstract:

Abstract: There is a cavity behind the tunnel lining as one of the main diseases in the construction and operation of road tunnel. It will change the interaction between tunnel lining and surrounding rock and induce the concentration even failure of tunnel structure. In this paper, the physical model test has been adopted, and three test cases were simulated: no cavity, one cavity and a few cavities. By comparing the surrounding rock pressure, axial force and moment of lining under the over surcharge on surface, some results can be summarized as following: (1) when there is no cavity behind the tunnel, the lining and the surrounding rock contact well, and the surrounding rock pressure, lining axial force and bending moment will increase as the increase of over surcharge. (2) when there are cavities behind tunnel lining, the surrounding rock pressure cannot be pass to the lining structure in the range of cavities. In that way, the rock pressure, axial force and bending moment of lining will reduce and the eccentricity will increase with the increase of over surcharge, which will lead to the cracking and failure of structure.

keywords: model test

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公路隧道结构预养护理念与技术研究

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摘　要：隧道结构预养护技术能延缓隧道损坏进入快速发展期，节约总体成本，而国内对于隧道结构预养护方面的研究刚刚起步，建立一套结合原有养护规范的预养护体系就迫在眉睫了。本文结合 15 版隧道养护技术规范的养护分级思路上，深入阐述了预养护理念，提出预养护条件下状况值标准，并对原有养护技术规范提出修改建议，给出预养护技术措施，建立了隧道结构预养护体系。对隧道长期保持良好的工作性能，节约养护成本具有重要意义。

关键词：分级研究；公路隧道；结构预养护；预养护技术

Research on Preventive Maintenance Concept and Technology of Highway Tunnel Structure

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Abstract:

The preventive maintenance technology of tunnel structure can delay the tunnel damage to a rapid development period and save the overall cost. However, the domestic research on the preventive maintenance of the tunnel structure has just started, and it is imminent to establish a preventive maintenance system combining with the original curing code. In this paper, the 15th edition of the tunnel maintenance technical specifications of the classification of conservation ideas, in-depth elaboration of the concept of preventive maintenance, preventive maintenance condition proposed value conditions, and proposed amendments to the original maintenance specifications, preventive maintenance technology and measures given to establish Tunnel structure preventive maintenance system. Long-term to maintain good performance of the tunnel, conservation costs conservation is of great significance.

keywords: highway tunnel;preventive maintenance of structure;preventive maintenance technology

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钢筋锈蚀对地铁盾构隧道纵缝接头力学性能影响研究

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摘　要：基于地铁盾构隧道环境条件及空间分布条件，对地铁盾构隧道管片进行氯盐侵蚀加速钢筋锈蚀试验，并以此为基础进行了钢筋锈蚀后纵缝接头正弯矩足尺试验。建立了纵缝接头三维数值精细化计算模型，并分析了钢筋锈蚀影响下地铁盾构隧道纵缝接头的力学性能退化状况。对足尺试验和数值计算结果进行对比分析，结果表明：（1）正弯矩作用下，钢筋锈蚀后纵缝接头的变形规律具有明显的阶段性特征。足尺试验中，纵缝接头变形可以划分为三个阶段。数值计算中，可定义六个特征点，纵缝接头变形划分为七个阶段；（2）前面几个阶段，钢筋锈蚀对纵缝接头变形无明显影响。至最后一个阶段，随着钢筋锈蚀层厚度的增加，螺栓应变及极限承载力均减小。螺栓应变最大值减幅较大，极限承载力减幅较小。

关键词：钢筋锈蚀；盾构隧道；纵缝接头；管片；力学性能

Influence Research of Reinforcement Corrosion on Mechanical Property of Longitudinal Joint in Metro Shield Tunnel

Zheng Yongbo
（Tongji University）

Abstract:

Based on the environmental condition and spatial distribution of metro shield tunnel, accelerated reinforcement corrosion experiments of segment in the environment of chloride attack are conducted and then full-scale tests with sagging moment are conducted. A 3d refined FEM model of longitudinal joint is established in order to analyze the deterioration status of longitudinal joint mechanical property under the influence of reinforcement corrosion. Compare and analyze the results of full-scale test and numerical computation, and the result shows: (1) with sagging moment, the deformation of longitudinal joint after reinforcement has obvious periodical characteristics. In the full-scale test, the deformation of longitudinal joint can be divided into three stages. In the numerical computation, the deformation of longitudinal joint can be divided into seven states considering the definition of six feature points; (2) previous stages, reinforcement corrosion has no obvious effect on the deformation of longitudinal joint. To the last stage, as the thickness of reinforcement corrosion increases, when longitudinal joint is destroyed, bolt strain and ultimate bearing capacity both reduce. The maximum bolt strain decreases greatly and ultimate bearing capacity decreases small.

keywords: Reinforcement corrosion;shield tunnel;ongitudinal joint; segment; mechanical property

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仰拱裂缝对地铁隧道衬砌力学性能的影响研究

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摘　要：通过模型试验与数值模拟研究了仰拱裂缝对地铁隧道衬砌力学性能的影响，研究结果表明：（1）仰拱位置存在裂缝时，预制裂缝位置更容易贯通，同时造成拱脚及拱顶区域裂损情况更加严重；（2）仰拱裂缝的存在削弱了结构的整体性，使得裂损区域结构内力大幅降低，恶化了两侧拱脚及拱顶位置的受力状态，加剧了其裂损过程；（3）仰拱位置裂缝数量越多，对结构影响越大，同等荷载条件下结构裂损越严重；（4）仰拱裂损区域局部刚度的下降导致衬砌与围岩接触压力分布形式发生改变，是造成衬砌内力及开裂规律发生改变的根本原因。

关键词：地铁隧道；仰拱；裂缝；模型试验；数值模拟；力学性能

Study on the Influence of Invert Cracks on the Mechanical Behavior of Metro Tunnel Lining

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Abstract:

In this paper, model tests and numerical simulations were carried out to study the influence of invert cracks on the mechanical behavior of metro tunnel lining. The results show that: (1) Through-cracks are easier to form at the precast crack-locations, causing the arch foot and the vault to crack more seriously; (2) The existence of cracks at the inverted arch weakens integrity of the lining and changes the stress state. Internal forces at the damaged area reduces considerably, deteriorating the stress state of the arch foot and aggravating the failure of tunnel. (3) The more the number of cracks, the greater the impact on the structure. Furthermore, the damage under the same load conditions becomes more serious with the increase of cracks. (4) Changes of the contact pressure acting the lining surface induced by the reduction of lining stiffness at the damaged area is the fundamental reason for the change of internal forces and the failure mode.

keywords: metro tunnel;inverted arch;cracks;model test;numerical simulation;mechanical behavior

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基于数值方法的隧道超前管棚支护效果评价

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摘　要：隧道埋深较浅或围岩较差时，常使用超前管棚作为强支护进行围岩加固，为研究管棚的支护效果，通过分析管棚的加固机理及影响因素，使用数值分析方法，研究了 3 种隧道埋深和4种围岩条件共12种计算工况对管棚支护效果的影响,分析了支护前后围岩变形量、变形百分比等，提出了套拱承载比和围岩承载比的概念对管棚的支护效果进行评价，为同类工程提供借鉴。

关键词：隧道工程；超前管棚；支护效果；评价

Study on the Evaluation of Support Effect of Tunnel Umbrella Arch Method Based on Numerical Method

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Abstract:

When the cover depth of tunnel is shallow or the surrounding rock is poor, umbrella arch method is usually used as strong support to reinforce surrounding rock. In order to study the support effect of umbrella arch method, based on the analysis of reinforcement mechanism and influencing factors of umbrella arch method, 12 calculation conditions of three tunnel depth and four surrounding rock conditions on the support effect of umbrella arch method was studied by numerical analysis method. The deformation amount and percentage of surrounding rock before and after support were analyzed. The concepts of umbrella arch bearing ratio (UABR) and surrounding rock bearing ratio (SRBR) were put forward to evaluate the support effect of umbrella arch method, which could provide reference for similar projects.

keywords: tunnel engineering; umbrella arch method; support effect; evaluation

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破碎围岩大跨公路隧道结构健康度评价方法研究

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（同济大学）

摘　要：目前关于大跨隧道结构在松动荷载作用下的受力变形与损伤演化机理研究相对较少，缺乏运营期结构的健康度评价体系与预警标准，不利于掌握隧道结构的安全状态。针对上述问题，通过建立二维及三维数值分析模型，研究了Ⅳ、Ⅴ级围岩下大跨隧道结构在松动荷载下的受力变形特性，依据变形及破损特征，建立了 5 级评价体系与 3 级预警标准。通过研究，提出：1）拱部松动荷载作用下大跨隧道的破坏过程分为四个阶段，分别为设计荷载下的弹性受力阶段、拱部松动荷载下的弹性受力阶段、结构开裂后的塑性工作阶段、加速变形破坏阶段；2）设计荷载下，荷载规范计算方法与三维数值模拟方法得出的隧道变形基本一致，验证了数值计算的可行性；通过数值计算，得出Ⅳ级围岩下结构极限承载力为 734kPa，拱顶沉降 6.75cm，边墙收敛 1.56cm，Ⅴ级围岩下结构极限承载力为 812kPa，拱顶沉降 10.47cm，边墙收敛 4.06cm；3）以拱顶开裂、局部压屈、拱顶拱腰压屈、拱腰压屈达到衬砌厚度的 1/3、钢筋拉断为关键节点，以结构受力、拱顶沉降、边墙收敛为评价指标，建立了Ⅳ、Ⅴ级围岩下大跨隧道的健康度评价体系及预警标准。

关键词：大跨隧道；衬砌结构；健康度；破碎围岩；松动荷载

Study on Health Evaluation Method of Large Span Highway Tunnel with Broken Surrounding Rock

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Abstract:

At present, there are few researches on the mechanism of deformation and damage evolution of large span tunnel structure under loosening load, and lack of health evaluation system and early warning standard of the structure in operation period, which is not conducive to grasping the safe state of tunnel structure. For these problems, this paper studied the mechanical and deformation characteristics of large span tunnel structure under loosening load under grade Ⅳ and Ⅴ surrounding rock by establishing two dimensional and three dimensional numerical analysis models. The 5-grade evaluation system and the 3-level early warning standard were established according to the characteristics of deformation and damage. Through these researches,this article got the following conclusions. 1)The failure process of large span tunnel under loosening load is divided into four stages: elastic stress stage under design load, elastic stress stage under loosening load, plastic working stage after structure cracking, accelerating deformation and failure stage; 2)Under design load, the tunnel deformation obtained by the three-dimensional numerical simulation method is basically consistent with the tunnel deformation obtained by the calculation method of load code, which verifies the feasibility of numerical calculation. By numerical calculation, it is obtained that

the ultimate bearing capacity is 734kPa, the settlement of arch top is 6.75 cm, the convergence of side wall is 1.56 cm under grade Ⅳ surrounding rock, the ultimate bearing capacity is 812kPa, the settlement of arch top is 10.47 cm, and the convergence of side wall is 4.06 cm under grade V surrounding rock; 3)Through taking the crack of arch top, partial buckling, arch top and arch waist buckling, the buckling depth of arch waist reaches 1/3 of the thickness of lining, steel bar break as key nodes, and taking the structural stress, the settlement of arch top and the convergence of the side wall as evaluation indexes, the health degree evaluation system and early warning standard of large span tunnel under grade IV and V were set up.

keywords: large span tunnel; lining structure; health grade; broken surrounding rock; loose load

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基于裂缝扩展有限元模型的隧道衬砌结构安全性评价方法

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摘　要：隧道衬砌裂损是运营隧道最常见的病害类型，裂损后衬砌结构承载力大幅降低，容易引发渗漏水、劣化、剥落掉块及复合型隧道病害，对隧道结构耐久性和安全性影响较大，而现行规范施行的评价方法可信度较低，缺乏基于结构承载性能的定量化的评价方法。本文利用 Abaqus 软件扩展有限元模块就隧道径向纵向裂缝对衬砌结构承载性能的影响进行了数值模拟，采用承载力衰减率对衬砌承载性能的影响程度进行了定量分析，提出了基于力学分析的结构承载能力评价方法，为隧道承载力的计算分析、衬砌结构的安全性评价以及预养护时机提供技术参考。

关键词：裂缝扩展有限元；承载力分析；安全性评价

Safety Evaluation Method of Tunnel Lining Structure Based on Crack Propagation Finite Element Model

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Abstract:

Tunnel lining cracking is the most common type of disease in operating tunnels. After cracking, the bearing capacity of the structure decreases greatly, and it is easy to cause seepage, material deterioration, peeling off blocks and composite tunnel diseases, which have a great impact on the durability and safety of tunnel structure. The reliability of evaluation methods implemented by the current specification is not satisfactory, and there is no quantitative evaluation method based on structural load-bearing performance. In this paper, the influence of cracks on the bearing capacity of lining structure is numerically simulated by using the extended finite element module of Abaqus software, and the influence degree of bearing capacity attenuation rate on the bearing capacity of lining is quantitatively analyzed. The evaluation method of structural bearing capacity based on mechanical analysis is proposed. All in all, this paper provides technical reference for the calculation and analysis of tunnel bearing capacity, the safety evaluation of lining structure and the tunnel pre-maintenance timing.

keywords: bearing capacity analysis; Safety evaluation

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高水压大直径越江电力管廊隧道结构健康监测方案探讨

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摘　要：高水压长期侵蚀、穿越及下卧土层软弱杂多变等特点使得水下电力管廊隧道结构的运营安全问题较为突出，合理开展健康监测是极为必要的。本文依托苏通 GIL 综合管廊大直径越江盾构隧道工程，在调研隧址地质条件、设计方案及运营控制要求的基础上，结合水土压力计算与结构力学性能分析，开展了大直径高水压越江盾构隧道结构健康监测方案的研究，确定了隧道结构的监测项目、监测部位、监测仪器选型方案及数据采集传输与处理等技术，并对监测数据的数字化管理方案进行了探讨。通过研究，1）选取了典型土层、高水压等具有代表性的 13 个断面，开展水土压力、钢筋应力、螺栓轴力、接缝张开监测，并全线实施沉降监测；2）设计了集工程信息可视化、健康监测实时管理、结构安全动态评估、仪器故障诊断等功能于一体的健康监测管理平台架构方案，指导了依托工程健康监测的实施及数据评价管理。方案可供类似水下隧道健康监测参考。

关键词：越江盾构隧道；结构健康监测；结构力学性能分析；数字化管理

Discussion on Structural Health Monitoring Plan for High Water Pressure and Large Diameter Cross-River Power Pipe Tunnel

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Abstract:

The characteristics of long-term erosion of high water pressure and crossing complicated and changeable soft substratum make the operation and safety of underwater power utility tunnel structure more prominent. Therefore, it is extremely necessary to carry out reasonable health monitoring. In this paper, supported by Sutong GIL large-diameter utility shield tunnel, the health monitoring project of large diameter and high water pressure crossing river shield tunnel was carried out through investigating tunnel site geological conditions, design and operation control requirements and combining water and soil pressure calculation and structural mechanics performance analysis, the monitoring items, monitoring parts of tunnel structure, selection of monitoring instrument and the technology of collection, transfer and processing of monitoring data of solution were determined in this paper. The digital management project of monitoring data was also discussed. Through research, 1) it was clear that the key monitoring parts were the highest water pressure in deep groove, severe scouring and silting in riverbed, obvious thickness changes of overburden soil, ultra-shallow buried section, silty soft clay, silty soil and other typical soil layers.13 monitoring sections were arranged to monitor soil and water pressure, rebar stress, bolt axial force and joint opening and settlement monitoring was arranged along the whole line. A digital health

monitoring program which integrated information visualization, real-time health monitoring management, structural safety dynamic evaluation, fault diagnosis of instrument and other functions was designed to guide the implementation of health monitoring and data evaluation management relying on engineering. The scheme can be used as reference for health monitoring of similar underwater tunnels.

keywords: Across-river shield tunnel;Structural health monitoring technology;Analysis of structural mechanical properties;Digital management

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冲刷作用下吸力式桶形基础水平承载力计算方法

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摘　要：水平承载力是衡量海上风电及海洋平台基础稳定性的重要指标；吸力式桶形基础是一种新式基础，而波浪、海流的冲刷作用会导致基础水平承载力的降低。笔者综合当前研究，修正了吸力式桶型基础水平承载力计算模型，提出了一种新的吸力式桶型基础水平承载力的计算方法；将计算值与水槽模型试验结果进行对比验证，同时探讨了长径比对基础弯矩承载力贡献量的影响。以冲刷深度和冲刷宽度两个参数表征冲刷作用效果，充分考虑冲刷深度以上剩余上覆土体对基础水平承载力的影响，提出了冲刷作用下基础水平承载力计算模型与计算方法，将计算值与水槽模型试验结果进行对比验证，同时探讨了冲刷深度及冲刷宽度对基础水平承载力的影响规律，为吸力式桶形基础实际工程设计施工提供一定的参考。

关键词：吸力式桶型基础；计算模型；水平承载力；冲刷

Calculation Method of Horizontal Bearing Capacity of Suction Bucket Foundation Under Scouring

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（Ocean University of China Hohai University　Ocean University of China　Hohai University）

Abstract:

The Horizontal bearing capacity is an important index to measure the stability of offshore wind power and offshore platform foundation; suction bucket foundation is a new type of foundation, and the scouring effect of waves and currents will lead to the reduction of horizontal bearing capacity of foundation. Based on the current research, the author revised the calculation model of horizontal bearing capacity of suction bucket foundation, and proposed a new calculation method of horizontal bearing capacity of suction bucket foundation. The calculated value was compared with the experimental results of flume model, and the influence of length-diameter ratio on the contribution of foundation bending moment bearing capacity was discussed. The scouring effect is characterized by two parameters: scouring depth and scouring width. The influence of residual overlying soil above scouring depth on the horizontal bearing capacity of foundation is fully considered. A calculation model and method for the horizontal bearing capacity of foundation under scouring are proposed. The calculated values are compared with the flume model test results. The influence of scouring depth and width on the horizontal bearing capacity of foundation is discussed, which can provide some reference for the practical engineering design and construction of suction bucket foundation.

keywords: Suction bucket foundation;Computational model;Horizontal bearing capacity; Scouring

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整体冲刷作用下吸力式桶形基础稳定性分析

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摘　要：吸力式桶形基础在正常工作过程中将始终受到波流的冲刷作用，海床的剧烈运动使其冲刷范围甚至会达到整体冲刷的情形，严重时将导致整个海上工程失稳破坏，带来巨大的经济损失。本文开展了砂土中整体冲刷作用对吸力式桶形基础稳定性影响的模型试验，分析了冲刷作用对基础位移模式、桶顶位移和转动点的影响规律。研究发现：整体冲刷作用不影响基础位移模式变化规律，在波浪循环荷载作用下基础位移模式始终表现为随着循环次数的增加从平动发展为转动；基础周围若存在整体冲刷将严重影响基础稳定性，冲刷深度对桶顶位移影响极大，基础桶顶最大位移与冲刷深度成平方关系；冲刷深度对于转动点位置影响较小，随着冲刷深度增加，转动点位置仅略微下移。

关键词：海上风电；吸力式桶形基础；整体冲刷；冲刷深度；稳定性

Stability Analysis of Suction Bucket Foundation Under General Scour Effect

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（Ocean University of China）

Abstract:

A When suction bucket foundation is in the working process, it is always under the scour effect which induced by the wave and current. General scour can even occurs because of the rough movement of the seabed. It will lead to instability and damage of the whole offshore engineering and then cause huge economic losses. Consequently, a model test was carried out to investigate the general scour effect on the stability of suction bucket foundation. The motion pattern, bucket top displacement and the rotation point position were analyzed. The results indicated that the motion pattern was not affected by general scour and always changed from translation to rotation with the increase of cyclic times under wave loads. General scour seriously affect the stability of the foundation. The scour depth had a great influence on the bucket top displacement. The maximum bucket top displacement was equal to a scour depty square. The position of rotation point, however, was little affected by scour depth. And the position of rotation point moved down slightly with the increase of scouring depth.

keywords: offshore wind power;suction bucket foundation;general scour;scour depth

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某高速公路隧道的爆破振动对邻近民房开裂的影响分析

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（福州大学）

摘　要：针对大面积侧向堆载影响下已加固滨海软土地层桩网铁路路基的侧移问题，采用有限差分软件模拟并分析了隔离桩措施对软土侧移特性的影响。结果表明：未施做隔离桩治理措施时，8m 侧向堆载对软土层水平位移的影响值达 124mm；采用单排隔离桩治理措施时，减少软土位移约为 30%～15%，采用双排隔离桩治理措施时，减少软土位移约为 80%～60%，当堆载高度增加时，单、双排桩隔离效果均有所降低；双排隔离桩对地层位移量及位移发展速率的控制效果均优于单排隔离桩，同时桩体自身变形量较小，稳定性较好。

关键词：公路隧道

Analysis of the Influence of Highway Tunnel Blasting Vibration on Adjacent Residential Houses Cracks

Deng Tao, Wu Peigui, Deng Weiwen, Cao Yang
（Fuzhou University）

Abstract:

Aiming at the lateral displacement of railway subgrade with reinforced coastal soft soil strata under the effect of large lateral loading, the finite difference software was used to simulate and analyze the influence of isolation piles on the lateral displacement characteristics of soft soil. The results show that the effect of lateral loading of 8m on the horizontal displacement of soft soil reaches 124mm when the measures of isolation pile are not applied. And the displacement of soft soil is about 30% ~ 15% when using single row isolation pile, when using double-row isolation pile control measures, the reduction of soft soil displacement is about 80% ~ 60%, when the heap height increases, the isolation effect of single-row and double-row piles is reduced. But the control effect of double row isolation piles on horizontal displacement and displacement development rate are better than single-row isolation piles, while the pile itself deformation smaller, better stability..

keywords: highway tunnel

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隔离桩对滨海软土铁路路基侧向堆载下的位移控制研究

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摘　要：针对大面积侧向堆载影响下已加固滨海软土地层桩网铁路路基的侧移问题，采用有限差分软件模拟并分析了隔离桩措施对软土侧移特性的影响。结果表明：未施做隔离桩治理措施时，8m 侧向堆载对软土层水平位移的影响值达 124mm；采用单排隔离桩治理措施时，减少软土位移约为 30%～15%，采用双排隔离桩治理措施时，减少软土位移约为 80%～60%，当堆载高度增加时，单、双排桩隔离效果均有所降低；双排隔离桩对地层位移量及位移发展速率的控制效果均优于单排隔离桩，同时桩体自身变形量较小，稳定性较好。

关键词：隔离桩

Displacement Control of Lsolation Piles Under Side Loading of Coastal Soft Soil

Yang Sheng, Cao Yang, Zhang Erwang
（Fuzhou University）

Abstract:

Aiming at the lateral displacement of railway subgrade with reinforced coastal soft soil strata under the effect of large lateral loading, the finite difference software was used to simulate and analyze the influence of isolation piles on the lateral displacement characteristics of soft soil. The results show that the effect of lateral loading of 8m on the horizontal displacement of soft soil reaches 124mm when the measures of isolation pile are not applied. And the displacement of soft soil is about 30% ~ 15% when using single row isolation pile, when using double-row isolation pile control measures, the reduction of soft soil displacement is about 80% ~ 60%, when the heap height increases, the isolation effect of single-row and double-row piles is reduced. But the control effect of double row isolation piles on horizontal displacement and displacement development rate are better than single-row isolation piles, while the pile itself deformation smaller, better stability.

keywords: Isolated piles

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