Abstract Proceedings for General Session of ISEV 2024

General Session-1: Climatic change effects on performance of foundation geomaterials in transportation infrastructure

Applicability of Lightweight Geomaterials for the Pavement Subbase in Cold Regions

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Presenter: Masanori Sugawara, Muroran Institute of Technology, Japan

ABSTRACT: When lightweight geomaterials are used in the pavement subbase in cold regions, it is necessary to consider their resistance to freeze-thaw and frost heaving. However, little conventional research has addressed this. A lightweight geomaterial recycled from expansive shale and sewage sludge was subjected to a frost heave test to address its suitability for use in the subbase in a cold region. A frost heave test and a soil particle density test were conducted under different conditions and showed this lightweight geomaterial to afford high quality when used in the subbase course. The material was found to restrain frost-heaving, and the California bearing ratio value was not lower after freeze-thaw, despite this lightweight geomaterial having a high water content, with many pores distributed in each particle. The deformation characteristics were also investigated with reference to the geomaterial's suitability for the subbase course. Three materials whose particle size distributions were adjusted by the addition of silica sand were used. In a series of cyclic tests, specimens at the optimum moisture content were subjected to 10000 cycles at two confining pressures. It was found that the deformation modulus tended to be constant under stress with a constant amplitude and that the deformation properties were stable.

Review of Research Progress in Temperature Field Analysis of Bridge Structures

Author(s): Jianghao Tian, Bin Yan, Xuruili Lou, Limei Yu
Presenter: Jianghao Tian, Central South University, China

ABSTRACT: The exposure of bridge structures to various temperature changes under different climatic conditions significantly affects the safety, structural stability, and lifespan of bridges. Therefore, studying the temperature field of bridge structures under temperature effects holds important scientific research value and engineering significance. This paper aims to analyse the influence of temperature changes on bridge structures. By integrating existing literature, it reviews the current research status of temperature fields in bridge structures, summarizes the fundamental principles and research methods of temperature field studies. Simultaneously, it analyses the limitations of these methods in the research process and identifies existing issues. Finally, based on the latest research advancements, this paper discusses the future development direction of bridge structure temperature fields, such as the integration of multi-physics field coupling models and intelligent monitoring technologies. This integration aims to further enhance the methods and applications of analysing bridge structure temperature fields.

Research progress and the prospect of roadbed vibration in cold regions of high-speed railway

Author(s): Guanwen Liang, Chengpeng Hong, Ying Wu, Haoran Fu, Xuecheng Bian, Chuang Zhao, Jianqun Jiang
Presenter: Guanwen Liang, Zhejiang University, China

ABSTRACT: Frost heave and thaw settlement have always been the primary dis-eases of railway roadbeds in seasonal freezing areas. The repeated frost heave and thaw settlement of roadbeds can quickly produce uneven frost heave deformation. Frost heave and thaw settlement of the roadbed will aggravate environ-mental vibration, thus affecting the smoothness of the track structure. Many scholars have analysed roadbed frost heave by numerical simulation, but the mechanism of frost heave inside roadbeds and whether it aggravates environmental vibration still need further study. There are still many problems that need to be solved about the mechanism of subgrade frost heave and melt subsidence un-der the coupling of three fields: moisture, temperature, and train cyclic load, the frost heave deformation mechanism of subgrade soil, the deformation source of subgrade frost heave, the temperature field distribution characteristics of sub-grade frost heave, the temperature field characteristics of track structure, and sub-grade vibration. Therefore, the construction of full-scale freeze-thaw model experimental equipment for high-speed railways and the related scientific tests are of guiding and practical significance to the freeze-heave anti-design, the control of freeze-heave disease, and the environmental vibration of high-speed railways in cold regions. At the same time, the current standards need to clarify the sub-grade structure further, filling requirements, and anti-freezing standards of high-speed railways in seasonally frozen soil areas, so the research and development of this device can also provide scientific research support for improving standards.

A Thermal-moisture-dynamic Coupled Model Considering Traffic Loading and Freeze-thaw cycles

Author(s): Ying Wu, Chengpeng Hong, Guanwen Liang, Haoran Fu, Xuecheng Bian
Presenter: Ying Wu, Zhejiang University, China

ABSTRACT: In recent years, global climate change has had a pronounced impact, leading to a surge in extreme weather events that have significantly disrupted the operation and utilization of transportation infrastructure. The current global warming trend has further exacerbated the thawing of permafrost in specific regions, resulting in a decline in the stability of high-speed railway embankments in permafrost areas under repetitive train loading, consequently compromising the safety of train operations. This study utilizes the COMSOL finite element software to conduct a rigorous hydro-thermal analysis of embankments. The analysis takes into account the influence of moisture-temperature variations on soil modulus, providing a comprehensive understanding of the dynamic response characteristics and critical velocity changes of embankments under the combined effects of freeze-thaw cycles and train loading. The findings of this study serve as a robust theoretical basis for the construction, operation, and speed enhancement of high-speed railways in frozen soil areas, contributing to the advancement of infrastructure development in these challenging environments.

Investigation of Reasonable Thickness for Cellular Concrete Aggregate Air Convection Embankment in Alaskan Permafrost Regions

Author(s): Hanli Wu, Dawei Wang, Haoran Fuang, Zepeng Fan
Presenter: Hanli Wu, Harbin Institute of Technology, China

ABSTRACT: Air convection embankment (ACE) is an excellent technique that us-es open-graded material to create a “semi-conductive system” to provide excel-lent thermal insulation in summer and enhance the cooling performance in win-ter to prevent permafrost foundation from thawing. Previous thermal and per-formance studies indicate that the overall performance of cellular concrete ACE was superior to the conventional crushed-rock ACE. Cellular concrete is prom-ising to be an alternative to crushed rocks for ACE to mitigate thaw settlement of permafrost foundation. However, the reasonable interlayer thickness of cellu-lar concrete aggregate ACE needs to be further determined to maximize cost-effectiveness and performance and facilitate future field construction. Hence, an interlayer thickness investigation of the cellular concrete aggregate ACE was conducted by comparing the thermal performance of cellular concrete aggregate ACEs with various interlayer thicknesses. The critical embankment principle was adopted to determine the reasonable thickness of cellular concrete aggre-gate interlayer to reduce cost and achieve desired performance. The variation of thaw depth under the cellular concrete aggregate ACE, with different interlayer thicknesses ranging from 20~140 cm, was investigated to determine the reason-able thickness for cellular concrete aggregate ACE.

General Session-2: Analyses and testing of environmental vibrations induced by vehicle, machine and human

Fast prediction of ground-borne vibration induced by metro train using the semi-analytical approaches

Author(s): Lihui Xu, Meng Ma
Presenter: Lihui Xu, Shandong University of Science and Technology, China

ABSTRACT: Fast prediction of the ground-borne vibration from underground metro tunnels is significant for efficiently designing vibration mitigation measures. This study introduces a rapid vibration prediction procedure utilizing semi-analytical models. The train-track-tunnel-soil system is considered periodic in the tunnel axis direction, allowing it to be uncoupled into the train-track subsystem for vibration source and the tunnel-soil subsystem for vibration transmission. The train-track model incorporates multi-body dynamics for the train and a Euler-Bernoulli beam with multi-layered spring supports for the track. The obtained supporting forces on the track bed adhere to the periodicity of the second kind and are decomposed into single components for implementation in the coupled tunnel-soil model. The track bed is simplified as a Euler-Bernoulli beam. The tunnel structure and soil layers are modeled as elastic continua, with couplings achieved through transmission and reflection matrices (TRM) and wave transformation. Additionally, two measures are proposed to enhance prediction efficiency. The accuracy of the predictions is validated by comparing vibration levels with in-site measurements. Finally, the study investigates the effects of track irregularity, train speed, and tunnel depth on ground-borne vibration from metro trains. Increasing tunnel depth and controlling train speed are identified as effective measures for reducing ground-borne vibration from a design perspective.

Field survey and evaluation method for fouled ballast using transmitted sound characteristics

Author(s): Takahisa Nakamura, Takahiro Kageyama
Presenter: Takahisa Nakamura, Railway Technical Research Institute, Japan

ABSTRACT: As the ballast crushing and refining progresses over time and the content of fine particles increases, the saturation of ballast increases during rainfall by decreasing in drainage, the strength decreases, and so settlement of ballast is likely to increase. At present, since there is no method for quantitatively evaluating the ballast condition at field spots, the ballast condition is visually checked, and the ballast renewal is performed in consideration of the track repair frequency. Therefore, we had investigated the condition of the ballast under different track repair frequency in the real ballasted tracks and evaluated the particle size distribution of the ballast sample. And we had developed an inspection method using sound transmission for quantitatively evaluating the ballast condition. This method uses the characteristic that as the ballast progressed to be crushed and refined from a new condition, it becomes difficult to transmit sound in ballast. Therefore, we report that the relationship between sound level of transmitting ballast and ballast fouled index have been evaluated by the full-scale model tests. Moreover, we report on the results of the field tests to verify validity of this method.

Evaluation of railway embankment settlements constructed using construction waste soil from tunnel excavation

Author(s): Fumika Tajima, Takahiro Kageyama, Takahisa Nakamura, Kazuki Ito, Hiroyuki Kawanakajima, Akira Sakata
Presenter: Fumika Tajima, Railway Technical Research Institute, Japan

ABSTRACT: In the "Design Standards for Railway Structures (Earth Structures)" in Japan, it is shown that high- quality construction waste soil from tunnel excavation can be applied to railway embankment material. It is important not to allow large settlement on the embankment supporting slab tracks in the design since it is difficult to repair track irregularity of slab tracks. However, the settlement characteristics under the cyclic loading of the train have not been sufficiently studied in the application of construction waste soil from tunnel to the embankment for slab tracks of the Shinkansen. Therefore, in this study, the authors have evaluated the amount of plastic settlement under cyclic loading on the embankment of construction waste soil using an analysis method based on the cumulative damage theory. First, we con-structed a test embankment using construction waste soil and conducted cyclic loading tests with a large vibratory machine. Next, we verified the validity of this analysis method by comparing the cyclic loading test results with the simulation results of the cyclic loading tests. Then, using this analysis method, the amount of plastic settlement of embankment for actual slab tracks on the Shinkansen was calculated and confirmed to be within the applicable range.

Investigation on the Hydraulic Behavior of Sandy Fouled Ballast

Author(s): Ahmed Nabil Ramadan, Jinxi Zhang, Li Zhang, Biao Xu, Yupeng Shen, Peng Jing

Presenter: Ahmed Nabil Ramadan, Beijing University of Technology, China

ABSTRACT: Ballasted tracks fouled with sand particles is wide spread phenome-non in different countries around the world. That affects dreadfully the hydraulic behavior of ballasted track in both saturation and unsaturation stages. For saturation stage, Kozeny-Carman equation has been used to predict the hydraulic conductivity based on the porosity after collecting data of different materials about or related to sandy fouled ballast, because of limited publications about that for sandy fouled ballast. Kozeny-Carman equation cannot be used directly for sandy fouled ballast without modifying its parameters and validating the results. The results of validation showed a high agreement with the results of measured hydraulic conductivity. Moreover, a theoretical equation derived that expresses the relationship between porosity of fouled ballast and its fouling index with setting up a new constant. Determination of the constant through an empirical equation has been done then validating with different seven samples of sandy fouled ballast. The validation results show there is a great coincidence between predicted and measured data of sandy fouled ballast porosity. Hence, using the modified equation of Kozeny-Carman is applicable for estimating the hydraulic conductivity of sandy fouled ballast depending on its porosity and fouling index.

Flow and vibration characteristics of ballast particles caused by high-speed train loads

Author(s): Chuang Zhao, Zheng Luo, Wenqing Cai, Xuecheng Bian, Yun-min Chen
Presenter: Chuang Zhao, Zhejiang University, China

ABSTRACT: The vibration of ballast layer is greatly intensified by high-speed train loads compared with those under the normal speeds, which would result in notable settlements of ballasted tracks. Although the macro-response validated discrete element method has been widely used for the dynamic behavior analyses of granular materials, the actual vibration characteristics of ballast particle accompanied with flow behavior in a high-speed railway remain unclear due to the lack of adequate testing validation. Herein, a Particle tracking velocimetry-based monitoring approach was developed upon the formerly established full-scale model testing facility. A ballast layer about 5.5 m in length, 4.5 m in width and 0.35 m in height was prepared, in which Smart Rocks that could record vibration histories were installed. Various actual loading combinations of train speeds up to 360 km/h and axle loads up to 25 tons were applied, during which photos were taken by camera fixed perpendicularly to the ballast layer. The monitored results indicated that the vibration amplitudes of ballast particles at 15 cm below the sleepers increased by nearly ten times with the rise of train speed from 100 to 360 km/h. Meanwhile, the vibration amplitude of ballast layer surface at track center under 360 km/h approached 0.82 g in the downward direction, which was close to the weightless state. The transiently disabled interlocking among ballast particles induced significant increases of displacements and rotations of ballast particles and a rapid development of settlement of ballast tracks. The accumulated displacements of surface ballast particles correlated positively with the settlement development of ballast layer. The obtained results disclosed the relationship be-tween particle movements and macro settlement of ballast layer and would pro-vide data support for further DEM-based researches.

General Session-3: Dynamic characteristics of soils and transportation infrastructure

Monitoring and analysis of the diaphragm wall construction-induced vibrations in deep sand deposit

Author(s): Mu-Zhi Li, Yan-Guo Zhou, Peng-Fei Yao, Duan-Yang Zhuang
Presenter: Yan-Guo Zhou, Zhejiang University, China

ABSTRACT: During the construction of diaphragm walls in deep deposits, the grooving machines, such as grab buckets or double-ringing slotters, collide with the constructed concrete walls, generating vibrations with various amplitudes and frequencies. These vibrations propagate through the concrete walls and the adjacent soils in the form of elastic waves. In this study, microseismic monitoring sensors were embedded around the diaphragm walls to continuously record the acceleration responses of the near-field soil throughout the entire construction process. Dynamic response characteristics of the near-field soil at different distances in horizontal direction and at different depths during the construction are analyzed. Different vibration features of near-field soil along the depth and the attenuation laws along horizontal distance are identified. These findings will contribute to the safety evaluation of diaphragm wall construction and the construction-induced soil disturbance in deep sand layers.

Identification of excitation forces acting on the tunnel structure for the prediction of ground-borne vibration

Author(s): Donghai Li, Weifeng Liu, Chunyang Li
Presenter: Donghai Li, Beijing Jiao-tong University, China

ABSTRACT: As a key factor in predicting ground-borne vibration induced by underground trains, determining the excitation forces acting on the tunnel structure is difficult by direct measurement due to their randomness, diversity and complexity. In this paper, a novel identification method based on field measurement and an analytical track model is developed, to obtain the excitation forces acting on the tunnel structure caused by the running trains on a track. In this method, firstly, the transfer matrix between the wheel-rail contact forces and rail vibration response in the frequency domain is established through the analytical track model based on the infinitely periodic structure theory. Next, the wheel-rail forces in a reference cell are specified by the measured rail acceleration, and then the frequency-domain excitation forces acting on the tunnel structure can be calculated. Moreover, the excitation forces are obtained using a vehicle-track model for comparison to validate the proposed method. The results show that the method can effectively identify wheel-rail forces and excitation forces for the prediction of ground-borne vibration.

Frequency Variation in Moving Mass-Bridge Systems of Civil Structures

Author(s): Judy Yang, Shuo Huang, Jong-Dar Yau
Presenter: Judy Yang, National Yang Ming Chiao Tung University, Taiwan

ABSTRACT: It was shown that the frequency of a moving mass-bridge system changes with time in reality. However, this phenomenon was seldom discussed in the literature and requires further investigation from the practical point of view. As such, this study first derives the analytical formulation to illustrate the frequency variation in a moving mass-beam system and then extends to derive the semi-analytical solutions of a moving mass-plate system; in addition, the three-dimensional models are established accordingly to numerically investigate the effects of moving mass on civil structures. From the numerical results, it is shown that the instantaneous frequency ratios of the first three modes can reach more than 10% for a moving mass-beam system with high suspension stiffness and large vehicle-to-bridge mass ratio, and the frequency variation for the first mode can reach 20% for a plate-type bridge. By comparison, it is noticed that the wave propagation is uniquely exhibited in the acceleration responses of a plate-type bridge, while this phenomenon is uncommon for a beam-type bridge.

Adaptability of High-Speed-Railway Long-Span Cable-Stayed-Bridge with Ballastless Tracks

Author(s): Bin Yan, Hexin Fu, Limei Yu, Haoran Xie
Presenter: Hexin Fu, Central South University, China

ABSTRACT: Due to the flexibility of long-span bridges, long-span bridges are widely used in railways. But the ballast track is frequently adopted in the track system of long-span bridges on China Passenger Dedicated Lines (high-speed railway). In order to improve the stiffness and geometric smoothness of track and unify the track form in the same section of the passenger dedicated lines, the laying of the ballastless track on long-span bridges has become a research hotspot. This paper taking the (35+40+60+300+60+40+30) m cable-stayed bridge on Nanchang-Ganzhou passenger dedicated line as an example, for bridge stiffness, Continuous Welded Rail on bridge, line during operation phase and durability of track structures, the adaptability of the ballastless track system on the bridge is fully studied. In this case, it is seen that ballastless track laying on a long-span bridge is a practical and feasible method, which can effectively reduce track maintenance, increase track safety and smoothness, as well as shorten the time it takes for passengers to travel.

Study on dynamic prediction driven by data-physics of surface settlement induced by shield tunnel construction

Author(s): Fang Dai, You Wang
Presenter: Fang Dai, Central South University, China

ABSTRACT: Surface settlement is an important problem in shield tunnel construction. The traditional machine learning model neglects the dynamic characteristics and internal physical laws of land subsidence when predicting land subsidence. In order to predict the surface settlement caused by shield tunnel construction more accurately and effectively, a physical information Extreme learning machine model (PIELM) was proposed to predict the surface settlement. Based on the analytical solution of Verruijt-Booker's semi-elastic plane hypothesis, the physical governing equations of tunnel settlement deformation in semi-infinite space are solved. By coupling the governing equation with the extreme learning machine, an improved data physics extreme learning machine model is constructed. The verification analysis shows that the prediction accuracy of PIELM is obviously better than that of the traditional single machine learning model ELM model. The results show that the accuracy of PIELM model is 82.26% higher than that of traditional ELM model. PIELM also greatly increases the speed of operations compared to the recently proposed PINN. Physical data dual drive prediction model can greatly improve the accuracy of land surface settlement prediction. It is proved that the model has good generalization ability and provides a new method for shield tunnel construction safety monitoring. Keywords: Shield tunnel, Physical-data dual driven, Extreme learning machine, Machine learning, Field monitoring.

General Session-4: Stabilization/reinforcement of foundation geomaterials of transportation infrastructure

Physical model tests of geocell reinforced soil foundation under moving wheel condition

Author(s): Shintaro Miyamoto, Yoshihisa Miyata
Presenter: Shintaro Miyamoto, National Defense Academy, Japan

ABSTRACT: The authors performed two-dimensional and three-dimensional physical model tests of geocell-reinforced soil foundations under moving wheel conditions to investigate the reinforcing effects of geocells. A series of physical model tests investigated the relationship between the number of moving wheel loads and wheel subsidence for different reinforcing conditions. This study clarifies that the geocell reinforcing effect under three-dimensional conditions is much higher than that of two-dimensional conditions. This paper describes the outline of physical model tests of geocell-reinforced foundations and reports of primitive test results. The reinforcing effects of geocell are discussed by comparing the results of some test cases.

Effect of octadecylamine on hydrophobic properties of red-bed mudstone subgrade fillers

Author(s): Yuqing Zhou, Xiaobin Chen, Zhaosheng Yu, Jiasheng Zhang, Mengli Wu
Presenter: Yuqing Zhou, Central South University, China

ABSTRACT: Red-bed mudstone is widely distributed in China. The subgrade fillers of weathered red-bed mudstone are easy to cause engineering disasters such as disintegration and deformation under the change of humidity. Therefore, it is necessary to modify the water resistance of coarse granular fillers and improve their disintegration resistance. The red-bed mudstone was modified with octa-decylamine to reduce its surface wettability and surface free energy. The hydrophobic properties of the modified soil were characterized by contact angle test and capillary water absorption test, and the optimal ratio of octadecylamine was obtained. The mechanism of hydrophobicity was analyzed by electron microscopy (SEM), infrared spectroscopy (FTIR) and X-ray diffraction (XRD). It was found that the polar molecules of octachylamine entered into the clay mineral layers to form tightly packed compounds based on ion-dipole intercalation, which improved the hydrophobicity of red-bed mudstone. The research can provide reference for prevention of red-bed mudstone subgrade disintegration disease in the future.

Horizontal resistance characteristics and simple evaluation method of coupled foundation for vehicle protection fence utilizing pull-out resistance of cast iron spiral piles

Author(s): Takahiro Kurokawa, Noriyuki Yasufuku, Yuta Ide, Makoto Nagata
Presenter: Takahiro Kurokawa, Hinode Holdings Co., Ltd, Japan

ABSTRACT: Spiral piles are a type of foundation for small structures made of twisted steel strip. Spiral piles provide high axial resistance and can be easily removed when no longer needed. The authors have focused their research on coupled pile structures that can convert the higher axial resistance of spiral piles into horizontal resistance. In this study, a coupled foundation structure using cast iron spiral piles and steel pipe piles, which have excellent shape flexibility and economic efficiency, was designed as a practical foundation for vehicle protection fences. In order to clarify its horizontal resistance characteristics, field pull-out tests and horizontal load tests were conducted using test soil and a full-scale test specimen. As a result, the onset characteristics of the pull-out resistance of spiral single piles and the horizontal resistance of the coupled foundation were analyzed, and a practical method of calculating the horizontal resistance in relation to the mechanical properties of the soil was presented.

Metal Ion Complex Impact on ζ Potential during Shield Muck Solidification

Author(s): Bosong Ding, Ping Lou, Rui Wang, Zhenyu Wang, You Wang
Presenter: Bosong Ding, Central South University, China

ABSTRACT: Shield tunneling generates substantial waste muck, conventional landfill and drainage disposal depletes land resources, causing ecological harm. Solidification enhances resource efficiency. Employing metal ion complex ZY-1 fortifies the hydration process in shield tunneling muck solidification. Through potential testing, the influence of ZY-1 on ζ potential across various particle surfaces was analyzed. Findings indicate metal ion complex effectively reduces ζ potential on various particle surfaces, diminishing the outer electric layer thickness, narrowing particle spacing, and enhancing consolidation. ZY-1 shows the most significant reduction in ζ potential on cement particle surfaces; at a concentration increase from 0 to 100 mmol/L, cement particle ζ potential decreases by 61.61%. The sequence of metal ion complex impact on ζ potential across different particle surfaces is as follows: cement > shield muck > calcium carbonate > calcium sulfate > calcium hydroxide.

Research on field compaction characteristics of cement-stabilized recycled aggregate road subgrade based on SmartRock

Author(s): Yuanjie Xiao, Tao Yang, Meng Wang, Yuliang Chen, Fanwei Meng, Xiaoming Wang, Wenjun Hua
Presenter: Tao Yang, Central South University, China

ABSTRACT: The utilization of recycled aggregate from construction demolition waste in road subgrade construction is a crucial step in addressing the issue of waste dumping, leading to significant environmental and economic benefits. However, limited research has been conducted on the particle migration and crushing characteristics of recycled aggregate when used as cement-stabilized materials during field compaction. To address this gap, this study was conducted in Hunan to analyze the chemical and physical properties of cement-stabilized recycled aggregate materials. Subsequently, compaction procedures for cement-stabilized recycled aggregate subgrade were presented, and the motion and breakage characteristics of the aggregates particles were tested. The results revealed that the acceleration of cement-stabilized recycled aggregate particles under weak vibration from heavy steel wheels was 10-45 times higher compared to mechanical static compaction. Under static compaction using engineering machinery, the aggregate particles primarily rotated along vertical and lateral directions, whereas under weak vibration from heavy steel wheels, the rotation was predominantly along the vertical direction. Moreover, under the weak vibration of the steel wheel, particles primarily turned along the vertical direction, while under the static pressure from engineering machinery, the vibration energy of particles mainly transferred along the vertical and longitudinal directions. Conversely, under the weak vibration from heavy steel-wheel vibratory roller, the energy transferred along the vertical direction and the traffic direction. Additionally, it was observed that the particle breakage of cement-stabilized recycled aggregate particles during field compaction was less severe compared to laboratory static compaction. The sub-particle distribution curve of the mixture under field compaction exhibited an intermittent pattern, distinctly different from the more pronounced particle distribution curve observed under laboratory static compaction.

General Session-5: Monitoring, evaluation and control of traffic induced vibrations of roads, railways and airfields

Study on relationship between road profile and structural damage of the pavement

Author(s): Masakazu Jomoto, Akira Kawamura
Presenter: Masakazu Jomoto, TR-Consultant Corporation, Japan

ABSTRACT: Road profile make running performance of the vehicle worse. As a result, the vehicle are exposed to uncomfortable vibrations especially from vertical direction and the vibration, causes great damage to the pavement surface and accelerates the progress of surface damage. The damaged pavements worsen not only the running performance of the vehicle still more, but the pavement itself as well. The progress of damage due to the interaction between vehicle vibration and rough road surface finally leads to disruption of the pavement. Various research studies on this issue of the interaction have reported so far. As to the relation between the pavement surface and the dynamic load of the running vehicle, current research activities used by the conventional vehicle simulation software packages are established, however there are little reports regarding effects of local road irregularities such as manhole and fault which cause transient vibration of the vehicle taking into account life cycle cost (LCC) of pavement. In this study, the vertical acceleration of the vehicle running on the irregularities and resulting dynamic load of the pavement was obtained experimentally and calculated theoretically by use of the simple Quarter Car model. Asphalt layer damage in order to validate this study was measured by FWD (Falling Weight Deflectometer) tests.

Field monitoring and analysis of ground surface and adjacent single pile vibrational responses induced by metro tunnel shield construction

Author(s): Rui Wang, Bin Yan, Bo-song Ding, You Wang
Presenter: Rui Wang, Central South University, China

ABSTRACT: Shield machines generate severe vibrations when operating in hard rock formations, but these vibrations are often ignored by engineers due to the short construction time. However, special buildings such as hospitals and old buildings adjacent to metro lines are very sensitive to this part of the vibration. In order to investigate the transmission mechanism of the shield construction vibration in the ground, this paper analysed the vibration response of the ground surface as well as the adjacent pile based on the field monitoring data. The results show that for the tunnel with excavation depths of less than 17 m, the ground surface vibration response in front of the cutter is more significant than that behind the cutter. The energy generated by the shield vibration is mainly concentrated in the low-frequency part below 5 Hz. The adjacent pile is more sensitive to the low-frequency component of the shield vibration, with the peak acceleration capable of reaching more than 8mm/s2 when the pile-tunnel distance is less than 3.84 m.

Intelligent evaluation method of pavement performance by monitoring the vibration of vehicle

Author(s): Wangda Guo, Jinxi Zhang, Yuxuan Zhang, Pei Li, Lei Nie
Presenter: Jinxi Zhang, Beijing University of Technology, China

ABSTRACT: Efficient evaluation for pavement performance has always been a significant problem for road engineers. However, the traditional methods for collecting pavement performance information may be either expensive or low efficient, depending on the automated degree. To address the above challenges, this paper proposed a low-cost, convenient, and intelligent method for pavement performance evaluation using vibration data and ground speed of vehicle. A lightweight intelligent terminal integrated an inertial measurement unit (IMU), a data transmission unit (DTU) and a global positioning system (GPS) was developed to collect various data induced by vehicle-road interaction. After data preprocessing and feature extraction, an unsupervised combined with supervised machine learning method was proposed to decouple the relationship between vehicle vibration, speed and pavement performance. The results showed that the proposed data-driven method clarified three pavement performance ratings. The validity of the proposed method was verified using the evaluation results from the repeated tests. Finally, the visual inspection for these evaluation results was provided on the map. This paper provides a low-cost insight for lightweight pavement performance evaluation, which has potential implications for monitoring the road quality in the field of road asset management.

Study on vehicle-induced vibration and secondary noise caused by GTC introduced in high-speed railway

Author(s): Yiting Chen, Fangbo Liu, Jizhong Yang, Dubei Feng, Man Peng
Presenter: Yiting Chen, China Railway Eryuan Engineering Group Co.Ltd, China

ABSTRACT: To realize the purpose of "Zero Interchanges" of air-rail intermodal transportation, a 350km/h high-speed railway is introduced into the airport GTC, but the vehicle-induced vibration caused by the high-speed railway passing through the GTC and the secondary noise of the commercial area above the GTC become urgent problems to be solved. To minimize the impact of the vehicle-induced vibration and the secondary noise in the commercial area above the GTC, three different options for the introduction of the main line are proposed and numerically analyzed by establishing a three-dimensional coupling model to compare the vehicle-induced vibration response of the different options and to select the optimal option. The results show that: (1) the frequency of GTC car-caused vibration caused by high-speed train operation is concentrated in 30~80Hz, and the vibration in the propagation process of bridge-pile-soil-GTC, the vibration in the frequency range of 30~200Hz decays rapidly, and the low frequency vibration in the range of 10~20Hz is amplified; (2) when the high-speed railway is introduced by three schemes of bridge and common slab, bridge-built separation and bridge and roadbed, the commercial area The maximum vibration level reaches 82.0dB, 70.2dB, 73.3dB respectively, and the vibration exceedance rate of bridge-built separation scheme is the lowest; the maximum secondary noise reaches 43.2dB(A), 33.1dB(A), 38.5dB(A) respectively, and only the secondary noise of bridge-built separation scheme meets the requirements; (3) using vehicle-induced vibration and secondary noise as evaluation criteria, the optimal solution for introducing a 350km/h high-speed railway into the airport comprehensive transportation hub GTC is bridge-built separation.

Three-dimensional Discrete Element Analysis of Crushing and Mixing Behavior of Existing Pavement Layer by Stabilizer

Author(s): Toyohiro Katou, Yuta Hirayam, Takatomo Fujii, Takashi Kurosu, Osamu Oikawa, Takashi Okayasu
Presenter: Toyohiro Katou, Kyushu University, Japan

ABSTRACT: In the roadbed reconstruction method, a rotor with bits for a stabilizer is used to break the existing asphalt mixture layer in-situ on the road, and mix and compact it with stabilizers such as cement or bituminous materials and the existing roadbed material to construct a new stabilized roadbed. The reconstructed roadbed quality (grain size and grain size distribution, etc.) is affected by the rotor bit arrangement and mixing speed. In this study, a three-dimensional discrete element method (DEM) was adopted to analyze the crushing and mixing behavior by the rotor of the stabilizer and the particle size distribution after mixing. The asphalt mixture layer consists of two layers with an asphalt layer and a roadbed layer, and was modeled by multidiameter DE particles. In particular, a bond model was introduced between the particles of the asphalt layer to reproduce the solidification forces between the particles that make up the asphalt. The rotor model was geometrically modeled with 35 bits, a cutting-edge diameter of 1,150 mm, and a width of 700 mm. The analysis reproduced the contact behavior between the rotor and the asphalt mixture layer by moving the rotor model at the mixing depth of 350 mm and the rotor travel speed of 1,500 mm/min, and investigated the motion (crushing, mixing, and reconstructing) of the particles that make up each layer.

General Session-6: Advances in geomaterial characterization, laboratory and field evaluation, and full scale testing

Effects of biochar on the physical properties and frost heave characteristic of Lanzhou loess

Author(s): Yongjia Wang, Xiang Li, Yiqing Pu, Nan Zhou, Junping Ren
Presenter: Yongjia Wang, Lanzhou University, China

ABSTRACT: The global climate change poses significant negative impacts on the sustainable development of human society and the safety of civil infrastructures, especially those in cold regions. Effective climate change mitigation requires both reductions of greenhouse gas (GHG) emissions and withdrawal of atmospheric carbon dioxide (CO2) to achieve the net zero emissions goal. The use of biochar as a soil amendment to both reduce GHG emissions and promote CO2 removal was proposed as a global strategy for climate change mitigation and has been intensively studied over the past decade. However, the effect of biochar addition on the physical and mechanical properties of cold regions engineering soils is rarely investigated and less understood. In the present study, the physical properties and frost heave characteristic of Lanzhou loess modified with biochar were experimentally studied. A series of laboratory tests were conducted on the loess and biochar to characterize their physical properties. And, six frost heave tests were carried out via a temperature-controlled system to quantify the behavior of the biochar-amended loess, considering the influences of the particle size and mass content of biochar. The results suggest that biochar can reduce the maximum dry density, increase the optimum moisture content and consistency limits of the tested loess, and the effect is related to the amount and particle size of biochar. Temperature gradient is the driving force for the migration of pore water. The largest increment in water content generally agrees well with the frost penetration depth. The addition of biochar could potentially decrease the amount of frost heave of the loess. These findings can provide valuable insights into the frost heave behavior of biochar-amended soils, as well as promote the application of biochar for frozen soil engineering and climate change mitigation.

Effect of Principal Stress Axis Rotation on Resilient and Permanent Axial Strains of Unbound Aggregate Materials

Author(s): Daoju Ren, Tatsuya Ishikawa, Tetsuya Tokoro
Presenter: Daoju Ren, Hokkaido University, Japan

ABSTRACT: Cyclic axial loads generated by the traffic significantly affect the deformation characteristics of the base and subgrade materials, which becomes an important factor for the rutting damage of the pavement structure. On the other hand, for a fixed point in the pavement structure, the direction of stress constantly changes during the movement of the wheel load, defined as principal stress axis rotation (PSAR), which also affects the deformation of the pavement structure. Mechanistic-Empirical Pavement Design Guide (MEPDG) proposed a model that combines resilient and permanent deformations to predict the rut depth of unbound granular materials. However, there are some disputes about whether the effect of PSAR has been considered. This study examined the behavior and relation of the resilient strain and permanent strain of crusher-run gravels under the effect of PSAR by multi-ring shear tests and further verified the validity and reliability of the MEPDG permanent axial deformation predictive model.

Numerical investigation on the slurry penetration performance of pulsating pressure

Author(s): Lubo Tang, Xiaobin Chen, Jiasheng Zhang, Jiarui Luo, Fantong Lin
Presenter: Lubo Tang, Central South University, China

ABSTRACT: Mud pumping phenomenon is one of the major railways defects, which can cause uneven subgrade settlement and seriously affect track stability. The common method for repairing this problem is steady pressure grouting. Nonetheless, mud pumping creates complex pore channels by causing fine particles to migrate within the subgrade. As a result, particles are prone to block small channels, and slurry often moves along the dominant channel under steady pressure. Consequently, the slurry diffusion range and grouting efficiency under steady pressure is limited. This study presents a new pulsating grouting technology that can generate self-induced pressure pulses. The grouting performance of the oscillating grouting technology is compared with that of steady pressure grouting. The results show that, under the same flow rate, the diffusion radius is increased by 15-30%. The effects of pulsating parameters, soil parameters and slurry parameters on diffusion distance are analyzed. The outcome of this research is expected to improve the efficiency and reinforcement effect of grouting technology, and it also provides a benchmark for the development of dynamic pressure grouting tools.

Safety Risk Assessment of Levee Structure Based on VIKOR Method and AHP-CRITIC Method

Author(s): QianJun Fan, RuXue Jia, Fang Dai, You Wang
Presenter: QianJun Fan, Central South University, China

ABSTRACT: With the continuous growth of dam construction scale, higher requirements are put forward for long-term safe and stable operation of DAMS, but there are few studies on dam safety risk assessment at present. In order to ensure the safety of levees during service, this paper builds a safety risk assessment model of levees structure by combining VIKOR method and AHP-CRITIC method based on multi-source information such as monitoring and prediction data, changes in surrounding environment and personnel mechanical management level. Through the example verification, it can be found that the calculated comprehensive assessment results of the safety risk of the levee are consistent with the actual situation, and the accuracy of the model is verified. It can provide the safety decision scheme for managers from the macro level.

A New Degradation Model for Rock Blocks to Simulate the Compressive Behaviors of Soil-rock Mixtures

Author(s): Junhua Xiao, Siqi Sun, Zhiyong Liu, Yingqi Bai, Jie Shan, Binglong Wang
Presenter: Junhua Xiao, Tongji University, China

ABSTRACT: Soil-rock mixture is a commonly used transportation geomaterial in high-fill project with heterogeneous compositions and complicated structures. A novel degradation model for rock blocks is established based on the Discrete Element Method to capture the compressive behaviors of soil-rock mixtures. The gradual degradation process of rock blocks can be considered, including slight degradation, corner breakage, and fracture. Among them, the simulation method of slight degradation is proposed based on the idea of contact detach, which can reflect the nonlinear stiffness of individual rock particles. The simu-lation of corner breakage adopts a method that considers the size effects and the Weibull distribution of rock strength. And the simulation method for fracture or smash is to search for blocks bearing excessive stress and replacing them with breakable clusters. The DEM model was calibrated with the laboratory test re-sult of force-displacement curve in particle compression test. Subsequently, a series of large-scale confining compression test simulations have been carried out to analyze the compression deformation behaviors and particle contact characteristics with different soil-to-rock ratio. The results show that for the se-lected sample, the stiffness is relatively high when the rock content is between 50% and 80%, which can be well explained at the meso-scale.

General Session-7: Dynamic interaction of vehicle and transportation infrastructure

A simple prediction method for cyclic plastic deformation of aged ballast in consideration of water content variation

Author(s): Abhay Kumar, Tatsuya Ishikawa, Namit Jain, Erol Tutumluer
Presenter: Abhay Kumar, Hokkaido University, Japan

ABSTRACT: This paper provides an insight into the impact of water content and aging on shear strength and cyclic plastic deformation of ballast. The ballast layer is designed as a free draining layer, but aging and generation of fines severely affect its deformation behavior and shear strength. To gain a better understanding of the shear strength characteristics, a series of monotonic loading triaxial compression tests were conducted on the aged ballast. The finding indicated that, with aging the shear strength of the ballast decreases. Moreover, it was also observed that the increase in water content negatively affects the shear behavior of the ballast. In order to comprehend the cyclic plastic deformation of the aged ballast, a series of cyclic loading triaxial compression tests were performed. The results revealed that the permanent deformation of ballast was significantly affected by both aging and water content. Thus, to understand the deformation behavior of ballast it is important to evaluate the synergistic effect of aging and water content. Furthermore, the applicability of the University of Illinois at Urbana-Champaign model (UIUC model) was evaluated to predict the cyclic plastic deformation of the aged ballast.

Numerical Simulation on the Influence of Ballast Aging and Water Content on Track Settlement

Author(s): Namit Jain, Tatsuya Ishikawa, Abhay Kumar, Erol Tutumluer
Presenter: Namit Jain, Hokkaido University, Japan

ABSTRACT: The railway track undergoes progressive deterioration over time because of cyclic loading imparted by passing trains. This leads to the development of various geometric defects, including settlement, misalignment, and twist, which collectively contribute to an undesirable running experience. Track deformations can arise from a multitude of factors, encompassing vehicle characteristics, track stiffness, substructure attributes (such as ballast, sleepers, and roadbed), and the dynamic forces arising from the interaction between the train and the track. In addition, ballast undergoes attrition and fouling with the accumulation of fine particles over time, owing to repeated loading and aging. Notably, alterations in water content induce significant modifications in the properties of the aged ballast. Consequently, the combination of the fine particle fraction and water content plays a pivotal role in the settlement behavior of the old ballasted track by weakening the ballast layer. This study primarily aims to predict the settlement behavior exhibited by aged ballast in a ballasted track during cyclic loading of the railway traffic. The train-track dynamic response simulations on a track containing ballast samples with different aging under various water contents were conducted using a two-dimensional (2-D) train-track interaction model to predict the settlement of the ballasted track subjected to the repeated train loads by the University of Illinois at Urbana-Champaign (UIUC) model. It was observed that ballast aging negatively affects its settlement and that the presence of water, along with ballast aging, further seriously affects the track settlement.

Fundamental Study on Response Characteristics of Supported and Unsupported Sleepers of Ballasted Tracks under Moving and Dynamic Lateral Loading

Author(s): Xu Chong, Takahisa Nakamura, Kimitoshi Hayano
Presenter: Xu Chong, Yokohama National University, Japan

ABSTRACT: Following an extended period of service or exposure to geohazards, the ballast beneath certain sleepers undergoes deformation, leading to complete separation from the bottom of the sleeper, referred to as an unsupported sleeper. This study delves into the dynamic response characteristics of both supported and unsupported sleepers in ballasted tracks, employing a moving vibrator. Specifically, a 1/9-size track model was meticulously crafted in the laboratory, encompassing 21 sleepers, 2 rails, and a ballast bed with a density of 1.6 g/cm3, with the aim of emulating Japanese high-speed railways. The investigation focused exclusively on scenarios where the central sleeper existed in an unsupported state. The mobile vibrator, outfitted with a pair of unbalanced 10g weights rotating in opposite directions, applied cyclic loading solely to rails in the lateral di-rection. Accelerometers affixed to both the sleepers and vibrator meticulously monitored dynamic acceleration and displacement in the lateral direction. The lateral displacements of the vibrator and both supported and unsupported sleepers were meticulously averaged within a peak interval time zone of 0.1 seconds as the vibrator traversed them. Furthermore, the study identified displacement relations between sleepers and the vibrator by scrutinizing the ratio of lateral dis-placements of the sleeper to those of the vibrator. The outcomes elucidated dis-tinctions in lateral displacement relations between the unsupported and supported sleepers. Moreover, these relations exhibited variability contingent on the depth of the gap for the unsupported sleeper. These findings posit the feasibility of promptly discerning sleeper-supported conditions through an in-depth analysis of the dynamic response exhibited by the vibrator and sleeper.

Investigating the mechanism of under-sleeper pads influencing lateral resistance of ballasted trackbed based on coupled discrete element-finite difference method (DEM-FDM) simulations

Author(s): Tan Pan, Yuanjie Xiao, Jiang Yu, Wang Meng, Xiaoming Wang, Chongchong Zhang, Erol Tutumluer
Presenter: Yuanjie Xiao, Central South University, China

ABSTRACT: The under-sleeper pad (USP) is extensively used in railway track structures due to its desired damping performance. The impact of USP on the stiffness and dynamic responses of track structures was well documented in the majority of the existing studies; however, few studies focus on its influence on the lateral resistance of the ballast bed. To address this deficiency and further disclose its governing mechanisms, a refined DEM-FDM numerical model was established for the three-dimensional(3D) sleeper-USP-ballast bed-subgrade system. The numerical model was subsequently calibrated and verified by using field-measured lateral resistance results of a typical heavy-haul railroad. The influencing mechanisms of USP on the multiscale performance indicators including lateral resistance of different parts of the loaded sleeper, ballast particle motion, and contact force were disclosed from a variety of numerical simulation scenarios. The results show that at the same level of lateral displacement, the mobilized ballast particles under the sleeper with USP had a deeper range of motion than those under the sleeper without USP, which led to greater lateral resistance. The unevenness of the USP surface is a major contributing factor to the increase in lateral resistance. Greater USP stiffness results in higher lateral resistance. The use of the USP could increase the lateral shear stress and the maximum normal contact forces under the sleeper, both of which increase with increasing USP stiffness.

Analytical study on the dynamic response of sandwich plate with coordinate-dependent material parameters caused by metro trains

Author(s): Wanbo Li, Weifeng Liu
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ABSTRACT: In this study, a unified analytical model is presented for out-of-plane vibration of sandwich plates with arbitrary boundary conditions. It is assumed that the displacement of the core plate varies linearly along the thickness. Based on the Kirchhoff hypothesis, the displacement solutions of base and constrained plates of sandwich plate are expressed as a two-dimensional Fourier series supplemented with several one-dimensional Fourier series. On this basis, the vibration distribution characteristics of sandwich plates induced by metro trains are obtained by applying the measured vibration acceleration on the boundaries of sandwich plates. Besides, the dynamic response of sandwich plates whose material parameters vary with coordinate positions can be solved well by the pro-posed method. According to the vibration distribution characteristics of sandwich plates, the material parameter distributions are purposively designed, which reduces the train-induced vibration on the sandwich plate significantly. Furthermore, some cases for various material parameter distributions of sandwich plates are given to study the vibration mitigation performance of these sandwich plates. Finally, the relationships between the vibration mitigation performance of the improved sandwich plates and their coordinate-dependent material parameters are fully investigated.