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Plenary Speeches

Structural Performance, Testing, and Deployment of Fiber Reinforced Polymer (FRP) Composites in Bridge Infrastructure

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Abstract: Corrosion of traditional reinforcement and structural steel remains a primary driver of bridge degradation globally. To mitigate these durability challenges, Fiber Reinforced Polymer (FRP) composites have been integrated into transport infrastructure. This paper presents a comprehensive synthesis of a multi-decade testing and deployment program, beginning with the landmark 1996 Clear Creek Pedestrian Bridge, the world's longest and first hybrid carbon/glass FRP pultruded I-girder bridge. The investigation tracks the technological evolution across four distinct domain areas: full-FRP structural members, Internal Glass/Carbon FRP (GFRP/CFRP) rebar deck reinforcement, externally bonded Carbon FRP (CFRP) fabric and pultruded laminate retrofits, and advanced spliced CFRP Rod Panels (CRPs). Detailed analytical formulas, mechanical property comparisons, test protocols, and field monitoring data are provided to demonstrate the efficacy and structural reliability of FRP systems.

Keywords: FRP components; beams; bars; laminates; fabrics; new construction; repair

Bridge Structural Health Monitoring in the U.S.: One Case – A 15 Year Journey

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Abstract: Beginning in the early 2000s researchers from the University of Delaware Center for Innovative Bridge Engineering championed the idea of a Structural Health Monitoring system for a new signature bridge that was to be constructed in Delaware. The Indian River Inlet bridge, the first major long span cable stayed bridge in the US to be built with a permanent SHM system, opened to traffic in 2012. This presentation will provide a brief overview of the story of the SHM system, from design and construction to present day operation. The full fiber-optic SHM system includes over 120 sensors and runs 24/7 collecting both “low-speed” and “high-speed” data. Data management, visualization, and interrogation were recently migrated to a modern digital twin platform. Over its lifespan, this SHM deployment has served dual roles: providing the bridge owner with data for ongoing maintenance and operations, and functioning as a robust, long-term research platform. The presentation concludes by outlining upcoming upgrades and enhancements planned to ensure the system's future efficacy.

Some Reflections on Fatigue Performance of Steel Bridges

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Abstract: This presentation will discuss several recent case studies on steel bridge fatigue cracking after decades in service as well as some reflections on design considerations and retrofit strategies for improving the long-term fatigue performance of steel bridges.

Prevention and Control of Seismic Damage to the Train-Track-Bridge System of High-Speed Railways under Near-Fault Earthquakes

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Abstract: This paper introduced typical seismic damage to the train-track-bridge system of high-speed railways under near-fault earthquakes, including shearing off of bearings, relative large displacement between piers and girders, damage to track structures, train derailment and other damages. The authors collaborated with key enterprises in the railway industry to develop friction pendulum bearings, metal dampers, and other seismic isolation devices, and conducted shaking table tests to verify the advantages and disadvantages of seismic isolation performance. Based on the seismic damage rules of the train-track-bridge system and the mapping relationship between seismic responses of different components, a multi-directional constraint beam device that significantly reduces track structure damage, as well as advanced devices such as large displacement capacity, constant damping, collision prevention, and self-resetting friction pendulum bearings, were proposed. The collaborative work between these devices could effectively reduce the degree of seismic damage to the train-track-bridge system. Finally, the research direction on the prevention and control of seismic damage to the train-track-bridge system of high-speed railways under near-fault earthquakes was introduced.

Keywords: seismic damage; train-track-bridge system; high-speed railways; seismic devices; near-fault earthquakes

Freeze-Thaw Resistance of Concrete with Hybrid Straw and Basalt Fibers under Early-Age Thermal Activation Curing

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Abstract: Low-temperature curing during winter construction delays cement hydration and compromises concrete durability in cold regions. This study combines early-age thermal activation with hybrid straw and basalt fibers to improve freeze-thaw resistance. Straw fiber contents of 2%, 4%, and 6% and basalt fiber contents of 0.1%, 0.15%, and 0.2% were investigated under different curing regimes, including initial heating at 60°C followed by curing at 5°C. Compressive strength, relative dynamic elastic modulus, and mass loss were measured, supplemented by SEM and XRD characterization. A convolutional neural network was developed to predict freeze-thaw damage. The mixture containing 4% straw fiber and 0.15% basalt fiber under thermal activation curing retained a relative dynamic elastic modulus of 82.35% and exhibited only 0.4% mass loss after 100 freeze-thaw cycles. Microstructural observations suggest that thermal activation promoted hydration, basalt fibers bridged cracks, and straw fibers modified pore structure, jointly limiting damage development. The model achieved training and testing R^2 values of 0.987 and 0.995, respectively, and predicted approximately 205 cycles to the failure threshold, compared with 135 for the unreinforced reference. These findings support mix design and curing selection for winter concrete construction while enabling agricultural waste utilization.



Materials and Performance

Evolution and Prospects of Structural Forms and Construction Technologies for Bridge Pylons

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Abstract: Bridge pylons are load-carrying components of cable-supported bridges, and their structural forms and construction technologies have evolved with increasing span, pylon height, structural complexity, and construction demands. This review traces the development of bridge pylons from timber, masonry and early metallic forms to steel, reinforced concrete (RC), steel-reinforced concrete (SRC), steel shell-concrete (SSC), and some emerging novel composite systems. Particular emphasis is placed on RC, SRC, and SSC pylons through comparative examination of representative projects, structural characteristics, segmental construction procedures, and major construction technologies. The review reveals a progressive transition from material-intensive on-site construction toward prefabricated reinforcement assemblies, rigid steel skeletons, factory-fabricated steel shells, and large-segment erection, together with increasing integration of load-carrying and construction functions. Nevertheless, extensive high-altitude operations, complicated multi-component connections, quality control of segmented concrete construction, and field-dependent operations remain major challenges. Future development should therefore emphasize prefabrication, modularization, standardized interfaces, accelerated erection, digital and intelligent construction, and low-carbon practices. These trends point toward integrated structural and construction design for pylons. As a prospective direction, a prefabricated steel shell-UHPC composite pylon incorporating a multi-path composite joint is further proposed, aiming to combine lightweight, factory fabrication and rapid on-site assembly.

Keywords: cable-supported bridge; pylon; structural forms; construction technologies; shell-UHPC composite pylon

Bond Behavior between Carbon Fabric Reinforced Cementitious Matrix (FRCM) Composites with Added Short Fibers and Concrete Substrates

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Abstract: Fabric reinforced cementitious matrix (FRCM) composites show an innovative solution for strengthening existing concrete structural elements to solve the drawbacks of organic resins in fiber-reinforced polymers (FRP) system. However, the brittle fracture of the cementitious matrix significantly reduces the efficiency of the fabric. Hence, the incorporation of short fibers into the matrix is proposed to increase the fabric efficiency. For externally bonded FRCM composites to structural element surfaces, it is a crucial issue to investigate the bond behavior at the fabric-matrix and matrix-substrate interfaces, where the effect of short fibers is non-negligible and requires further investigation. In this study, a single-lap direct shear test was used to investigate the bond behavior between carbon FRCM composites with added short fibers and concrete substrates. 36 specimens were tested and discussed by considering the effects of bond length, volume content of short fibers, type of short fibers, and bond width. The experimental results were discussed in terms of failure mode, load-slip curve, and characteristic parameters. Subsequently, the contribution of weft yarns was studied and accounted for in the developed bond-slip model, which additionally takes into account the effects of the volume content of the short fibers, the type of short fibers, and the bond width.

Keywords: bond behavior; fabric reinforced cementitious matrix (FRCM) composites; short fibers; concrete; bond-slip model

Sustainable Valorization of Dredged Sludge into Flowable Backfill: Engineering Performance and Strength-Normalized GWP/Cost of Alkali-Activated OPC–GGBS–FA Binders

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Abstract: Stockpiling and disposal of dredged sludge impose environmental burdens. Its reuse as flowable backfill requires balancing workability, strength, stability, emissions, and cost. Twelve alkali-activated ordinary Portland cement (OPC)–ground granulated blast-furnace slag (GGBS)–fly ash (FA) mixtures (CGF) and OPC and GGBS references were tested under fixed water content, binder dosage, and activation conditions. Engineering properties were measured, and X-ray diffraction and scanning electron microscopy characterized microstructure. Material-stage global warming potential (GWP) and cost were quantified per tonne of oven-dry sludge and normalized by age-specific unconfined compressive strength (UCS). Increasing OPC content reduced initial flowability and generally shortened setting times; 1 h flow correlated more closely with setting time than initial flow. At fixed OPC content, replacing GGBS with FA slightly improved flowability but reduced UCS. At 28 d, CGF460 achieved the highest UCS (4.54 MPa) and lowest strength-normalized GWP and cost among CGF mixtures. Relative to the OPC reference, UCS increased by 84.8%, while normalized GWP and cost decreased by 68.3% and 55.7%, respectively. CGF631 minimized drying shrinkage, while CGF550 and CGF640 retained approximately 95% of pre-immersion strength after 3 d immersion. These findings inform binder selection that balances placement requirements, hardened performance, and material-stage burdens.

Keywords: dredged sludge; flowability; alkali activation; drying shrinkage; global warming potential

Viability of Fiber-Reinforced Geopolymer Mortar as a Protective Layer for Coal Gangue Concrete Piles in Cold Regions: Balancing Materials, Applications, and Sustainability

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Abstract: This study developed functionally graded concrete for pile foundations in cold regions, using fiber-reinforced geopolymer mortar (FRGM) as the protective layer and coal gangue aggregate concrete (CGAC) as the structural core. VAE emulsion and hybrid fibers reduced FRGM drying shrinkage by 87.9%, improving its compatibility with CGAC. Specimens with varying FRGM and coal gangue aggregate (CGA) replacement ratios were designed using the equivalent-area method. Their frost resistance, mechanical properties, and strengthening mechanisms were investigated. Experimental results, numerical simulations, and life-cycle assessment were then integrated into a five-dimensional evaluation framework. The FRGM layer improved performance through physical toughening and chemical strengthening. As its replacement ratio increased, damage evolution shifted to a two-stage pattern, delaying accelerated failure. At 30% FRGM replacement, the average number of freeze–thaw cycles to failure increased by 24.97%. A pile design with 30% FRGM and 50% CGA replacement satisfied mechanical, cover-thickness, and frost-resistance requirements while offering strong load-bearing capacity, sustainability, and cost-effectiveness.

Jointly Consideration the Stress-Strain Curve of Concrete and Nonlinear Creep of Concrete in Concrete Creep Theories

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Abstract: The foundation of existing phenomenological creep theories for concrete lies in the assumption that linear Hooke's law describes the relationship between stresses and instantaneous strains, with these strains considered purely elastic until concrete reaches its compressive strength. In practice, these equations accurately describe the stress-strain state of concrete at low loading levels not exceeding approximately 40 % of the concrete compressive strength. Researches by scientists in the field of concrete and reinforced concrete theory have shown that the relationship between stress and relative instantaneous strain of concrete in the case of short-term compression is nonlinear (stress-strain curve). The development of creep calculation methods for concrete that consider the stress-strain curve under conditions of concrete nonlinear creep is a relevant issue to be solved for further advancement of the reinforced concrete theory. Thus new refined theoretical models for the study of concrete creep were proposed, which jointly consider the nonlinear relationship between stresses and creep strains of concrete (nonlinear creep) and the nonlinear relationship between stresses and instantaneous strains of concrete (stress-strain curve).

Bond-Slip Behavior of Deformed Steel Bars in Geopolymer Ultra-High-Performance Concrete

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Abstract: Geopolymer ultra-high-performance concrete (GUHPC), produced by replacing cement with industrial waste or natural aluminosilicates, achieves substantial carbon reduction while delivering ultra-high strength and high durability, making it highly promising structural material for prefabricated joints. Prior to its application, however, the bond-slip behavior between steel reinforcement and GUHPC must be clarified, since the synergistic effect of the dense GUHPC matrix and steel fibers render conventional concrete bond theories directly inapplicable and leaves the interfacial bond mechanism and constitutive relationship insufficiently understood. To address this, the bond-slip behavior between deformed steel bars and GUHPC is investigated in this study through central pull-out tests on 99 specimens from 33 groups. The test variables comprised bar diameter d (12, 16 and 20 mm), steel fiber volume fraction (1.0%, 2.0% and 3.0%), anchorage length (3d, 4d, 5d, 6d and 7d), and cover thickness (1d, 1.5d, 2d and 3d). The effects of these critical parameters on failure mechanisms and bond strength characteristics were examined. The results indicate that average bond strength decreases with increasing anchorage length but improves with greater cover thickness. In addition, the addition of steel fibers enhances bond strength and post-peak performance by bridging microcracks and improving lateral confinement. This enhancement, however, is less pronounced for 20 mm bars owing to the reduced relative cover. As bar diameter increases from 12 to 20 mm, bond strength first rises and then declines, with 16 mm bars exhibiting relatively balanced confinement. Anchorage length is identified as the dominant factor: specimens with 3d-5d anchorage predominantly failed by pull-out, whereas those with 6d or more failed by bar rupture. Under sufficient cover, the minimum anchorage length for 12-20 mm HRB400 bars is approximately 6d. These findings provide a basis for the design and application of GUHPC in reinforced concrete structures.

Carbide Slag and Waste Glass-Derived C–S–H Seeds for Low-Cement Calcined Coal Gangue–Limestone Binders

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Abstract: Lowering the cement content of calcined coal gangue–limestone binders is limited by insufficient portlandite and slow early hydrate formation. This study examined a dual use of carbide slag (CS), a calcium-rich industrial residue: as a calcium source partially replacing limestone and, together with waste glass, as a precursor for a wet-ground C–S–H-containing seed product (WSeed) that replaced part of the cement. Setting, mortar strength up to 90 d, isothermal calorimetry, quantitative XRD, mass-balance estimates of metakaolin reaction, ^{29}Si MAS NMR, mercury intrusion porosimetry and SEM–EDS were used. Increasing CS substitution raised strength, promoted metakaolin reaction and carboaluminate formation, and refined the pore structure without increasing alite hydration at 28 d. Replacing cement with WSeed shortened setting and increased strength at all ages. Versus the unseeded blend, 7 d strength rose by 21.4%, whereas 168 h cumulative heat per unit binder increased by only 0.7%, associating the gain with changes in hydrate assemblage and pore refinement rather than greater heat release. At only 24.7 wt.% cement, the CS–WSeed binder reached 48.4 MPa at 90 d, 98.4% of the Portland cement reference and comparable to a commercial C–S–H seed. Two industrial wastes thus enable further cement reduction in calcined gangue binders.

Keywords: calcined coal gangue; carbide slag; waste glass; c–s–h seeds; low-clinker binder; pore refinement

Mechanisms of Microbial Mineralization Repair and Performance Enhancement of Solid Waste Concrete in Cold Regions

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Abstract: Targeting water-exposed highway culverts in Heihe and bridges in Qitaihe, China, this study investigates microbial mineralization repair and performance enhancement of solid waste concrete for cold-region infrastructure. Expanded perlite and recycled porous materials were compared as carriers. Photosynthetic cyanobacteria and Bacillus subtilis were separately immobilized in expanded perlite by vacuum impregnation. Loaded carriers replaced fine aggregate in mortar at 10%, 20%, and 30% by volume. Mineralization kinetics, crack healing, strength recovery, and permeability were evaluated using microstructural characterization and entropy-weighted TOPSIS analysis. Bacillus subtilis promoted rapid calcite clustering, whereas cyanobacteria formed filamentous biomineral networks associated with photosynthesis and extracellular polymeric substances. The porous carrier provided microbial protection and moisture storage, facilitating mineral deposition within cracks and connected pores. At 10% replacement, the Bacillus subtilis group achieved 88.75% crack healing and 85% compressive strength recovery after 28 days, with the highest TOPSIS closeness of 0.9040. Field implementation includes C40/C50 concrete specimens and localized microbial-carrier placement in bridge and culvert components, supported by structural monitoring. These applications connect laboratory optimization with cold-region engineering practice. Potential extensions include erosion protection of sediment-discharge facilities at the Sanmenxia Water Control Project, while long-term field durability remains under evaluation.

Keywords: microbial mineralization; solid waste concrete; cold-region infrastructure; crack self-healing; entropy-weighted TOPSIS

Optimization of Conductive Network and Snow-Melting Performance of Reduced Graphene Oxide–Carbon Fiber–Steel Fiber Ternary Conductive Concrete for Cold-Region Pavements

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Abstract: To address pavement icing in cold regions and the environmental pollution caused by conventional deicing methods, this study developed a ternary electrically conductive concrete (TECON) incorporating reduced graphene oxide (rGO), carbon fiber (CF), and steel fiber (SF). The conductive network and matrix structure were optimized by regulating rGO dosage, and the mechanical properties, electrical conductivity, frost resistance, and snow-melting efficiency were systematically evaluated. At an rGO mass fraction of 0.09%, T-ECON achieved optimal overall performance: a 28-day compressive strength of 60.6 MPa, electrical resistivity of 773 Ω·cm, and no failure after 300 freeze-thaw cycles. At this dosage, the concrete slab melted snow up to 150 mm thick within 2.4 h at −15 °C, with significantly reduced energy consumption. The rGO and fiber-based conductive media exhibited functional complementarity, enabling complete construction of conductive pathways and synergistic optimization of the matrix structure. This ternary system offers a viable pathway for engineering applications of electrically conductive concrete heated pavement systems in cold regions, potentially replacing conventional deicing salts and mitigating negative impacts on infrastructure and the ecological environment.

Keywords: conductive concrete; reduced graphene oxide; carbon fiber; steel fiber; snow melting; cold-region pavement

Wind, Vibration, and Aerodynamics

TLS-STformer: Integrating Trend-Level-Shock Decomposition and Asymmetric Spatio-Temporal Attention for Wind Power Forecasting

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Abstract: Accurate wind power forecasting underpins reliable grid operation, yet deep learning models often show phase lag and over-smoothing during ramp events, partly because historical SCADA data and future numerical weather prediction (NWP) data are fused symmetrically despite their different temporal roles. This study proposes TLS-STformer, a physically motivated asymmetric dual-stream network. A Trend-Level-Shock (TLS) decomposition encoder separates each patched input into slow trends (via Legendre polynomial projection), baseline levels (via a multilayer perceptron) and transient shocks (via convolutional blocks on first-order differences). An asymmetric spatio-temporal attention (ASTA) mechanism then combines past-masked temporal self-attention on historical power with future-guided spatial cross-attention on full-horizon NWP data, so that future meteorological information guides the predicted power trajectory. Compared with five state-of-the-art baselines, TLS-STformer ranks first on all eight metrics over 1- to 16-step (15 min to 4 h) horizons, with average RMSE and MAE of 8.04 MW and 4.84 MW, the latter 19.3% lower than the best baseline. Five-fold expanding-window validation on three wind farms yields the lowest mean MAE and RMSE at every site, and 69 of 75 Diebold–Mariano tests significantly favor the proposed model. Ablation studies confirm the complementary contributions of the TLS encoder and ASTA mechanism.

Keywords: wind power forecasting; deep learning; sequence patching; spatio-temporal attention; time-series decomposition

Effects of Atmospheric Stability and Rotor Ground Clearance on Wind Turbine Wake Characteristics

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Abstract: Atmospheric stability and rotor ground clearance are important factors affecting wind turbine wake development. However, their combined influence on wake characteristics under different atmospheric conditions remains unclear. This study investigates the effects of atmospheric stability and rotor ground clearance on wind turbine wakes using large-eddy simulations. Different turbine configurations and atmospheric stability conditions are considered to examine the spatial distribution and downstream evolution of wake flows. Based on the simulated time-averaged velocity fields, wake velocity distributions, recovery characteristics, vertical displacement, and flow asymmetry are systematically analyzed. Results indicate that wake velocity deficits decrease more rapidly under unstable atmospheric conditions, whereas stable conditions are associated with more persistent wake structures. Furthermore, different rotor ground clearance configurations exhibit distinct wake characteristics, particularly in terms of vertical displacement and asymmetric velocity distributions. The differences between turbine configurations also vary with atmospheric stability, suggesting an interaction between atmospheric stratification and turbine installation geometry. These findings provide insights into wind turbine wake development under complex atmospheric boundary layer conditions and offer a reference for improving engineering wake modeling.

Keywords: atmospheric stability; wind turbine wakes; large-eddy simulation; wind engineering

Aerodynamic Assessment of the Tsing Lung Bridge for Wind-Resistant Design

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Abstract: The Tsing Lung Bridge is Hong Kong's first sea-crossing suspension bridge with dual two-lane carriageways. Located in a typhoon-prone region and with a main span of 1,280 m, the bridge requires a rigorous assessment of its wind-resistant safety. This study combines computational fluid dynamics (CFD) simulations, sectional-model and full-bridge aeroelastic-model wind tunnel tests, and finite-element-based wind-induced response analysis to examine the bridge's aerodynamic force coefficients, including static force coefficients and flutter derivatives, as well as its vortex-induced vibration, flutter stability, and buffeting response. CFD analysis shows that the central solid barriers significantly improve the bridge's flutter stability. Sectional-model wind tunnel tests further confirm that the optimized girder with central solid barriers satisfies the design requirements for flutter, vortex-induced vibration and buffeting under different flow conditions. During construction, however, the 1.4m height upper stabilizing plates are required to meet the flutter stability requirements. Full-bridge aeroelastic-model tests verify the good wind-resistant stability of the optimized girder section. Finite-element analyses of seven construction and completed bridge states show that the calculated critical flutter speeds and buffeting responses agree well with the experimental results. Overall, the optimized girder section provides satisfactory wind-resistant stability and meets the wind-resistant design requirements.

Keywords: long-span bridge; wind-resistant design; aerodynamic optimization

A Tandem Narrow-Band Aeroelastic Model for Investigating Multimodal Vortex-Induced Vibrations of Long-Span Bridges

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Abstract: Modal competition within overlapping vortex-induced vibration (VIV) lock-in regions has been observed in long-span bridges, but remains difficult to reproduce using conventional sectional and full-bridge aeroelastic models. This study develops a medium-scale tandem narrow-band aeroelastic model to investigate competition between vertical bending modes, using the Humen Bridge as an engineering example. A two-step geometric scaling method combines overall longitudinal scaling with local transverse scaling, preserving aerodynamic cross-sectional details while reproducing multiple vertical bending modes. The model incorporates an internal core beam, narrow-band shells, ballast, springs, and internal balances, enabling synchronous measurements of aerodynamic forces and structural responses. Modal tests show good agreement between measured and target dynamic characteristics, with frequency deviations below 5% for the first three modes. Wind tunnel tests at a zero-degree angle of attack reveal two VIV lock-in regions and the sequential occurrence of three vertical bending modes within the same lock-in region. Spectral and time–frequency analyses further identify time-varying modal contributions, including transitions from first-mode dominance to comparable participation of the first three modes and back to first-mode dominance. These results demonstrate modal competition and suppression, with dominant modes changing across wind speeds and over time. The proposed method provides an experimental platform for investigating multimodal bridge VIV and identifying nonlinear vortex-induced forces at a scale comparable to conventional sectional models.

Keywords: long-span bridges; wind tunnel testing; vortex-induced vibration; tandem narrow-band aeroelastic model; vertical modal competition

A Tesla-Valve-Inspired Noise Barrier for Bridge Decks: Suppressing Vortex-Induced Vibration While Retaining Acoustic Shielding

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Abstract: Continuous solid noise barriers shield traffic noise on long-span bridges but aggravate the bluff-body effect of the deck and intensify vortex-induced vibration (VIV), whereas permeable barriers relieve the aerodynamic response at the cost of acoustic insulation. Inspired by the Tesla valve, this study proposes a thin Tesla-type bridge noise barrier (TTNB) of periodically arranged asymmetric cavities, with the internal flow path, not porosity alone, as the design variable. Two-dimensional CFD confirmed that the simplified cavity array retains direction-dependent flow resistance, with a reverse-to-forward pressure-drop ratio of 2.513 at 5 m/s. Acoustic finite element models of an anechoic chamber and an open bridge section quantified the insertion loss over 200–2500 Hz: the TTNB provided shielding comparable to a solid barrier, about 3 dB weaker at the two near-field points but locally stronger at several mid- and high-frequency points. Sectional-model wind-tunnel tests showed that the TTNB reduced the peak vertical VIV amplitude by more than 94% at +3° and about 88% at 0°, with no evident lock-in. Fluid–structure interaction simulations reproduced this response and attributed it to modified flow separation and wake organization. The TTNB thus reconciles acoustic shielding with VIV suppression, offering a reference for combined acoustic–aerodynamic design.

Keywords: Tesla valve; Tesla-type bridge noise barrier; vortex-induced vibration; insertion loss; direction-dependent flow resistance; wind tunnel test

Wind-Farm Power and Fatigue-Load Optimization through Yaw Control Considering Wake Effects

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Abstract: Farm-level yaw control can increase the power output of a wind farm by strategically redirecting turbine wakes. However, power-oriented yaw optimization may increase turbine fatigue loads, while the effects of wake-induced turbulence are often insufficiently represented. This study presents a coherent power–load optimization framework for wind-farm-level yaw control that accounts for wake effects. First, the structural response and out-of-plane tower-base bending-moment fatigue loads are calculated under varying wind speeds, turbulence intensities, yaw angles, and wake-turbulence conditions. A deep neural network surrogate is then developed to predict fatigue loads across these operating conditions. Its architecture is tailored to the dimensions of the input data, achieving a prediction error of 885 kN·m. The surrogate is incorporated into the proposed optimization framework, and its performance is compared with that of a power-only optimization method. Numerical results show that the proposed framework achieves a power gain of approximately 8%, comparable to that of power-only optimization, while reducing by 85% the additional fatigue loads associated with power optimization. These findings demonstrate the potential of incorporating fatigue-load prediction into wind-farm yaw control.

Keywords: wind farm; yaw control; wake effects; fatigue loads; deep neural network

Spectrum Decrement Methods for Bridge Modal Damping Identification from Free-Decay Responses

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Abstract: Reliable damping identification is essential for assessing vibration performance in long-span bridges, yet conventional free-decay methods are sensitive to noise, modal decomposition and limited record length. This study presents a spectrum decrement framework that relates spectral amplitude decay between two equal-length response segments to modal damping ratios. Three implementations are considered: Fourier power spectrum decrement for single-channel measurements, singular value spectrum decrement for multichannel measurements, and an autoregressive extension for improved spectral resolution. The multichannel formulation uses mode-shape consistency to screen spurious modes, while the autoregressive formulation retains common poles and the original amplitude ratio between segments. Numerical studies, laboratory tests on a stay cable, a shear frame and a scaled cable-stayed bridge, and full-scale bridge tests demonstrate the applicability of the framework. In the six-storey numerical study, singular value spectrum decrement achieves a mean damping identification error of 3.96%, compared with 15.30% for logarithmic decrement and 10.27% for covariance-driven stochastic subspace identification. For noise-free five-second records, autoregressive spectra resolve all six reference modes. Repeated full-scale tests show stable frequency estimates but greater damping variability. The results support efficient modal damping estimation without prior single-mode decomposition and clarify the effects of noise, record length and excitation amplitude.

Keywords: modal identification; damping estimation; free-decay response; spectrum decrement; autoregressive spectral analysis

Aerodynamic Admittance for Buffeting Analysis of Bridge Decks: A Combined Experimental–Numerical and Field Validation Study

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Abstract: Aerodynamic admittance functions (AAFs) are key parameters governing the accuracy of buffeting analyses of long-span bridges. To improve the accuracy and reliability of AAF identification, this study combines active wind tunnel tests (WTTs), large-eddy simulations (LESs), and field measurements to investigate the AAFs of bridge deck sections and validate predicted buffeting responses. First, AAFs under narrow-banded sinusoidal gusts are identified using active WTTs and LESs. Next, three-dimensional broad-banded turbulent inflows are synthesized from measured strong-wind characteristics at the bridge site, and LESs are used to identify AAFs and compare results across inflow conditions. Finally, the identified AAFs are incorporated into time-domain buffeting analysis, with responses evaluated against field measurements from four one-hour strong-wind events. Results show that AAFs identified by LESs and active WTTs under sinusoidal gusts agree within 5%, and those obtained under different inflow conditions are generally consistent. Buffeting analysis using the identified AAFs shows good agreement with field measurements, with deviations below 10%, and provides more accurate predictions than the classical Sears function for the investigated cases. These findings provide a practical basis for identifying AAFs and assessing buffeting responses of long-span bridges.

Keywords:

Full-Scale Measurement of Wind-Induced Displacements and Modal Identification of a Super High-Rise Building Using Ground-Based Interferometric Radar

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BEI Membership: No

Abstract: Full-scale displacement measurements and reliable higher modal identification under wind hazards remain critical yet challenging tasks for super high-rise structures. This study evaluates the field applicability of ground-based interferometric radar (GBIR) for full-scale, non-contact displacement measurement and operational modal analysis of super high-rise buildings under typhoon conditions. To overcome the challenge of identifying low-energy higher modes masked by dominant fundamental sway responses in radar-derived displacement records, a hybrid modal identification framework is introduced. First, the recursive variational mode extraction (RVME) algorithm is adapted by incorporating an adaptive penalty factor selection mechanism, in which the optimal range of the penalty factor correlates with the bandwidth empirically defined using peak spacing. The covariance-driven stochastic subspace identification (SSI-COV) is subsequently applied to the isolated narrowband components. The adapted RVME/SSI-COV framework was evaluated through a six-degree-of-freedom numerical model across 1000 random realizations at a 10 dB signal-to-noise ratio. The practical applicability of the GBIR system was demonstrated through a full-scale field monitoring campaign of a 339.88 m super high-rise building in Xiamen, China, during Typhoon Kong-rey (2024). Cross-system verification against resampled, double-integrated, and drift-corrected accelerometer data demonstrated excellent temporal evolution and structural trend consistency with the radar-measured displacements. The natural frequencies and damping ratios extracted from the GBIR measurements yielded excellent agreement with contact-sensor results for the fundamental sway, torsional, and second sway modes. Furthermore, the mode shapes identified from the GBIR and contact-sensor measurements captured similar overall deflection trends, particularly across the upper-height region.

Keywords: ground-based interferometric radar (GBIR); non-contact displacement measurement; operational modal analysis (OMA); recursive variational mode extraction (RVME); wind-induced vibration

Vortex-Induced Vibration Mitigation and Aerodynamic Characteristics of Wind Bracing Members in Decorative Bridge Arches

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Abstract: The low-wind-speed vortex-induced vibration (VIV) of wind bracing members in a decorative arch bridge is investigated using finite element analysis (FEA), field measurements, and computational fluid dynamics (CFD) simulations, with a focus on vibration characteristics, aerodynamic excitation mechanisms, and mitigation measures. Modal analysis indicates that the third vibration modes of both the southern and northern steel arches are dominated by the first symmetric in-plane vertical bending mode of the wind bracing members, with natural frequencies of approximately 2.83 Hz. Field measurements reveal pronounced vertical VIV at wind speeds of 3~5m/s, with a dominant frequency of approximately 2.70 Hz, in good agreement with the modal analysis results. CFD simulations show that the shear layers in the wake of the original round-ended rectangular cross-section undergo alternating roll-up and periodic vortex shedding, inducing unsteady surface pressures and aerodynamic forces. Strong pressure fluctuations are primarily concentrated near the transitions between the leeward curved ends and the adjacent flat surfaces. Two VIV mitigation measures are proposed: rotating the cross-section by 90° and increasing its dimensions. Both measures increase the natural frequency of the corresponding vertical bending mode and shift the predicted wind-speed range susceptible to VIV toward higher velocities. These findings provide insights into the aerodynamic excitation mechanisms of wind bracing members and offer guidance for VIV mitigation in similar bridge structures.

Keywords: vortex-induced vibration (VIV); vibration mitigation; wind bracing members; field measurements; computational fluid dynamics (CFD); finite Element Analysis (FEA)



Monitoring

Full-Field Dynamic Reconstruction and Deflection Field Identification of Bridges Using System Equivalent Model Mixing

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Abstract: Impact vibration testing and structural identification are powerful tools for assessing structural flexibility and have been widely used in bridge load capacity evaluation. However, traditional impact tests require dense instrumentation across the entire bridge deck, which significantly limits testing efficiency and flexibility. Building a full-field dynamic model with high spatial resolution from sparse measurement configurations remains challenging. To address this, this paper proposes a framework for full-field dynamic reconstruction and deflection field identification of bridges based on System Equivalent Model Mixing (SEMM). The hybrid modeling paradigm allows extending the dynamics of an experimental model with sparse measurement degrees of freedom (DoFs) to a numerical model with a denser set of DoFs. This process yields a refined hybrid structural dynamic model that preserves the fidelity of the experimental model while leveraging the high resolution of the numerical model. Subsequently, full-field modal parameters extracted from the hybrid model are used to synthesize the full-field flexibility matrix, which accurately characterizes the load-deformation relationship of the structure. Finally, the deflection field under any virtual load can be reconstructed using the full-field flexibility matrix. The effectiveness of the proposed framework is validated through two numerical structures and one experimental structure. Comparisons with the classic dynamic expansion method highlight the adaptability and superiority of the proposed framework under sparse measurement configurations. This framework paves the way for full-field state perception and rapid mobile inspection of bridge structures, demonstrating its potential as a standard tool for bridge impact vibration testing.

Keywords: impact vibration testing; structural identification; full-field dynamic model; system equivalent model mixing; flexibility matrix

Long-Term Field Measurements on the Dynamic Responses of Cable-Supported Photovoltaic Structures

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Abstract: To investigate the wind-resistant performance of cable-supported photovoltaic (PV) structures (CSPSs), long-term field measurements were conducted at two monitoring locations. Wind velocity, wind direction and temperature, cable tension and PV module acceleration, were continuously recorded throughout the measurement period. Artificial excitation tests were carried out to identify the dynamic characteristics of the CSPS, and finite element models were established to validate the measured frequencies. The collected field data were analyzed to investigate the time-dependent relaxation of cable tension, temperature-induced variations in cable tension, structural dynamic characteristics, and the effects of wind velocity and wind direction on structural responses. The results show that the cable tension and structural responses were significantly affected by wind velocity and showed negative correlations with temperature. The first several natural frequencies were close to the corresponding modal frequencies obtained from finite element analysis. The long-term field measurements provide experimental support for the wind-resistant design and safety evaluation of CSPSs.

Keywords: cable-supported photovoltaic structures; field measurements; wind-induced vibration; cable tension

Research on Large-Deformation Reconstruction Theory for Monitoring the Deformation of Main Cables in Long-Span Suspension Bridges

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Abstract: In the structural health monitoring of suspension bridges, the deformation of the main cable is an important indicator for assessing the overall structural behavior and service performance of the bridge. Traditional vision-based measurement and displacement sensing methods have certain limitations in long-distance monitoring, complex environments, and applications where sensor placement is restricted. In contrast, strain-based shape sensing provides a promising alternative for monitoring the deformation of main cables. However, due to their high flexibility and substantial deformation, accurately reconstructing the geometrically nonlinear deformation of suspension bridge main cables under large displacements and rotations remains challenging for existing shape reconstruction methods. To address this issue, this study combines the co-rotational method with the inverse finite element method to develop a geometrically nonlinear large-deformation reconstruction approach for suspension bridge main cables. The proposed method utilizes strain measurements to reconstruct the spatial configuration of the main cable, and its effectiveness is validated through numerical analyses. This study provides a theoretical basis for large-deformation monitoring of suspension bridge main cables.

Keywords: cables; large deformation; geometric nonlinearity; strain; structural health monitoring

Smartphone-Based Large-Displacement Measurement and Time-Domain Reconstruction in Bridge Seismic Tests: Insights into Bearing-Motion Observability

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Abstract: Large-displacement bridge tests require noncontact measurements when contact sensors face stroke and mounting constraints. This study presents a smartphone-based framework combining ROI-constrained feature management, pyramidal Lucas–Kanade tracking, displacement-state inheritance recovery (DSIR), background correction, and numerical time alignment. Across five valid quasi-static bearing cases, 80 displacement extrema from 100 to 400 mm showed a mean absolute vision–reference difference of 2.543 mm. DSIR reduced mean feature-replacement jumps from 13.59 to 1.53 pixels in ten-seed shaking-table tests. In a separate two-seed bearing-video test, the mean 1050-frame deviation decreased from 32.776 to 7.923 pixels. Synthetic tests achieved ground-truth RMSE below 0.05 pixels across three motion profiles under nominal imaging, although abrupt glare caused tracking failure. After temporal registration, nine bridge shaking-table cases yielded Pearson correlations of 0.917–0.992 and NRMSE values of 2.63–7.38%. The results support smartphone vision as a supplementary displacement-measurement method under stated conditions, but do not establish independently validated friction-interface state identification or energy accuracy.

Keywords: bridge seismic testing; smartphone vision; displacement-state inheritance recovery; friction pendulum bearing; visual observability; time-domain registration

Physics-Guided Temperature-Conditioned Normalizing Flow for Bridge Anomaly Detection under Environmental Variability

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Abstract: Environmental variability can obscure structural anomalies in bridge vibration responses and reduce the reliability of structural health monitoring (SHM). This study proposes a physics-guided temperature-conditioned normalizing flow (PTC-Flow) for bridge anomaly detection. The model learns the conditional density of encoder representations from healthy data and uses the latent-space negative log-likelihood as the anomaly score. Two physics-guided regularizers preserve low-frequency spectral information and promote latent continuity across nearby temperatures. The shared sensor encoder and cross-sensor attention handle different sensor configurations without architectural changes. On the Z24 bridge, PTC-Flow achieved an area under the receiver operating characteristic curve (AUC) of 0.9884 and an accuracy of 97.29%. Healthy-state scores showed negligible monotonic dependence and extremely low nonlinear predictability from temperature, while an AUC of 0.9246 was retained within the overlapping temperature range. Compared with CVAE, cointegration, and MD-TBin, PTC-Flow provided the best overall balance between detection performance and temperature robustness. After fine-tuning with limited baseline data from the KW51 bridge, PTC-Flow achieved an AUC of 0.9746 and an accuracy of 94.67%, supporting cross-bridge transferability. These results show that PTC-Flow reduces temperature influence on anomaly detection while preserving anomaly-sensitive information, providing a reliable method for bridge SHM under environmental variability.

Keywords: structural health monitoring; anomaly detection; damage detection; deep learning; neural network

Modal Parameter Identification and Damage Feature Identifiability of a Long-Span Suspension Bridge under Spatial Sensor Loss

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Abstract: This study investigates the feasibility of a midspan-centered sensor reduction scheme for modal identification of a long-span suspension bridge in Xiamen, using data from the bridge's structural health monitoring system as the primary dataset. Complete-channel monitoring records are used to establish a modal-parameter baseline and characterize environmental variability, separating environmental effects from identification errors associated with sensor reduction. A series of reduced sensor layouts centered on midspan nodes is evaluated using matched time windows. Frequency deviation, mode-shape MAC at shared measurement locations, and identification stability are used to assess the retained modal information. Localized stiffness reduction is introduced in a finite-element model to examine whether the proposed assessment can account for damage-related interference in real-bridge monitoring. The resulting frequency shifts are compared separately with identification errors caused by sensor reduction. The analysis evaluates how retaining selected midspan nodes affects target-mode identification while reducing sensor requirements, providing a basis for balancing monitoring performance with engineering feasibility and economic cost.

Keywords: long-span suspension bridge; structural health monitoring; sensor missing; DBSCAN-SSI; damage identification

Real-time Identification of Bridge Foundation Scour Using Structural Monitoring Data via Bayesian Inversion and Physics Informed Neural Networks

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Abstract: Scour around the bridge foundations can cause changes in dynamic characteristics and potential structural instability. Direct measurement of scour depth remains challenging. A hybrid prediction framework combining Bayesian inversion and physics-informed neural networks (PINNs) is proposed for real-time scour depth identification. First, a structural dynamic model incorporating the effects of scour protection and foundation settlement is established. Based on routinely monitored structural responses, Bayesian inversion is employed to identify scour-induced equivalent embedment depth parameters, thereby establishing a probabilistic mapping between the natural frequencies of the foundation and the corresponding scour depth. Subsequently, this mapping is embedded into a PINN framework as a physical constraint by introducing a physics-guided network branch and modifying the hidden-layer architecture, enabling real-time prediction of scour depth evolution. The proposed method relies solely on conventional structural monitoring data, providing a practical and efficient solution for online scour identification of bridge foundations.

Keywords: scour; bridge foundations; bayesian inversion; physics informed neural networks; natural frequency

Time-Varying Characteristics Analysis and Damage Detection for Bridges under a Moving Vehicle Using High-Resolution Time-Frequency Methods

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Abstract: As vehicles traverse the bridge, the dynamic responses of bridges present time-varying characteristics owing to the effect of vehicle-bridge interaction (VBI). Accurately identifying the time-varying characteristics of bridges under a moving vehicle and detecting the damage in bridges are crucial for the condition assessment of bridges. The time-frequency analysis (TFA) methods, such as the short-time Fourier transform (STFT) and the wavelet transform (WT), are promising for addressing these issues through identifying the structural instantaneous frequencies (IFs) from measured responses of bridges under the action of moving vehicles. However, the limited resolution of these TFA methods hinders their ability to offer comprehensive insights into the dynamic characteristics of VBI systems.
To resolve these limitations, several improved high-resolution TFA methods have been developed by the authors' group to improve the resolution of time-frequency representations, such as an improved local maximum synchrosqueezing transform with adaptive window width (ALMSST) (Tang et al. 2023), a modified variational nonlinear chirp mode decomposition (MVNCMD) (Shang et al. 2024), a generalized S-local maximum reassignment transform (GS-LMRT) (Tang et al. 2025a), a local maximum synchrosqueezing wavelet transform (LMSSWT) (Tang et al. 2025b), and an adaptive linear chirplet local maximum synchrosqueezing transform (ALC-LMSST) (Tang et al. 2026), for tracking the time-varying characteristics of bridges and detecting damage in bridges under a moving vehicle. Numerical simulations and laboratory experiments on VBI models are conducted to verify the effectiveness of the proposed methods.

Keywords: vehicle-bridge interaction (VBI); time-varying characteristics; damage detection; time-frequency analysis (TFA) method; local maximum synchrosqueezing transform (LMSST); variational nonlinear chirp mode decomposition (VNCMD); generalized S-local maximum reassignment transform (GS-LMRT); local maximum synchrosqueezing wavelet transform (LMSSWT); adaptive linear chirplet local maximum synchrosqueezing transform (ALC-LMSST)

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References:

Lei Tang, Xu-Qiang Shang, Tian-Li Huang*, Ning-Bo Wang, Wei-Xin Ren. An improved local maximum synchrosqueezing transform with adaptive window width for instantaneous frequency identification of time-varying structures, Engineering Structures, 2023, 292: 116543.

Xu-Qiang Shang, Lei Tang, Tian-Li Huang*, Ning-Bo Wang, Wei-Xin Ren. Time-varying characteristics analysis of bridge under moving vehicle using a modified time-frequency method with limited sensors, Engineering Structures, 2024, 316: 118528.

Lei Tang, Xu-Qiang Shang, Yang-Zhu Zhang, Tian-Li Huang*, Ning-Bo Wang, Wei-Xin Ren, Damage detection for bridges under a moving vehicle based on generalized S - local maximum reassignment transform, Engineering Structures, 2025a, 330: 119953.

Lei Tang, Xu-Qiang Shang, Tian-Li Huang*, Ning-Bo Wang*, Hua-Peng Chen, Time-varying instantaneous frequencies identification for bridges under a moving vehicle based on local maximum synchrosqueezing wavelet transform, Structures, 2025b, 79: 109608.

Lei Tang, Zheng-Jie He, Tian-Li Huang*, Yi-Bin He, Bo Yang. Nonlinear characteristics of cracked bridges under a moving vehicle based on adaptive linear chirplet local maximum synchrosqueezing transform, Engineering Structures, 2026, 357, 122590.

Repair and FRP Composite

Interfacial Slip and Partial-Composite Flexural Behavior of Large-Corrugation EPCFA-CSP Bridge Deck Panels with an Unreinforced EPCFA Layer

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Abstract: To address insufficient local stiffness, pavement deterioration, and weak interfacial composite action in conventional orthotropic steel bridge decks, this study proposes an elastic polyurethane–fly ash composite–corrugated steel plate (EPCFA-CSP) bridge deck. Two component-level four-point bending tests were conducted on deep-corrugated steel plates with an unreinforced EPCFA layer, with (EPCFA-3W-P) and without (EPCFA-3W-N) mushroom-shaped steel pins. Load–deflection responses, interfacial slip, and midspan strain distributions were analyzed. Steel pins increased the pronounced-slip load from 315.04 to 465.92 kN (47.9%) and the ultimate load from 420.05 to 548.14 kN (30.5%). They reduced average interfacial slip near the loading points at ultimate load from approximately 7.3 to 4.0 mm (45.2%), improving deformation compatibility. However, the pinned specimen still exhibited partial-composite behavior. A theoretical model incorporating slip-induced stiffness reduction and the tensile contribution of the unfolded corrugated steel section was developed, supplemented by finite element analysis to interpret the flexural response and parameter trends. The results demonstrate that steel pins delay interfacial slip development and enhance partial composite action. The conclusions primarily apply to monotonic static bending.

Keywords: EPCFA-CSP bridge deck; interfacial slip; partial-composite action; flexural behavior; corrugated steel plate

Molecular Dynamics Investigation on Internal Interfacial Bonding and Failure of Polyurethane Concrete under a Wide Temperature Range for Rapid Bridge Deck Repair

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Abstract: Polyurethane concrete is widely applied for rapid paving and repair of bridge decks. Nevertheless, its internal interfacial bonding and failure behaviors under a wide temperature range remain insufficiently understood. This work constructs interface models of polyurethane with SiO_2, $CaCO_3$ and Al_2O_3 aggregates using molecular dynamics simulations. The interfacial bonding mechanism and temperature response characteristics are investigated at five temperatures corresponding to real service environments. Tensile simulations combined with cohesive model fitting are adopted to clarify the failure mechanism, which is further validated by macro-scale tensile tests. The results demonstrate that electrostatic interaction dominates the interfacial bonding. Interfacial adhesion energy and hydrogen bond strength reach peaks at 298 K; both rising and falling temperatures remarkably degrade the interfacial bonding stability. Among the three aggregates, SiO_2 achieves the best bonding and tensile performance with polyurethane. Polymethylene polyphenyl isocyanate (PAPI) serves as the critical component for interfacial bonding, and tensile failure is dominated by cohesive failure within the matrix. This study provides theoretical support for aggregate selection, material design and engineering application of polyurethane concrete intended for rapid bridge deck repair.

Keywords: polyurethane concrete; failure mechanism; temperature effect; bridge deck repair

Experimental Techniques

Experimental Study on the Overall Stability of Axially Loaded Steel Members under Different End Constraints

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Abstract: This paper presents an experimental investigation into the overall stability behavior of axially loaded welded I-section steel members under different end constraint conditions. Two boundary configurations were tested: (i) fixed about the strong axis and hinged about the weak axis, and (ii) hinged about the strong axis and fixed about the weak axis. Monotonic static loading was applied using a manual hydraulic system with synchronized load, deflection, and strain recording. Experimental ultimate capacities were 22.1 kN for Case (i) and 48.0 kN for Case (ii) an increase of 117%. Theoretical values per GB 50017 were 29.1 kN and 55.1 kN, respectively, indicating reductions of 24% and 13% due to initial imperfections. Both cases exhibited flexural buckling with limit-point instability. Findings demonstrate that weak-axis fixity is significantly more effective than strong-axis restraint in improving stability, because the weak axis governs the flexural buckling of I-section members. The results highlight the critical role of initial imperfections in real structural behavior.

Keywords: axially loaded steel member; overall stability; end constraint; flexural buckling; initial imperfection; experimental study

Axial Compressive Behavior of PBL-Stiffened Double-Skin UHPC Composite Walls

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Abstract: To address the poor post-peak ductility of double-skin ultra-high-performance concrete (DSU) axial compression members with studs and other discrete connectors, this study proposes a PBL-stiffened DSU configuration (PBL-DSU) for lightweight bridge pylons. Nine axial compression tests and detailed finite-element analyses were conducted. The failure modes, load–displacement response, local buckling behavior of the steel faceplates, ultimate capacity, and residual capacity were investigated. The results showed that the PBL ribs effectively restrained local buckling and enabled the buckled faceplates to continue carrying load. The measured ultimate capacities were comparable to those predicted by the plastic superposition approach. The confinement effect provided by the steel faceplates and PBL ribs enabled the crushed UHPC to retain a certain post-peak load-carrying capacity. The residual capacity ratio (RR) of the specimens ranged from 0.66 to 0.87. For a steel contribution ratio $\delta < 0.56$, RR increased approximately linearly with δ. To achieve $RR \geq 0.70$, δ should not be less than 0.42 and 0.38 for steel fiber volume fractions of 1.5% and 1.9%, respectively. Finally, a equation for ultimate capacity and a regression equation for RR were developed. Both equations showed good agreement with the experimental and finite-element results.

Keywords:

Experimental Real-Time Hybrid Simulation of High-Damping Rubber Bearings in Isolated Bridges at Low Temperatures

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Abstract: High-damping rubber (HDR) bearings show pronounced stiffness hardening at low temperatures, and their loading-rate dependency becomes more significant. Most earlier studies on the temperature effect of HDR bearings were carried out under low-rate loading conditions, which makes it difficult to capture their seismic response under realistic earthquake excitation. In this study, real-time hybrid simulation (RTHS) tests were performed at 23, 0, and −20 °C, and the RTHS test results were compared with those from pseudo-dynamic hybrid simulation (HS) tests conducted at a constant, low loading velocity. Cyclic shear loading tests were carried out to examine the hysteretic behavior of HDR bearings at 23, 0, and −20 °C. In addition, the bilinear model and the thermo-mechanical coupled modified Park-Wen (TMC MPW) model were used to simulate the seismic responses of a bridge isolated with HDR bearings at different temperatures, and the simulation results were compared with those obtained from the RTHS tests.

Keywords: high-damping rubber (HDR) bearings; real-time hybrid simulation test; low temperature effect; loading-rate dependence; thermo-mechanical coupled model

Experimental Investigation of Mode Competition in Bending-Torsion-Coupled Vortex-Induced Vibration of A Semi-closed Box Girder

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Abstract: When bending and torsional vortex-induced vibration (VIV) lock-in regions overlap in long-span bridge girders, conventional single-mode analysis cannot fully capture modal competition. This study investigates coupled VIV of a semi-closed box girder through sectional-model wind tunnel tests varying frequency configurations, angles of attack, and damping ratios. Four configurations represent overlapping lock-in regions, isolated bending and torsional VIV, and closely spaced natural frequencies (ratio ≈ 1.1). Structural responses and internal-balance forces were measured synchronously. Least-squares rigid-body decomposition was applied to the response data, while spectral, modal identification, and time–frequency analyses quantified frequency-band contributions and tracked modal branches. A 1D-CNN-Transformer model further separated dominant branches, cross-coordinate contributions, and coupling residuals. Results show a transition from bending dominance through joint modal participation to torsional dominance, accompanied by modal competition and redistribution of frequency-band contributions. Frequency configuration affects lock-in alignment and modal competition, whereas damping ratio and angle of attack regulate amplitudes, lock-in ranges, and modal contributions. Coupling is concentrated within a narrow transition region under overlapping lock-in conditions but persists over a wider wind-speed range for closely spaced frequencies. The proposed framework supports multimodal VIV identification and wind-resistant bridge design.

Keywords: wind tunnel testing; semi-closed box girder; vortex-induced vibration; mode competition; bending-torsion coupling; response separation



Modeling and Advanced Analysis

A Finite Particle Method Framework with Embedded Meshes and Cohesive Elements for SFRC Fracture Analysis: Numerical and Experimental Studies

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Abstract: The flexural failure of steel fiber-reinforced concrete (SFRC) beams is governed by two concurrent mechanisms: matrix cracking and fiber bridging. To reproduce this process within an explicit framework, a two-dimensional fracture analysis model for SFRC beams was developed based on the finite particle method (FPM), incorporating non-conforming meshes and cohesive elements to simulate fiber-matrix interactions. Physical fibers are discretized using beam elements and geometrically coincide in space with shadow fibers that maintain kinematic compatibility with the concrete matrix. Zero-thickness cohesive interface elements are inserted along the entire fiber length between the physical and shadow fibers to capture interfacial bond-slip behavior. Experimentally, four-point bending tests were conducted on three groups of beam specimens with fiber volume fractions of 0%, 0.4%, and 0.8% under displacement control using an MTS electro-hydraulic servo testing system. Numerically, corresponding FPM models were established, and their predictions were compared against experimental data. The proposed FPM-based model provides a computationally stable explicit approach for predicting the post-cracking performance of SFRC members, offering distinct advantages over conventional finite element methods (FEM) by eliminating global stiffness matrix assembly, naturally handling fracture and contact, and avoiding mesh regeneration.

Keywords: finite particle method; cohesive interface element; steel fiber-reinforced concrete; non-conforming mesh; damage and fracture

Sequential Coordinated Lightweight Optimization of Offshore Wind Turbine Jackets and Transition Pieces

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Abstract: A sequential framework combining jacket geometry and sizing optimization with transition piece topology optimization is proposed for lightweight offshore wind turbine support structures. A support structure based on the NREL 5 MW reference turbine and OC4 jacket is investigated. A critical state is selected from OpenFAST coupled simulations, and a corresponding equivalent static analysis model is established in ANSYS. First, five design variables—base spacing, leg diameter and wall thickness, and X-brace diameter and wall thickness—define 405 discrete configurations. The configuration with the minimum jacket steel mass is selected while keeping maximum equivalent stress and top horizontal displacement no greater than the baseline values. Next, the optimized jacket interface conditions will inform transition piece topology optimization to adjust load paths through material redistribution, followed by coupled dynamic verification of the final assembly. The completed jacket stage yields reductions of 21.80% in steel mass, 6.91% in maximum equivalent stress, and 16.28% in top horizontal displacement under the same frozen equivalent static loads. Comparative analyses indicate that increased base spacing can compensate for response deterioration caused by member size reductions, providing a basis for subsequent coordinated lightweight design of the jacket and transition piece.

Keywords: offshore wind turbine; jacket substructure; transition piece; sequential coordinated optimization; lightweight design

Appraisal of Split Pylon Cable-Supported Bridges Subjected to Gravity Loads

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Abstract: It has been suggested by several authors that split-pylon cable-stayed bridges, where pylons form a V shape extending longitudinally along the bridge, may improve structural efficiency. But their benefits relative to conventional vertical-pylon systems remain insufficiently quantified across different span lengths. This study compares split- and vertical-pylon cable-stayed bridges under gravity loading to assess how pylon inclination affects structural economy and environmental performance. For each span and configuration, the zero-displacement method is used to establish a reasonable completed-bridge state, providing a consistent basis for comparison. Split-pylon configurations with inclination angles of 60°, 70°, and 80° are evaluated using force volume, strain energy, and embodied carbon. The results show that all considered split-pylon configurations reduce total force volume by more than 25% relative to the vertical-pylon bridge and reduce embodied carbon by up to about 18.6%. Among the configurations considered, the 70° split-pylon bridge provides the best overall structural performance, reducing embodied carbon and strain energy by approximately 17% each. These findings suggest that appropriately inclined split pylons, particularly the 70° configuration, can provide an efficient and lower-carbon alternative for the preliminary design of cable-stayed bridges.

Numerical Study on Wind Environment Characteristics at a Long-Span Continuous Rigid-Frame Bridge Site in Mountainous Terrain

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Abstract: To investigate wind environment characteristics at a mountainous bridge site, the terrain around a long-span continuous rigid-frame bridge with a main span of 168m crossing a valley was modeled, and the wind field was simulated with the Realizable k-ε model under 14 inflow directions, in which 429 measurement points were arranged in 13 families along the bridge axis, each with one deck point and 32 vertical levels up to 1700 m. Results show that the wind environment at this site is governed by the valley terrain: attack angles at deck height reverse from 5.44° to −5.01° between opposite inflow directions, and the wind speed amplification factor reaches a maximum of 1.49 under oblique inflow, indicating that such inflow is channeled and accelerated by the terrain. The fitted power-law exponent ranges from 0.20 to 0.40 and spans terrain categories C and D of the Chinese code, indicating that a single terrain category cannot represent such a site. The three-component turbulence intensities, integral length scales and power spectral densities were further evaluated and compared with code provisions. These results provide a basis for wind environment assessment at similar mountainous bridge sites.

Analysis of the Influence of Pile–Soil Interaction on the Mechanical Behavior of Long-Span Continuous Rigid-Frame Bridges with V-Shaped Piers

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Abstract: This study takes a long-span continuous rigid-frame bridge with V-shaped piers as a case study to examine the role of pile–soil interaction, which is often neglected or oversimplified in practice. Three approaches—the "m" method, the equivalent embedment method, and the direct embedment method—were used to simplify the soil–pile interaction, and finite element models were developed in Midas/Civil to analyze the mechanical behavior of the bridge at the completion stage and under live load. A field monitoring campaign conducted during construction validated the numerical results. The results show that, compared with the two embedment simplifications, the "m" method produces smaller internal forces and vertical displacements in the V-piers and in the principal control sections at the ten-year stage after completion, while the longitudinal displacement of the superstructure is marginally larger. Under live load and under the most unfavorable load combination at the ultimate limit state of load-carrying capacity, the peak bending moment at the V-pier top, girder stresses, and stresses at the V-pier base obtained with the "m" method are all lower. Monitoring data agrees well with predictions. It is concluded that incorporating pile–soil interaction better captures the actual mechanical response of the integral system and helps optimize the prestressing tendon layout ratio of the superstructure and the cross-sectional dimensions of the V-piers.

Keywords: combined pile cap for separated decks; V-pier continuous rigid-frame bridge; closure sequence; mechanical behavior of pile cap; smeared crack model

Effect of Closure Sequence on the Mechanical Behavior of the Pile Cap in a Continuous Hybrid-Girder Bridge with V-Shaped Piers and a Shared Pile Cap for Separated Decks

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Abstract: The decks act cooperatively through the common cap in long-span V-pier continuous rigid-frame bridges with a shared pile cap for separated decks, and the closure sequence—within and between decks—induces eccentric loading that markedly alters the final geometry and stress state. A six-span bridge was analyzed using MIDAS/Civil full-bridge and MIDAS/FEA local cap models incorporating the smeared crack model, comparing four synchronous and four asynchronous closure schemes across nine local closure states. Within-deck sequence significantly affects alignment: closing side spans first and proceeding symmetrically side–secondary–centralis optimal, giving ten-year deflection of −101 to −105 mm and end camber of 16–18 mm, whereas side-span-last schemes reach −224 to −231 mm and 113–131 mm. Synchronous closure keeps both decks nearly identical (deflection difference 2–4 mm); asynchronous closure widens this to 14–22 mm, with the reversed scheme worst, subjecting the cap to eccentric loading. Each 1 °C temperature change alters the closure gap by 1–1.2 mm, consistent with field data, while each 1000 kN of jacking force increases girder-end distance by 5 mm and camber by 6.64 mm. For symmetrically side–secondary–centralis scheme, the cap's maximum principal tensile stress is 3.98 MPa with a crack width of 0.012 mm, matching the classical 0.014 mm; cracks concentrate at the cap bottom between pile rows. Synchronous side–secondary–central closure is recommended.

Keywords: shared pile cap for separated decks; continuous rigid-frame bridge with V-shaped piers; closure sequence; mechanical behavior of pile cap; smeared crack model

Analysis and discussion of the mechanism underlying scatter in structural damping ratio identification

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Abstract: In structural health monitoring and modal parameter identification, considerable scatter in identified damping ratios has been reported. This study explains the influence of external excitation on such scatter from the perspective of structural dynamic equilibrium. Based on the existing physical interpretation of damping, the bare structure damping ratio and apparent damping ratio are defined. A load-estimation-aided method is proposed to identify the bare structure damping ratio through iterative "load estimation–damping inversion–parameter update." Numerical verification uses a harmonically excited single-degree-of-freedom system to compare acceleration-only measurements, fused acceleration and displacement measurements, and stochastic subspace identification (SSI). The inversion error of the bare structure damping ratio is approximately 12.3% with acceleration-only measurements and decreases to 4.6% with fused measurements. Output-only SSI yields an apparent damping ratio of 0.001, markedly different from the true value of 0.05. Under the linear viscous damping model adopted, when external excitation deviates substantially from the input assumptions of output-only identification methods, these methods may struggle to distinguish bare structure damping from external excitation, contributing to scatter in identified damping ratios. Introducing load estimation and improving its accuracy can improve bare structure damping ratio identification under forced vibration.

Key Technologies for Safe Shield Tunnelling and Intelligent Construction in Water-Rich Karst Regions

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Abstract: In water-rich karst formations, shield and TBM tunnelling faces two coupled hazards: adverse ground ahead of the face—cavities, conduits, water-conducting fractures and confined aquifers—that may trigger water and mud inrush or collapse, and accelerated cutter wear driven by soft-hard transitions, abrasive minerals and water-assisted corrosion, which reduces efficiency and causes downtime. The concealed, heterogeneous karst amplifies uncertainty, making intelligent recognition of excavation states essential for safe tunnelling. This paper reviews recent advances in geological identification and cutter condition sensing for intelligent shield tunnelling in water-rich karst regions. Ahead prediction follows four pathways: pre-excavation borehole and mapping surveys with risk zoning; multi-source geophysics combining seismic, transient electromagnetic and resistivity imaging; hybrid mechanism-and-data-driven models built on thrust, torque and specific energy aligned with exposed geology and enhanced by physics-informed learning; and deep-learning multimodal workflows fusing geophysical images, operational time series and documents with uncertainty quantification. The framework was validated in the Xuzhou Metro project. For cutter health, the review covers mechanics-based energy models, data-driven vibration and acoustic monitoring, and hybrid frameworks that fuse mechanical priors with deep learning to estimate remaining useful life, detect abnormal wear and support condition-based cutter change.Challenges remain in robustness under nonstationary conditions and domain shift, data governance, open benchmarks and uncertainty reporting. A unified continual-learning, closed-loop framework is proposed to improve safety, productivity and life-cycle cost.

Keywords: shield tunnelling, intelligent construction, water-rich karst regions

Parameter Optimization and Empirical Design Formulas for Vertical Tuned Liquid Column Gas Dampers in Large-Span Structures

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Abstract: Vertical tuned liquid column gas dampers (VTLCGDs) are passive vibration control devices whose design parameters are commonly determined using traditional fixed-point theory, which is primarily applicable to undamped primary structures. To extend the parameter optimization of VTLCGDs to damped primary structures and improve their vibration control performance, this study develops single- and multi-objective parameter optimization methods and corresponding empirical design formulas for large-span structures. First, analytical expressions for the optimal tuning parameters under different control targets were derived for undamped primary structures under harmonic loading by considering three response objectives: relative displacement, relative velocity, and absolute acceleration. The optimization was then extended to damped primary structures through numerical analyses over a range of structural damping ratios, from which empirical design formulas were developed. Furthermore, a multi-objective optimization framework was established to balance the relative displacement and absolute acceleration responses, and corresponding empirical design formulas were derived. Numerical validation demonstrated that the proposed empirical formulas accurately predicted the optimal parameters, providing a computationally efficient alternative to direct numerical optimization. The multi-objective optimization approach achieved a balanced reduction in structural displacement and acceleration responses, highlighting the applicability of the proposed design formulas to the vertical vibration control of large-span structures.

A Digital Twin Framework for Nonlinear Dynamic Response Modelling and Intelligent Monitoring of Cable Structures

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Abstract: Cable structures are widely used in bridge and offshore engineering, and mooring lines are the main load-bearing cables of floating offshore wind turbines. Under wave loading and platform motion, their dynamic response is nonlinear and partly governed by local flow–structure interaction, which makes it difficult to predict and monitor. Digital twins can address both problems by coupling physics-based models with monitoring data. This study establishes a digital twin framework for mooring lines by integrating wave-flume experiments, nonlinear numerical modelling, distributed fibre-optic sensing. Particle image velocimetry is used to characterise the local flow field around the line. A finite particle method-based virtual model simulates large deformation and dynamic tension under wave loading and top-end excitation. Φ-OTDR serves as the twin's data interface, and the measured optical phase is converted to strain for direct comparison with the model predictions. Experimental validation shows correlation coefficients above 0.80 between predicted and measured responses. A deep learning method is further developed to identify damage states, achieving an accuracy above 83% under low signal-to-noise conditions. The framework links nonlinear cable mechanics with distributed sensing and provides a basis for digital-twin-based structural health monitoring of offshore mooring systems, cable-supported bridges, and similar structures.

Keywords: cable structures; mooring lines; dynamic response; digital twin; finite particle method; Φ-OTDR

Effects of Mesh Types in the Dynamic Mesh Region on Numerical Simulations of Flow Around Typical Cross-Sections and Vortex-Induced Vibration

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Abstract: Numerical simulation is an important tool for investigating flow around structural cross-sections and the associated vortex-induced vibration (VIV). In two-dimensional partitioned dynamic mesh simulations, mesh type in the dynamic-mesh region may affect computational results, as different mesh types vary in mesh generation and zone connectivity. This study compares structured and hybrid mesh strategies using a thin flat plate and a single-box-girder cross-section, while keeping the computational domain, boundary conditions, and other major simulation settings consistent. For the thin flat plate, flow simulations at various angles of attack and VIV simulations are performed. The aerodynamic force coefficients are compared with theoretical results, and the vibration responses obtained using the two mesh strategies are compared. For the single-box-girder cross-section, VIV simulations are conducted at various reduced velocities using the geometric model and relevant parameters adopted from a previously published study. The results indicate that the computed aerodynamic coefficients of the thin flat plate are reasonable. The overall trend of the single-box-girder vibration response is generally consistent with the reference results, although a deviation is observed in the reduced velocity corresponding to the peak response. Overall, the two mesh strategies yield broadly similar results for the models and conditions investigated, suggesting that both are applicable to the simulations considered.

Keywords: numerical simulation; structured and hybrid meshes; local mesh configuration; typical cross-sections; vortex-induced vibration response

Seismic, Fatigue, and Durability

Seismic Risk Assessment Method for Regional High-Speed Railway Bridge Networks

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Abstract: Earthquakes may damage multiple bridges and disrupt high-speed railway networks in seismic regions. This study develops an integrated risk assessment framework addressing spatially variable ground motions, structural damage–operation coupling, and multi-level functionality loss. Regional seismic wavefields are simulated using a hybrid frequency–wavenumber and finite element (FK–FE) method accounting for source rupture, propagation paths, and complex site effects; Fourier neural operators and U-Net enable rapid prediction across seismic scenarios. A nonlinear train–track–bridge coupled model is developed to characterize how earthquake-induced structural damage affects train running safety. A multi-level functionality assessment framework covering post-earthquake traffic, structural load-bearing capacity, and collapse resistance is established. Based on probability density evolution, functionality loss probabilities and their probabilistic relationships are quantified to jointly assess structural safety and operational performance. Bridge-level functional reliabilities are embedded into railway network topology to establish a component–bridge–section–route–network probabilistic propagation model. Combined with seismic hazard from multiple potential sources, the model quantifies network traffic risks and supports route optimization. Case studies demonstrate improved wavefield simulation efficiency, probabilistic characterization of structural and operational functionality loss, and network-level risk assessment under multiple seismic sources, supporting post-earthquake operations and emergency transport decisions.

Keywords: high-speed railway; bridge network; seismic wavefield simulation; risk assessment

Seismic Performance Optimization of a Combined Self-Centering Isolation System for Simply Supported Railway Bridges

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Abstract: Self-centering bearings provide seismic isolation and restoring capacity, but require additional measures to limit displacement under minor and strong earthquakes. This study investigated a combined system comprising self-centering bearings, sacrificial shear keys, and mild-steel damping tenons for a simply supported railway bridge with 15 m piers. Nonlinear time-history analyses were conducted in ABAQUS using seven near-fault ground motions applied separately in the longitudinal and transverse directions. Shear-key strengths were assessed at peak ground accelerations of 0.1 g and 0.2 g, while tenon yield strength and post-yield stiffness ratio were examined at 0.4 g and 0.64 g. Shear keys limited bearing displacement to below 2.7 mm at 0.1 g; recommended failure strengths were 600-650 kN longitudinally and 200-250 kN transversely. Adding damping tenons reduced bearing displacement but increased pier-top displacement and pier-base moment. Increasing tenon yield strength shifted energy dissipation from bearing friction toward tenon plasticity and pier hysteresis. A multi-criteria efficacy coefficient method integrating component responses and energy dissipation identified 300 kN as the optimal tenon yield strength within the investigated range. These findings support coordinated parameter selection to balance displacement control, energy dissipation, and pier protection.

Keywords: self-centering; shear keys; damping tenons; energy dissipation; parameter optimization

Shake Table Tests of Gravity Well-Inspired Double Friction Pendulum Systems under Bi-Directional Ground Motions

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Abstract: Seismic isolation systems for bridges must accommodate large lateral displacements while effectively controlling seismic forces and maintaining adequate self-centering capacity. To improve the performance of conventional friction pendulum bearings, a gravity-well double friction pendulum system (GW-DFPS) is proposed, incorporating a variable-curvature sliding surface to achieve displacement-dependent stiffness and enhanced frictional energy dissipation. Unlike conventional systems with fixed curvature or discrete sliding stages, the proposed configuration enables progressive stiffness softening and extends sliding trajectories as displacement increases. The seismic performance of the GW-DFPS was evaluated through shake table tests on a scaled isolated bridge superstructure subjected to unidirectional and bidirectional ground motions with varying intensities and site characteristics. The experimental observations demonstrate stable sliding behavior, effective force reduction, and substantial displacement accommodation under strong seismic excitation. Bidirectional motions generally induce greater isolator displacements than unidirectional motions, while acceleration demands remain effectively controlled. The system also exhibits satisfactory self-centering performance, with consistently small residual displacements. Energy analyses further illustrate the contributions of gravitational restoring action and velocity-dependent friction to the overall seismic response. The results support the feasibility of variable-curvature friction pendulum isolation for improving bridge resilience under severe earthquakes.

Keywords: gravity well; friction pendulum bearing; trajectory; pulse; near fault earthquakes

Development of a Sandwich-Structured Shape Memory Alloy Honeycomb Damper

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Abstract: This paper presents novel sandwich-structured superelastic shape memory alloy (SMA) honeycomb dampers. The system comprises a superelastic SMA honeycomb plate that provides self-centering and large deformation capacity, a high-damping rubber core, metallic and rubber infills (round or hexagonal) that support the SMA walls and dissipate energy, and two encased steel plates to restrain out-of-plane buckling of the honeycomb plate. First, the numerical simulation method is validated against experimental results of a non-sandwiched SMA honeycomb damper. Subsequently, a comparative study is conducted to assess the mechanical performance and local stress and strain distribution of various sandwich-structured SMA honeycomb dampers. Finally, the optimal configuration is identified. The results demonstrate that sandwich-structured SMA honeycomb dampers substantially enhance strength and energy-dissipation capacity while effectively reducing stress and strain concentrations compared with their non-sandwiched counterparts.

Keywords: sandwiched honeycomb damper; shape memory alloy; high damping rubber; metal core; stress and strain contour

Seismic Performance of Shear Keys in Skewed Bridges: Full-Scale Pseudo-Static Tests

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Abstract: Due to the skew-induced alignment with the cap beam, the seismic behavior of shear keys in skewed bridges may differ from that in straight bridges. Nevertheless, their lateral capacity is still commonly estimated using methods originally developed for straight bridges, a practice that could introduce considerable uncertainty into seismic performance assessment, particularly in the absence of experimental validation. To address this, pseudo-static tests were conducted on 10 full-scale shear keys with skew angles of 0º, 30º, 45ºand 60º, considering the vertical reinforcement ratio of the shear key and the horizontal bar diameter of the cap beam. The test results reveal that larger skew angles transform the failure mode from symmetric diagonal shear failure to asymmetric flexure-torsion-shear coupled failure. Concurrently, the lateral load capacity exhibits a substantial decline with increasing skew angle, and is also markedly affected by reinforcement configuration; the capacity of DK4 (60º) dropped to only half that of DK1 (0º). The backbone curves of skewed shear keys exhibit four distinct stages: elastic, plastic, descending and failure stages. Both the energy dissipation capacity and secant stiffness of shear keys decrease with increasing skew angle. These findings provide a basis for the design of shear keys in skewed bridges.

Keywords: shear key; pseudo-static test; skew angle; seismic performance

Hybrid Regression for Seismic Response Prediction of Cable-Stayed Bridges Using Pulse Decomposition, FEM, and Feature Fusion

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Abstract: To enhance robustness in predicting cable-stayed bridge responses under near-fault pulse-like (NFP) ground motions, a method integrating multiscale wavelet decomposition, Gaussian process regression (GPR) and multiple linear regression (MLR) is proposed. NFP motions are adaptively decomposed into narrow-band pulse components and a residual non-pulse-like component. Using a finite element model, GPR models are trained for the displacement at the location of interest under each component. MLR then combines component responses into the total response. For a cable-stayed bridge, results show that the key features influencing pulse component responses are peak ground velocity which characterizes the peak energy flux, characteristic period (R_T) which matches with the bridge's natural period, and energy represented by the cumulative average velocity (*CAV*). For the residual component responses, only R_T and *CAV* are significant. R_T contains the most essential mapping information in both models as it considers both the excitation and structural periods, and small changes in R_T cause significant prediction variations. Compared to a baseline GPR model trained directly using all three raw ground-motion features, the proposed MLR model achieves markedly better robustness and predictive accuracy with a small set of training samples.

Keywords: near-fault pulse-like ground motion; narrow-band pulse decomposition; structural response prediction; gaussian process regression; features extraction; partial-gravity-anchored cable-stayed bridge

Study on Hysteretic Behavior of Self-Centering Friction Energy Dissipation Brace with Non-Prestressed Disc Springs

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Abstract: Self-centering energy dissipation braces (SCBs) provide both recovery and energy dissipation capacities during earthquakes. However, the deformation capacity of conventional SCBs is often constrained by the high-level prestress required in elastic self-centering components, limiting their hysteretic performance under severe earthquakes. This study introduces a novel self-centering brace with non-prestressed disc springs (NP-SCB). The configuration, working mechanism, and theoretical restoring force model of the NP-SCB are presented. In order to validate the concept, experimental tests and finite element analyses were then conducted. The test results show the NP-SCB specimen exhibited excellent hysteretic behavior, and the maximum residual axial strain in NP-SCB is only 0.07%. The proposed restoring force model accurately predicted the hysteretic response of NP-SCBs. The energy dissipation capacity was closely associated with the reactivation displacement and can be enhanced by reducing sliding friction force F_s or increasing disc spring stiffness K_d. Compared to traditional pre-stressed SCBs, NP-SCBs showed a 9.86% to 500% improvement in deformation capacity. The structural seismic response can significantly reduce by introducing NP-SCBs.

Keywords: self-centering brace; non-prestressed disc springs; hysteretic behavior; reactivation displacement; numerical simulation

Enhanced corrosion fatigue analytical framework for suspenders: Integrating bending effect and fracture process of wire bundle

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Abstract: Suspender is widely recognized as an integral component in calculating the corrosion fatigue life based on linear elastic fracture mechanics, traditionally overlooking the bending effect and the wire fracture process. To enhance the accuracy of fatigue life assessment for corroded suspenders, an advanced analytical framework was developed. The arrangement and configuration of the steel wire bundle inside the suspender component were analyzed. The corrosion intrusion and wire breakage process were numerically modeled, facilitating a comprehensive corrosion fatigue life analysis. Findings reveal that enhanced methodology yields more conservative evaluation outcomes compared to conventional approaches. Bending effect and the wire bundle fracture process significantly accelerate the fatigue crack propagation in corroded steel wires, leading to a maximum reduction of 17.35% in the fatigue life of short suspender, whereas the impact on long suspender is comparatively minimal. The integration of displacement-controlled device has been shown to effectively delay the onset of fatigue failure.

Keywords:



Performance Evaluation

Seismic Fragility Analysis of Cable-Stayed Bridges with Fluid Viscous Dampers Considering Device Failure States and Uncertain Performance Evolution

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Abstract: Fluid viscous dampers (FVDs) are widely employed in cable-stayed bridges to reduce seismic damage and consequently enhance seismic resilience. Nevertheless, their vibration mitigation performance is limited by ultimate failure states and influenced by the unexpected performance evolution. This study aims to reveal the mechanisms by which these two factors impact damper effectiveness from a fragility perspective. First, the parameter evolution of FVDs was determined through computational fluid dynamics simulations and cyclic testing. A unified restoring force model was developed, incorporating both failure states and a multi-parameter evolution criterion that accounts for the gap and thermal effects. Seismic fragility analysis of a cable-stayed bridge equipped with FVDs was conducted. The effects of damper failure states and performance evolution with uncertainty were further investigated. The results indicate that the damping coefficient is negatively correlated with temperature, whereas the velocity exponent shows a positive correlation. Neglecting damper failure leads to an overestimation of their effectiveness in mitigating structural responses. Compared to the damper with constant performance, the evolved damper increases the probability of structural seismic damage while slightly reduces its own failure risk. The influence of temperature variation is more significant than that of the gap.

Keywords: fluid viscous damper; cable-stayed bridges; seismic fragility; damper failure; gap effect; thermo effect

Structural Damage Identification via Extended Kalman Filtering with Joint Tikhonov and Enhanced Sparse Regularization

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Abstract: Extended Kalman filter (EKF)-based damage identification methods have received considerable attention owing to their ability to handle uncertainties from model inaccuracies and measurement noise, and to recursively track damage parameters in real time for structural health monitoring (SHM). However, damage identification constitutes a challenging dynamic inverse problem: the high dimensionality of the augmented state vector, together with strong measurement noise, aggravates ill-conditioning, leading to degraded accuracy and even convergence failures in conventional Bayesian filtering algorithms. To address these limitations, this paper proposes an EKF framework incorporating joint regularization techniques for structural damage identification. First, Tikhonov regularization is introduced into the gain computation to prevent numerical singularity during the EKF recursion. Second, prior information on the sparsity of damage distribution is incorporated through a pseudo-measurement technique, in which the log-sum or arctan-sum penalty function serves as the sparse constraint. As illustrated through a geometric interpretation, both functions provide stronger sparsity-promoting capability than the conventional l_1 regularization. The effectiveness of the proposed method is validated experimentally on a shear frame structure and a cantilever beam. The results demonstrate that structural damage can be accurately localized and quantified even under limited measurements and high noise levels.

Keywords: damage identification; extended kalman filter; sparse regularization; tikhonov regularization; structural health monitoring

Multi-Defect Segmentation of Bridge Concrete Surfaces Using SAM3 with Fine-Tuning

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Abstract: Bridge concrete surface defects such as cracks, honeycombing, spalling, rebar exposure and voids threaten the long-term structural safety. Traditional manual inspection is labor-intensive, risky and time-consuming. In this work, we develop a pixel-level segmentation framework for multiple concrete surface defects based on SAM3. Lightweight Adapter and LoRA modules are integrated to fine-tune the pre-trained foundation model, eliminating the need for full parameter retraining and reducing computational overhead. The model generates accurate pixel-wise masks to delineate the boundaries of various bridge concrete defects from field inspection images. The proposed method can reliably identify different types of surface damage, serving as a practical visual perception tool to support automatic defect screening and assist routine bridge maintenance.

Keywords: bridge concrete surface defects, pixel-level segmentation, SAM3, lightweight fine-tuning

Study on Axial Compression Performance of LC3 Concrete-filled Short Columns with Steel Core Cold-ribbed Square Steel Tube

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Abstract: To investigate the axial compression performance and low-carbon potential of LC3 concrete-filled steel-core cold-formed ribbed square steel tubular short columns, five specimens were designed and tested under axial compression, and carbon emissions were calculated using the carbon emission factor method. Results show that the carbon emission per unit volume of LC3 concrete is 39.2% and 67.9% lower than that of conventional concrete and ECC of equal strength, respectively. Steel tube confinement significantly improves the ultimate bearing capacity and ductility of the specimens. LC3 concrete-filled specimens exhibit the highest strength coefficient and the lowest embodied carbon emission per unit strength. A refined Abaqus finite element model was established and validated against the test results, and parametric analyses show that the optimal steel tube confinement effect is achieved when the confinement coefficient ranges from 0.7 to 1.0. The composite columns therefore offer favorable axial compression performance and significant low-carbon advantages, showing broad engineering application prospects.


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