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Editorial: Static and dynamic performance analysis of structures and materials under complex loads and environmental excitation

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Editorial on the Research Topic
Static and dynamic performance analysis of structures and materials under complex loads and environmental excitation

The rapid evolution of structural materials and construction methodologies has ushered in a transformative era for civil engineering, driven by the urgent need to achieve carbon neutrality and enhance infrastructure resilience. As societies demand safer, more durable, and environmentally adaptive structures, the imperative to understand the static and dynamic behaviors of materials and systems under complex loads has never been more critical. This Research Topic seeks to address these challenges by consolidating cutting-edge research on the interplay between innovative materials, advanced analytical techniques, and real-world engineering applications. The contributions within this Research Topic reflect a multidisciplinary effort to bridge theoretical insights with practical solutions, offering novel perspectives on structural integrity, damage mitigation, and performance optimization across diverse engineering domains.

The global push toward sustainable infrastructure has catalyzed the adoption of novel materials such as fiber-reinforced composites, high-performance concrete, and smart sensing technologies. However, their integration into large-scale projects necessitates rigorous evaluation under realistic conditions, such as seismic events, typhoon-level wind loads and prolonged environmental degradation. This research emphasizes the dual focus on macro-scale structural resilience and micro-scale material behavior, recognizing that the durability of infrastructures hinges on both the robustness of their components and the adaptability of their design. By exploring interactions between dynamic loads, environmental factors, and material properties, the featured studies collectively advance our capacity to predict, monitor, and enhance structural performance in increasingly volatile climates.

The ten articles published in this Research Topic exemplify the diversity and depth of contemporary research in this field. Ji et al. investigate the cyclic performance of steel-tube-enabled precast column connections, offering a paradigm shift in emulative design for seismic-resistant structures. Their experimental findings underscore the potential of modular construction to balance prefabrication efficiency with seismic durability. Complementing this, Qin et al. delve into fatigue damage mechanisms in plain and steel fiber-reinforced concrete, proposing a microplane model that correlates stiffness degradation with cyclic loading patterns. This work not only refines predictive tools for material fatigue but also provides actionable insights for designing longer-lasting pavements and bridge decks subjected to repetitive vehicular stresses.

Environmental exposure remains a persistent threat to material longevity, particularly in coastal and industrial settings. Li et al. examine the dynamic mechanics of reef limestone concrete during dry-wet carbonation cycles, revealing how microcrack propagation under fluctuating humidity accelerates energy dissipation. Their findings highlight the vulnerability of marine structures to climate-induced degradation, urging the adoption of corrosion-resistant additives in coastal infrastructure. Similarly, Guo et al. explore the flexural behavior of high-performance concrete (HPC) under prolonged alkaline immersion, linking mesoscale fracture mechanisms to the efficacy of alkali-silica reaction (ASR) inhibition measures. These studies collectively advocate for material innovations that harmonize strength with environmental adaptability. The intersection of traditional materials and modern reinforcement techniques is exemplified by Li et al., who demonstrate how carbon fiber-reinforced polymer (CFRP) strengthening can revitalize aging wooden arch bridges. Through experimental and numerical validation, their work provides a blueprint for retrofitting heritage structures without compromising historical aesthetics. Meanwhile, Zhang et al. address a ubiquitous yet understudied issue: the compression behavior of steel angles with bolt-hole defects. By quantifying the load-bearing penalties imposed by localized imperfections, their research informs safer fabrication standards for steel frameworks in high-rise buildings and transmission towers.

Dynamic load modeling and computational mechanics form another pillar of this Research Topic. Jianqiu et al. present a theoretical framework for predicting soil column deformation under impact loads, integrating the Duncan-Chang constitutive model with real-world validation. This approach enhances the accuracy of geotechnical simulations for scenarios such as pile driving or landslide impacts. On the structural health monitoring front, Ying et al. investigate the coupled static-dynamic response of thermally damaged mortar, offering a methodology to assess fire-affected buildings' residual capacity.

The Research Topic also ventures into granular material science, with He et al. establishing empirical relationships between micro-texture, Vickers hardness, and the polished stone value (PSV) of high-friction aggregates. Their models enable pavement engineers to select skid-resistant materials proactively, reducing accident risks on highways. Lastly, Huang et al. analyze the lateral impact resistance of notched steel tubes, revealing how localized flaws alter energy absorption mechanisms.

Collectively, these studies highlight pivotal advancements in understanding how materials and structures respond to complex challenges, emphasizing the critical need for multiscale analysis that connects atomic-level behavior to large-scale structural performance, the transformative potential of smart technologies like fiber-optic sensing and advanced computational modeling in enabling real-time infrastructure monitoring, and the urgent requirement to align innovation with sustainability goals to ensure new materials and methods support global decarbonization efforts. As climate change accelerates the occurrence and intensity of extreme events, the knowledge generated through this Research Topic equips engineers to develop infrastructure that is not only more robust and intelligent but also inherently adaptable to the unpredictable demands of the 21st century. Looking ahead, challenges persist in standardizing performance metrics for emerging materials, scaling laboratory findings to field applications, and optimizing life-cycle costs for sustainable systems. Future research must prioritize cross-disciplinary collaboration, leveraging advances in artificial intelligence, nanotechnology, and renewable materials to address these gaps. We extend our gratitude to all authors, reviewers, and editors who contributed to this Research Topic, fostering a dialogue that will shape the next-generation of civil engineering solutions.

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