



Editorial Special Issue "Extreme Sciences and Engineering"

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1. Introduction

Due to uncertainties stemming from climate change, natural and man-made disasters, and extreme events, unexpected disruptions in the operation of our countries' infrastructure may put the functioning of our societies and their economies at risk. Such disruptions may result from many kinds of hazards and physical and/or cyber-attacks on installations and systems [1]. Recent events have demonstrated the increased interconnectivity among the impact of hazards, of the two kinds of attacks and, conversely, the usefulness of operators combining cyber- and physical-security solutions in order to protect critical installations of the global infrastructure. New ideas and innovations for a comprehensive yet installationspecific approach are necessary to secure the integrity of existing or future, public or private, connected and interdependent assets, installations and infrastructure systems. This special issue of 'Extreme Sciences and Engineering' enables the communication of the highest-quality research that highlights the role of mechanics, sciences and engineering in multi-disciplinary areas across materials science, physics, and engineering. Emphasis is placed on the impact, depth and originality of new concepts, methods and observations at the forefront of applied sciences. In light of the above, this special issue was introduced in order to collect the latest and highest-quality research on relevant topics, and more importantly, to address the present challenges of mitigating extreme events in regard to resilience and sustainable infrastructure systems. There were 37 papers submitted to this special issue, and 15 papers were accepted (i.e., 40% acceptance rate). When looking back on previous special issues, various topics have been addressed, mainly on natural disasters, structural resilience, and infrastructure technologies.

2. Understanding Responses to Extreme Events

The first paper by Wu et al. [2] presented the complex behaviors of the shield tunnel lining when it is exposed to fire. The thermal behavior of such joints when exposed to fire was experimentally investigated in full scale. In addition, the effectiveness of using concrete-filled steel tubes (CFSTs) to restore joint strength after a fire was also investigated. They reported that: (1) The effect of the joint gap on the temperature distribution was observed to change markedly during heating; (2) The temperature of the bolt end was much higher than that of the bolt mid-point, suggesting that insulation of the bolt ends is probably called for; (3) The bearing capacity and flexural stiffness of the fire-damaged segment joints can be significantly improved by strengthening them with CFSTs.

Kaewunruen and Tang [3] discovered new findings for railway ballasts in extreme weather conditions. The railway ballast is frequently used by the railway industry to enhance constructability and practicality. Their results revealed that the increase in the flood level will result in increasing the dynamic damping by more than 50% of a dry, natural ballast whilst reducing its stiffness and natural frequency. These novel insights are of great significance for exploring the non-linear dynamic traits of ballasts in extreme



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Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). environments, which can be integrated into the coupled train-track analysis that can better and more realistically express the dynamic train-track interaction and the load-transfer mechanism of flooded railway tracks.

Park et al. [4] developed a Tempcore process simulator (TPS) to analyze the microstructural evolution of quenched and tempered rebar. There has been an increasing need to relate the complex microstructures to the resulting properties of quenched and tempered rebar. The results showed that TPS can simulate the Tempcore process with a high degree of fidelity and reliability.

Wu et al. [5] investigated the integrity of suspenders, which play a critical role in the serviceability and reliability of a bridge during its lifetime. The study assessed the fatigue life of the suspenders, accounting for the stochastic wind and traffic loads using the in-situ monitoring data. The results indicate that it is of paramount importance to consider both the wind and traffic load effects in the fatigue reliability evaluation of the suspenders. The research could provide essential guidelines for the optimization of inspection and replacement in the maintenance practices for suspenders.

Zhang et al. [6] also addressed the fatigue issue in UWS bridges due to corrosion. The result shows that the Corrosion-Fatigue life can be quantified under the effects of the stress range, stress ratio, corrosive environment and average daily truck traffic (ADTT). The result has revealed the different influence that the parameters have on the initiation life and propagation life.

Xu et al. [7] investigated seismic damage scenes relating to non-structural indoor components, which is critical for virtual earthquake safety drills and can teach occupants how to survive during earthquakes. They developed a virtual scene-construction method for the seismic damage of suspended ceilings and moveable furniture using building information modeling (BIM). A virtual earthquake scene of the indoor non-structural components was constructed and applied in an earthquake safety drill. The outcome of this study provided well-founded scenes of the seismic damage to non-structural indoor components for performing virtual earthquake safety drills. This work is part of a digital twin that could enable sustainable cities [8].

Lu et al. [9] addressed the resilience of cities through an accurate and rapid assessment of seismic damage, economic loss, and post-event repair time, which can provide an important reference for emergency rescue and post-earthquake recovery. Based on cityscale nonlinear time-history analysis (THA) and regional seismic loss prediction, a real-time city-scale time-history analysis method is proposed in this work. The method proposed in this work has been applied to many earthquake events and provides a useful reference for scientific decision making related to earthquake disaster relief, which is of great significance to the enhancement of the resilience of earthquake-stricken areas.

Hamarat et al. [10] highlighted the large-amplitude dynamic responses of the trainturnout interaction with increased traffic. They determined the impact forces and evaluated the dynamic behaviors of a railway turnout and their effects on such turnout components as bearers, ballasts, and so on. The study also investigated the use of composite materials in railway turnout structures. The new insight that was gained from this study shows that neglection of the contribution of dynamic forces can result in the unsafe underestimation of train-turnout behaviors.

Zheng et al. [11] investigated the fatigue performance of rib-to-deck joints in orthotropic steel decks (OSDs) using both thickened edge U-ribs (TEUs) and conventional U-ribs (CUs). The fatigue test results and in situ monitoring data were investigated. The results showed that a notably higher fatigue reliability can be expected in the rib-to-deck joints in OSDs that use TEUs rather than CUs, which in turn can lead to a notable improvement in fatigue life.

Li et al. [12] developed the world's first three-dimensional (3D) coupled train-tracksoil interaction model that combined the multi-body simulation (MBS) principle and finite element modeling (FEM). They then investigated the vibration responses of pore water pressures, effective and total stresses, and the displacement of soils under different train speeds and soil moduli. The original insight from this study provides a new and better understanding of the saturated ground vibration responses to high-speed railway systems that use slab tracks in practice. This insight will help track engineers to effectively inspect, maintain, and improve soil conditions, resulting in a seamless railway operation.

Hamarat et al. [13] focused on track settlement, which is a common problem that is observed in ballasted railway tracks. This study investigated the relation between unsupported sleepers/bearers and a railway turnout system in order to develop an understanding of the response of the turnout system under dynamic loadings. The results show that the performance of fiber-reinforced foamed urethane (FFU) bearers is promising and that unsupported bearers carry significant loads at particular locations, which is contrary to the sleepers on normal tracks that are subjected to insignificant loads.

3. Retrofitting to Mitigate Extreme Risks

Xu et al. [14] presented a new understanding of a double-column self-centering pier that was fused with shear links, which is a novel structure that was developed in order to reduce residual deformation and facilitate post-earthquake repair. With this novel structure, the seismic resilience of bridges can be improved, and the reliability of lifeline infrastructure can be ensured. This paper presents the proposed pier configuration and investigates the mechanical behavior of the pier. The outcomes of this work can serve as a reference for further development of the design and retrofit methods for the innovated pier.

Heng et al. [15] developed an innovative longitudinal rib, which is named the thickened edge U-rib (TEU) and has been proposed to enhance the fatigue strength of rib-to-deck (RD) joints and validated through model tests. In the analysis, a stochastic traffic model was employed in order to comprehensively simulate the vehicle-induced fatigue actions. The new findings showed that the fatigue life of RD joints can be significantly prolonged by using TEUs, and that the prolongation rates are varied from 141% to 161% depending on the calculation methods and traffic models that are used.

Cai et al. [16] developed a series of shaking-table tests for a ten-story suspended concrete structure that was equipped with viscous dampers in order to evaluate the dynamic responses and vibration damping performance of suspended structures. The test results showed that the damping ratio and the frequency of suspended structures that are installed with dampers (called a damping suspended structure) can be adjusted compared to a conventional suspended structure with rigid-bar links (conventional suspended structure). The damping suspended structure certainly had a considerable and stable reduction in strain response.

Shao et al. [17] presented the world's first steel frame retrofitted by novel metallic bending energy absorbers that were made of low-yield-point steel with the yield strength of approximately 100 MPa. New results were achieved by conducting comprehensive shaking-table tests on a quarter-scaled model of a two-story, one-span building structure that was subjected to incremental intensity levels of input earthquake records. This study indicates the influential role of the novel low-yield-point absorber, in that the overall seismic performance of the retrofitted structure can be improved adequately for survival in high-intensity seismic fortification areas.

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