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Editorial

Symmetry in Civil Transportation Engineering

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Symmetrical structures, such as tunnels, diaphragm walls, and blasting charge structures, are becoming increasingly prevalent in civil transportation engineering. Research into the stability, vulnerability, durability, and other issues related to these symmetrical structures or buildings plays a crucial role in the fields of civil transportation engineering. Particularly in underground space construction, supporting structures are typically symmetrical, and the crack propagation patterns in the surrounding rock or soil as a result of excavation unloading, as well as the deformation and stress distribution of the supporting structures, also exhibit symmetry. Furthermore, structures in civil transportation engineering are often subjected to symmetrical or asymmetrical loads, making symmetry a widespread feature of this field. Therefore, the enhancement and utilization of both symmetrical and asymmetrical structures, along with the evaluation of the effects of symmetrical and asymmetrical loads, are of great importance for optimizing engineering design, enhancing structural stability, and advancing the development of engineering construction.

This Special Issue focuses on symmetry in civil transportation engineering, encompassing a total of 10 papers. Its research scope extensively covers key aspects such as load symmetry and structural symmetry. Meanwhile, it further explores the expansion of the application of symmetry in other facets of civil transportation engineering.

Symmetrical loads can enable the structure to bear forces more evenly, reducing the risks of local instability and failure and ultimately enhancing the overall safety of the structure. Moreover, symmetrical loads contribute to predicting the behavior of the structure under differing loads. Ref. [1] conducted research on the micro-vibration responses of experimental buildings induced by complex traffic loads and the related vibration isolation. The study found that under various loads, especially when the loads are symmetrically distributed, the building structure may experience vibration amplification. Ref. [2] utilized the finite element method in order to analyze the mechanical characteristics of deep foundation pit support structures under asymmetric loads. The results indicated that the horizontal displacement of the left support structure increases with the augmentation of asymmetric load, while that of the right side decreases. The maximum displacement emerges near the excavation surface, the diaphragm wall endures the maximum bending moment, with the bending moment on the left side being greater than that on the right side, and the maximum axial force of the internal support also rises with the asymmetric load.

By establishing precise mechanical and numerical models, mechanical responses such as stress, strain, and displacement of the structure under diverse load conditions can be analyzed in depth. Additionally, leveraging symmetry can simplify model construction and improve computational efficiency and accuracy.

Ref. [3] investigated the deformation and stress of the rock mass surrounding a circular tunnel shaft, taking into account the impacts of seepage and brittle damage and establishing a mechanical model of the surrounding rock mass. When making assumptions

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based on model, the shaft surrounding rock was presumed to be an isotropic, continuous, and plastically incompressible porous medium. The Drucker–Prager yield criterion was adopted to derive the elastic–plastic analytical formula of the surrounding rock, and its rationality was verified using examples.

Ref. [4] evaluated the optimal strength measurement indices for the seismic performance of axisymmetric horseshoe-shaped tunnels in soft soil at distinct burial depths. The analysis demonstrated that the peak ground acceleration is the optimal strength measurement index for shallow-buried tunnels, while the peak ground velocity is the optimal choice for medium-buried tunnels. For deep tunnels, the velocity spectrum intensity is the best. By means of numerical simulation analysis, a seismic fragility curve for predicting the tunnel damage probability was established, providing a reference for assessing the seismic risk of horseshoe-shaped tunnels constructed in soft soil.

Ref. [5] quantified the uncertainty of train loads and established an axisymmetric numerical calculation model for the vibration response of tunnel walls under a probabilistic framework. When constructing the model, in addition to the symmetry manifested in the structure and load, a consistent viscous-spring artificial boundary was adopted for the model boundary, which also embodied a certain degree of symmetry. This boundary condition can effectively diminish the wave reflection effect at the boundary and ensure that the vibration propagation characteristics in the model conform to the actual situation. The probability distribution of the tunnel wall vibration response was obtained through a simulation and compared with the measured results in order to validate the accuracy of the simulation results.

Ref. [6] pointed out the limitations of the existing conformal mapping methods in tunnel engineering. Based on this, the conformal mapping theory in the research and analysis field was profoundly studied, and a new mapping program suitable for various tunnel boundaries was proposed. Through the conformal mapping and inverse mapping of six typical deep-buried tunnel cross-sections, such as rectangular holes, multi-arc tunnels, horseshoe-shaped tunnels, and multi-porous tunnels, the accuracy of the approximate mapping function and its significance in tunnel mechanical analysis were explored.

Ref. [7] proposed a new anchor–pipe–cable support structure (ACC), which is a support member that fixes the anchor cable inside an axisymmetric pipe with a C-shaped cross-section. The application of an ACC in the roadway of Shuangliu Coal Mine was studied, and its shear resistance mechanism was evaluated. By means of a combination of double-shear tests, numerical simulations, and on-site monitoring, the shear mechanical properties of the ACC and anchor cables were compared. It was established that the ACC can improve the shear resistance and effectively control the surrounding rock deformation.

Ref. [8] focused on medium-deep hole straight-hole cut blasting. In view of the shortcomings of continuous charging, the segmented charging technology was put forward. The numerical model adopted a symmetric structure. When the charge was symmetrical, the upper part was affected by the free surface and produced a spalling effect, expanding the damage range, ultimately reflecting the symmetric relationship between the structure and the blasting effect. In the segment ratio design, it was discovered that when the upper segment ratio was 0.4, the blasting effects of the upper and lower segments were balanced, conforming to the principle of energy symmetric distribution. At this time, the cavity volume was the largest, achieving the superior cutting effect.

In addition to the related achievements mentioned above, Ref. [9] applied symmetry to civil transportation engineering materials and studied the performance of pumice lightweight aggregate concrete with different silica fume contents under sulfate wet-dry cycles. It was observed that with the increase in cycle times and silica fume content, pumice lightweight aggregate concrete's corrosion resistance first increased and then decreased,

and the corrosion resistance of this material was best with 6% silica fume content. Taking 6% silica fume content as the center of symmetry, various durability indices displayed obvious mirror symmetry on both sides. Given that silica fume is able to optimize the pore structure, a gray prediction model was established to provide a basis for concrete durability assessment and maintenance decision-making. Ref. [10] was aimed at the numerous problems brought about by urban traffic congestion to cold chain logistics, and established a multi-objective vehicle routing optimization model. By utilizing the LNSNSGA-III algorithm, chromosome coding and multi-step operations were carried out, underscoring the importance of symmetry in multi-objective optimization and cross-regional distribution. Certain conclusions were drawn, namely that the LNSNSGA-III algorithm effectively balances cost, carbon emissions, and freshness; the regional traffic congestion coefficient optimizes traffic conditions; a reasonable match between vehicle types and distribution routes improves distribution efficiency; optimizing departure time enhances average freshness and reduces traffic congestion; and there is a direct symmetric relationship between maintaining an appropriate refrigeration temperature and freshness in cold chain logistics, emphasizing the importance of consistent refrigeration conditions. The abovementioned viewpoints offer novel perspectives and exploration directions for the further advancement of symmetry in the field of civil transportation engineering.

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