Editorial

Special Issue on Tunnel Construction and Underground Space Technology

Qi Zhang 1,*, Guozhu Zhang 2 and Xiaobin Ding 3

1 School of Civil Engineering, Southeast University, Nanjing 210096, China
2 School of Transportation, Southeast University, Nanjing 210096, China; zhanggz@seu.edu.cn
3 School of Civil and Transportation Engineering, South China University of Technology, Guangzhou 510640, China; dingxb@scut.edu.cn
* Correspondence: zhangqi@seu.edu.cn; Tel.: +86-25-5209-1224

1. Introduction

Currently, the development of deep earth space is an important strategic, scientific, and technological goal. The demand for and construction of traffic tunnels and underground buildings are gradually increasing. Underground structures are often built in complex geological environments and are faced with engineering problems such as high ground stress, high geothermal stress, large water inflow, and frequent geological disasters. The creation of deep tunnels and underground structures is an important development trend in tunnel and underground engineering, which belongs to the interdisciplinary research field of geotechnics, structure, geology and planning, and so on. The refined construction standard system, geological information collection and transmission, and the theory and method of underground structure design are the main technical problems in efficient and safe construction.

This Special Issue is dedicated to promoting the exchange and sharing of research on tunnel construction and underground space technology. The collection of papers brings the latest research results from scholars and practitioners in the field, including standard construction systems, underground engineering technology, information collection and monitoring, structural design theories and methods, and other topics. Each study provides unique and novel insights into tunnel and underground engineering, aiming to innovate and solve the bottleneck technologies of tunnel and underground space construction.

2. Topics in This Special Issue: “Tunnel Construction and Underground Space Technology”

For this Special Issue, ten highly innovative and practical articles about tunnel construction and underground space technology were selected. The topics of these articles include structural design, surrounding rock stability, and operation security during the process of engineering project evaluation, building, and operation and maintenance. The articles will lead researchers and engineers to extensive discussions. Brief introductions to the articles in the Special Issue and a graphic abstract (Figure 1) are provided as follows.

Zhai et al. [1] derived a simplified analytical solution for steel plate strengthened circular tunnel concrete linings while considering various interface slip modes. The distribution of lining deformation, internal force, and the interaction stress between the tunnel lining and steel plate were then investigated with the consideration of three modes: no slip, full slip, and elastic slip. The result demonstrates the importance of the well-bonded interface to maximize the benefits of the steel plate strengthening approach. The influence of interface shear stiffness and steel plate thickness on the composited tunnel lining performance was then investigated. The results indicate that the improvement of the interface shear stiffness can enhance the overall structural stiffness of the strengthened tunnel lining, resulting in...
increases in the interaction stresses and lining forces simultaneously. The study provides a path for improving the tunnel lining performance.

Du et al. [2] used the Hyperstatic Reaction Method (HRM) to study the lining internal forces of a quasi-rectangular tunnel by transforming the strength parameters of rocks that obey the Hoek–Brown failure criterion into equivalent strength parameters of the Mohr–Coulomb (MC) criterion. Additionally, different influencing factors, including tunnel depth, rock unconfined compressive strength, and the geological strength parameter (GSI), are analyzed on the lining internal forces of the quasi-rectangular tunnel. The study concludes that the influencing factors have a significant effect on the lining internal forces of the quasi-rectangular tunnel. The work provides a theoretical reference for designing the support structure of a quasi-rectangular tunnel following the Hoek–Brown criterion.

Yao et al. [3] established a two-dimensional finite element model of a double-track tunnel and soil with and without a middle partition wall to analyze the change in the dynamic response of the tunnel structure caused by adding a middle partition wall. The displacement and acceleration responses of the upper part (zone A), the lower part (zone B), the tunnel bed, and the surrounding connecting part (zone C) of the double-track tunnel are studied. The results indicate that the addition of the middle partition wall improves the displacement and acceleration response distribution of the double-track tunnel structure. The research results provide a reference for the structural design of middle partition walls to ensure the safety and stability of trains running in double-track tunnels.

Zhang et al. [4] used numerical analysis to study the effect of constructing new tunnels near existing tunnels. The vertical displacement of the vault and the horizontal displacement of the adjacent side wall of the existing tunnel are analyzed to study the effect. It is found that the tunnel spacing between the newly constructed and existing tunnels has an obvious influence on the maximum vertical displacement of the vault and the maximum horizontal displacement of the adjacent side wall of the existing tunnel. Newly built tunnels should be kept at least 2 d away from existing tunnels, so that the influence of excavation can be minimized. The research results can provide practical experience and reference for the construction of new side-by-side tunnels.

Du and Liu [5] adopted the kinematic method of limit analysis theory to calculate the seismic bearing capacity of the shallow strip foundation on a rock mass obeying the non-linear modified Hoek–Brown failure criterion. Three angle parameters are used to control the mechanism shapes, and the equivalent friction angle and equivalent cohesive are adopted to faithfully reflect the shape characteristics of the failure mechanism. The seismic action is considered using the pseudo-static method, which is simplified to the inertial force determined by the horizontal seismic coefficient. The influences of the surface

<table>
<thead>
<tr>
<th>Subsurface structures</th>
<th>Existing problems</th>
<th>Related articles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underground building</td>
<td>Interior space design of underground building</td>
<td>Jia et al. (2023)</td>
</tr>
<tr>
<td></td>
<td>Project evaluation: tunnel layout and support structure design</td>
<td>Yao et al. (2022)</td>
</tr>
<tr>
<td></td>
<td>Project construction: construction machinery operation</td>
<td>Zhang et al. (2022)</td>
</tr>
<tr>
<td></td>
<td>Project construction: surrounding rock stability and lining design</td>
<td>Ding et al. (2023)</td>
</tr>
<tr>
<td></td>
<td>Project maintenance: tunnel fire safety</td>
<td>Zhai et al. (2022)</td>
</tr>
<tr>
<td>Tunnel</td>
<td>Foundation bearing capacity under seismic load</td>
<td>Du and Liu (2022)</td>
</tr>
<tr>
<td>Underground foundation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
overload, the properties of the rock mass, and the seismic action on the shape and ultimate bearing capacity of the failure mechanism are investigated. The findings promote the study of the seismic bearing capacity of foundations and provide data references for engineering.

Li et al. [6] combined partial full-scale model tests and numerical simulations to study the temperature distribution pattern, fire impact depth, and the maximum temperature of the lower surface on the bottom steel shell of a steel–concrete–steel immersed tube tunnel under different thermal insulation technology solutions. The research results show that adding fireproof layers can significantly lower both the steel shell’s surface temperature and the depth of fire impact, and both single-seam and double-seam schemes of calcium silicate boards are recognized as optimal fireproof schemes. The findings provide experience for protecting steel–concrete–steel structures from fire.

Ding et al. [7] used an analytical hierarchy process (AHP) to study the effect of geological, machinal, and operational risk factors in the tunneling process, which can quantitatively assess the risk of mud cake formation when using a tunnel boring machine (TBM). Twenty-two influential parameters are carefully selected where the liquidity index, plasticity index, cutterhead torque, and total thrust force contribute to around 45% of the total influence on mud cake formation, while machinal factors are less influential than geological and operational factors. A tunnel section from the Guangzhou Metro Line 22 that had mud cake formation is used for verification. The above findings have a strong effect on excavation work efficiency.

Zhang et al. [8] adopted numerical simulation and field monitoring to analyze the influence of different burial depths and soil–rock interface positions on the deformation of the surrounding rock and the internal forces of the support structure in an ultra-small clearance tunnel. An ultra-small clearance tunnel in Guizhou was selected as the research object. The study finds that the deformation of the surrounding rock of the following tunnel will be larger than that of the first tunnel when the soil–rock interface is located below the foot of the arch. It is also concluded that the position of the soil–rock interface has a significant influence on the initial support force of the first tunnel. The findings could provide a basis for the design and construction of ultra-small clearance tunnels in upper soil and lower rock composite soft strata.

Tung et al. [9] conducted 3D CFD analysis of smoke distribution and CO concentration variation in order to investigate the smoke behavior of different ventilation modes. Considering scenarios of traffic with and without congestion, the study then compares ventilation modes in two pairs based on the same fire scale of 30 MW with four longitudinal gradients (0%, 2%, 4%, 6%). The research findings contribute to a more objective evaluation of the difference between various longitudinal ventilation modes considering traffic conditions and provide more useful insights for the emergency planning of longitudinal ventilation operation in tunnel fires.

Jia et al. [10] evaluated the IPA–Kano model for underground atria for promoting the sustainable development of underground atria. Three cases in the main urban area of Chongqing are taken as the research object, and three types of elements that have different impacts on the atria are identified using the IPA–Kano model. An optimization path for the design elements of atria is established by integrating three types of elements and their actual performance. These findings provide a path for developers and operators to know the public’s preferences for further renovation.

3. Summary

The detailed deconstruction and analysis of underground structures and their geological environment is an important prerequisite for the sustainable development of tunnel and underground engineering. Therefore, this Special Issue is dedicated to combining various theoretical and practical perspectives to discuss cutting-edge issues in tunnel construction and underground space technology, including standard construction systems, engineering information collection and monitoring, structural design theory, geological risk assessment, etc. Based on the background of engineering practice, the selected research articles put for-
ward original viewpoints and methods on engineering structure design and construction, rock and soil deformation analysis, and fire safety design. We would like to acknowledge the experts and scholars who provided innovative academic research results for this Special Issue. These selected articles provide important references for future studies relating to tunnel construction and underground space technology.

**Funding:** This research received no external funding.

**Acknowledgments:** The Guest Editors would like to thank the authors for their contributions to this Special Issue and all the Reviewers for their constructive reviews.

**Conflicts of Interest:** The authors declare no conflict of interest.

**References**

3. Yao, S.; He, J.; Xu, P. The Change in Dynamic Response Distribution of Double-Track Tunnel Structure Caused by Adding Middle Partition Wall. *Buildings* 2022, 12, 1711. [CrossRef]

**Disclaimer/Publisher’s Note:** The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.