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Discussion of "Study on Asphalt-Cement Materials for Seismic Isolation Layer of Shield Tunnels"

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This paper presents a discussion of "Study on Asphalt-Cement Materials for Seismic Isolation Layer of Shield Tunnels" by Qi Yang, Ping Geng, Liangjie Wang, Bingbing Zhao, and Pingliang Chen. https://doi.org/10.1061/(ASCE)MT.1943-5533.0004466.

The authors have presented a comprehensive investigation on asphalt-cement (A-C) materials for seismic isolation layer of shield tunnels based on laboratory tests and numerical simulations. The physical and mechanical properties of the A-C materials such as fluidity, consistency, and ultimate compressive strength were studied and the influence of the mass ratio of cement/asphalt on these properties was investigated as well. The results show that the fluidity, consistency, and compressive strength of A-C materials increased with the content of cement percentage (by weight). In addition, the cement/asphalt mass ratio of 50% was considered optimum for the seismic isolation layer because experimental results revealed no obvious deformation was found before peak stress, and few cracks on the specimens' surface were observed after the loading process. Then the A-C materials with a 50% ratio of cement/asphalt were further investigated by using FLAC3Dd numerical simulations, in which the A-C materials were applied to a field shield tunnel (Shantou Bay Undersea Tunnel) with an outer diameter of 14.0 m located in a hard-soft stratum. In the numerical simulation, the El Centro earthquake wave (3.12 Hz), the Wenchuan earthquake wave (1.02 Hz), and the artificial earthquake wave (1.47 Hz) were used to investigate the antiseismic capacity of the A-C-based isolation layer in the shield tunnel. The horizontal displacement and principal stress of the segmental linings were studied to evaluate the effectiveness of the seismic isolation layer. The simulation results show that the A-C-based seismic isolation layer could significantly reduce the maximum principal stresses of the tunnel near the hard-soft stratum junction. And the reasonable fortified length of the A-C seismic isolation layer in this study was 3.5 times the tunnel diameter from the stratum junction to both sides. The discussers highly appreciate the work of the authors and would like to provide some comments regarding the experimental process, results, and analysis.

Synchronous backfill grouting is of great importance to the safety of shield tunneling. Many construction accidents of shield tunneling are due to improper grouting, especially in water-rich ground strata, resulting in water inrush, mud bursting, leakage, corrosion, segments faulting, and even a disastrous tunnel collapse (Liang et al. 2022; Ye et al. 2020, 2021; Ying et al. 2022). In this study, the authors used a cationic fast-cleft and slow-coagulate emulsified asphalt to make A-C samples. The discussers recommend the authors explain why they chose cationic emulsified asphalt to make seismic isolation layer. Based on the previous literature, the asphalt emulsion type has a significant effect on the properties of cement-emulsified asphalt mortar (CEAM) (Jiang et al. 2021). The cationic emulsified asphalt-based CEAM would have low elastic modulus and strengths. And the anionic emulsified asphalt-based CEAM exhibits a relatively high elastic modulus and better mechanical performance (Wang et al. 2015). Therefore, specifying the rationale for choosing emulsified asphalt type could provide a valuable reference for other similar studies.

The auxiliary additives such as water reducer, defoamer, and viscosity-modifying agent play an important role in controlling the properties of CEMA. In this study, the 8013HPWR early-strength and high-performance water reducer was used to make testing specimens. It is worthwhile that the authors explain how to choose the auxiliary additives like superplasticizers in this study to guarantee the stable and proper performance of the CEMA-based isolation layer in the shield tunneling.

The mechanical properties of A-C-based grouting materials depend on the hydration of cement and the demulsification of asphalt emulsion. The preceding interactive and counterbalancing process results in the characteristics of the final phased CEAM. Therefore, the preparation technology is imperative to the performance of the CEAM-based seismic isolation layer. The agglomeration of emulsified asphalt, cement particles, and other raw materials should be avoided. In addition, the sequences in which the different materials are added are also critical. The feeding (preparation) order should be taken care of to minimize the direct contact of emulsified asphalt and dry cement particles to avoid emulsified asphalt demulsifying in advance, and cement and sand are wrapped in the asphalt membrane. Therefore, could the authors introduce the experience of how to ensure the properties of A-C materials during specimen preparation?

The size effect of specimens on the properties of CEAM-based materials also needs to be focused on (Jiang et al. 2023). The nominal strength of laboratory-size specimens differs from that of larger structural members used in real construction structures (Kim and Yi 2002). The difference in the nominal strength is a direct consequence of energy release into a finite-size fracture process zone. The size effect is quite apparent in the compressive failure of quasi-brittle materials such as concrete. Therefore, it is worth studying the size effect in cementitious materials. In this study, 70.7 × 70.7 × 70.7 mm cubic A-C samples were used to conduct properties tests.

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Will the properties of CEAM in the backfill grouting of actual shield tunneling construction match the laboratory test results? Do we need to introduce surplus coefficients to ensure the quality of CEAM during the practical application? The discussers believe the authors could provide a reasonable explanation for this question.

The grouting mechanism, especially the diffusion theory of penetration grouting in shield tunneling, is of great importance to the safety and stability of shield tunneling (Li et al. 2022a, b; Liu et al. 2021). When the grouts are injected into the ground, it triggers soil expansion and excess pore water pressure, which significantly disturb the surrounding area of the shield tunnel. In addition, the interface between the soil and grouts changes with the ongoing diffusion of pressurized grouts, influencing the stability of the shield tail voids and further negatively affecting the safety of shield tunneling. Therefore, reliable grouts diffusion mechanisms shall be developed to address the aforementioned issues. In this study, the diffusion properties of the A-C-based materials were not considered to simplify the simulation analysis. However, improper control of grouts diffusion behind the segmental linings may result in safety concerns, and inadequate grouting could negatively affect the grouting quality, weakening the antiseismic ability of the A-C-based seismic isolation layer in the shield tunneling. Therefore, the diffusion theory of penetration grouting in shield tunneling is recommended to be considered in the future study, contributing to the accuracy of numerical simulations. The discussers would like to ask for opinions on this aspect.

The practical application value of the A-C-based backfill grouts should be the priority consideration in this study. The matching criteria between the properties of grouts and the corresponding geological conditions should be established. In this study, the hard-soft stratum was used as the geological condition to numerically investigate the antiseismic function of the A-C materials during shield tunneling. However, the authors did miss the critical geological information, such as the seismic conditions of the project site (Shantou Bay area). And what is the relationship between earthquake frequency and geology? The clarification could help add practical value to this study. In addition, is the A-C material suitable for real shield tunneling construction? Will the A-C-based grouts pollute the grouting pipes and surrounding formations? The pumpability of the grouts also determines the grouting quality, influencing the quality of the seismic isolation layer. The discussers believe the authors could provide a reasonable explanation for these questions.

Shield tunneling has been the dominant tunnel construction method for many countries such as Japan, the United States, and China, especially in soft soil areas, due to its advantages of a fast construction schedule, low disturbance to the surrounding environment, and a high level of automation (Huang et al. 2022a, b; Zhang et al. 2022). The authors' research is of great value to the technical advances and promotion of shield tunneling technology. The discussers believe the authors would complete more comprehensive and valuable studies after reviewing and answering the preceding discussions and questions.

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