Postprint: Study on Temperature Field Evolution Characteristics in High-Geothermal Tunnels Based on Temperature-Time Effect (TTE) of Material Thermal Parameters

Authors: Liu Xinrong, Wang Yan, Zhou Xiaohan

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Abstract

Investigating the evolution of temperature fields in high-geothermal tunnels is crucial for optimizing thermal control strategies. Field monitoring obtained the spatiotemporal distributions of rock temperature (Tr), environmental temperature (Te), and air flow velocity (Wv), while laboratory experiments quantified the response characteristics of thermal parameters of surrounding rock and lining materials varying with temperature. A transient heat transfer model based on tunnel ventilation was established, which considers the time-temperature effect (TTE) of material thermal parameters, and was validated through numerical simulation. The research findings indicate: (1) Compared with the constant material thermophysical parameter model, the proposed TTE model reduces the temperature prediction error by 17.6% during the secondary lining construction process. (2) The variation characteristics of tunnel temperature peak, heat dissipation peak, and temperature difference between the center and edge of the secondary lining under the influence of different factors were investigated. (3) The thermal insulation structure leads to a substantial increase in the peak temperature of concrete (15.6°C) during the early stage of secondary lining construction, which is detrimental to its early strength development. However, after the release of hydration heat is completed, the sandwich-type thermal insulation structure helps to reduce the temperature of the entire secondary lining. (4) A multivariate prediction model coupling Tr, Te, and Wv was established, which can accurately estimate extreme temperatures and heat dissipation rates at various construction stages.

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Full Text

Preamble

Temperature Field Evolution Characteristics in High Geothermal Tunnels Considering the Thermo-Temporal Effect (TTE) of Material Thermal Properties

Xinrong Liu[1,2], Yan Wang[1], Xianhan Zhou[1,2]

[1]School of Civil Engineering, Chongqing University, Chongqing 400045, China
[2]Key Laboratory of New Technology for Construction of Cities in Mountain Area of the Ministry of Education, Chongqing University, Chongqing 400045, China

Abstract

Investigating temperature field evolution in high geothermal tunnels is essential for optimizing thermal control strategies. This study captured spatiotemporal distributions of rock temperature (Tr), environmental temperature (Te), and air flow velocity (Wv) through field monitoring, and quantified the temperature-dependent response characteristics of thermal parameters for both surrounding rock and lining materials via laboratory experiments. A transient heat transfer model based on tunnel ventilation was established, incorporating the thermo-temporal effect (TTE) of material thermal properties, and validated through numerical simulation. The findings reveal that: (1) compared with models assuming constant thermal properties, the proposed TTE model reduces temperature prediction errors by 17.6% during secondary lining construction; (2) the variation characteristics of tunnel temperature peaks, heat dissipation peaks, and temperature differences between the center and edge of the secondary lining were examined under various influencing factors; (3) thermal insulation structures cause a significant increase in concrete peak temperature (15.6°C) during the early construction stage of the secondary lining, which is detrimental to early strength development, yet after hydration heat release, sandwich insulation structures help reduce temperatures throughout the secondary lining; and (4) a multivariate prediction model coupling Tr, Te, and Wv was developed to accurately estimate extreme temperatures and heat dissipation rates at each construction stage.

Keywords: high geothermal tunnel; thermo-temporal effect; temperature field evolution; sandwich insulation structure

Note: Figure translations are in progress. See original paper for figures.