Experimental Study on Load-Bearing Stability of Tunnel Corrugated Steel Arches under Surrounding Rock Load (Postprint)

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Abstract

Corrugated steel plate structures exhibit light self-weight and excellent mechanical properties. To investigate the stable bearing capacity performance of corrugated steel arches as primary support structures in tunnels, this study, based on scaled model tests, analyzed the buckling deformation trends and critical loads of corrugated steel arch structures, with particular emphasis on the influence of corrugation shape distribution and lateral pressure, revealing the buckling deformation process and final instability pattern of corrugated steel arches under loading. First, a comparative analysis was conducted on the deformation, buckling patterns, and stable bearing capacity between corrugated steel arch shells and flat steel plate arch shells, discussing the enhancement mechanism of corrugations on arch shell bearing capacity. Second, the sand soil medium was removed to simulate a condition with a lateral pressure coefficient of zero; load was applied to the corrugated steel arch until structural buckling occurred, examining the final buckling pattern and stable bearing capacity of the corrugated steel arch structure. Finally, by comparing the buckling deformation differences of corrugated steel arches with and without sand soil medium under loading, the mechanism of lateral pressure influence on corrugated steel arch buckling was elucidated. Experimental data demonstrate: the critical load of corrugated steel arches reaches 7000 kN, representing an increase of over tenfold compared to flat steel plate arches (580 kN); under direct vertical loading, the critical load is 5110 kN, with 63 cm settlement at the arch crown at instability, bulging of the trough section at the arch haunch, and an elliptical cross-section. Under critical load, the primary buckling location of corrugated steel arches remains concentrated in the arch haunch-to-crown region, and lateral pressure significantly reduces overall displacement by suppressing radial deformation. Furthermore, strain results reveal that longitudinal strain in corrugated steel arches evolves synchronously with the buckling process, while peak radial strain in the cross-section concentrates at the arch crown and haunch, with symmetric strain distribution at the crest section. The research findings can provide theoretical basis and technical support for design optimization, construction-stage stability control, and surrounding rock interaction analysis of corrugated steel arches in large-span tunnels.

Full Text

Preamble

Experimental Study on Bearing Stability of Tunnel Corrugated Steel Arch Under Surrounding Rock Pressure

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Abstract

Corrugated steel plate structures offer advantages of light self-weight and excellent mechanical performance. To investigate the stable bearing capacity of corrugated steel arches as primary support structures in tunnels, this study employs scaled model testing to analyze buckling deformation trends and critical loads, with particular emphasis on the influence of corrugation geometry and lateral pressure, revealing the buckling deformation process and ultimate failure modes of corrugated steel arches under loading. Comparative analysis between corrugated and flat steel plate arches demonstrates the strengthening mechanism of corrugations on load-bearing capacity. The study also examines the final buckling morphology and stable bearing capacity under direct vertical loading (simulating a lateral pressure coefficient of zero by removing sand medium) until structural buckling occurs. Furthermore, by comparing buckling deformation differences between tests with and without sand medium, the mechanism of lateral pressure effects on arch buckling is elucidated.

Experimental results indicate that the critical load of corrugated steel arches reaches 7000 kN, representing more than a tenfold increase over flat steel plate arches (580 kN). Under direct vertical loading, the critical load is 5110 kN, with 63 cm of crown settlement at failure, trough sections bulging at the haunches, and an elliptical cross-sectional shape. At critical load, buckling primarily concentrates in the haunch-to-crown region, with lateral pressure significantly reducing overall displacement by restraining radial deformation. Strain measurements reveal that longitudinal strain evolves synchronously with the buckling process, while radial strain peaks concentrate at the crown and haunches, with symmetric distribution across crest sections. These findings provide theoretical foundations and technical support for design optimization, construction-stage stability control, and rock-structure interaction analysis in large-span tunnel applications employing corrugated steel arches.

Keywords: tunnel engineering; corrugated steel arch; scaled model test; surrounding rock pressure; bearing stability