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Flat Prestressed Unbonded Retrofit System for Strengthening of Existing Metallic I-Girders

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Abstract

In this study, a novel retrofitting system is developed to strengthen existing metallic I-girders using prestressed unbonded carbon fiber reinforced polymer (CFRP) plates. The system relies on a pair of mechanical clamps. Each clamp holds two CFRP plates (each having cross-sectional dimensions of 50 × 1.4 mm) and anchors their prestressing forces to a metallic I-girder via friction. A finite element (FE) model was established to optimize the design of the required mechanical components, and a set of pull-off tests was performed to evaluate the capacity of the optimized system. The proposed flat prestressed unbonded retrofit (FPUR) system was then applied on a 6.4-m-long steel I-beam, and the excellent performance of the system, in terms of stress reduction in the beam bottom flange, was confirmed based on the results of a set of static four-point bending tests. Moreover, a fatigue four-point bending test was conducted on the steel I-beam, strengthened using the proposed FPUR system with a prestressing level of 53% (i.e., approximately 1120 MPa prestress in the CFRPs). Experimental results of the high-cycle fatigue test confirmed the excellent fatigue performance of the proposed FPUR system, as no prestress loss was observed after 20 million fatigue cycles. An analytical model is proposed to accurately predict the stress state in an I-girder strengthened with the proposed FPUR system, while design recommendations are provided concerning the practical use of the system. Relying on the laboratory experimental test results, the proposed FPUR system was used to strengthen the metallic cross-girders of a 121-year-old bridge in Australia.

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