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Seismic response evaluation of segmental column-supported bridges with innovative hybrid sliding-rocking joints to cross fault ruptures

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Extended Abstract

Across-fault ground motions generally involve strong dynamic impulse and permanent ground displacement, which can impose significant spatially nonuniform deformation demands on bridge structures. Segmental column-supported bridges have considerable potential for low-damage and recoverable seismic performance because their segmental joints can accommodate seismic deformation through joint opening, rocking, and self-centering action. However, under large permanent ground displacement, conventional segmental columns may still experience concentrated damage at segment ends and excessive residual deformation. These issues make it difficult to simultaneously satisfy the requirements of damage mitigation and post-earthquake functionality. To address these challenges, a novel hybrid sliding-rocking joint is proposed in this study to enhance the seismic resilience of segmental column-supported bridges crossing active fault rupture zones.

The proposed joint consists of duct adaptors and a low-friction curved contact interface. A coordinated deformation-control mechanism is achieved through the combined action of a rocking-dominant joint at the column base and sliding-dominant joints at the inter-segmental interfaces, as shown in Figure 1. The duct adaptors are introduced to enlarge the allowable tendon deviation and inter-segmental sliding capacity, thereby able to accommodate larger permanent ground displacement. Compared with conventional flat sliding interfaces, the curved contact interface generates a geometry-induced restoring effect during unloading, which is beneficial for reducing post-earthquake residual sliding.

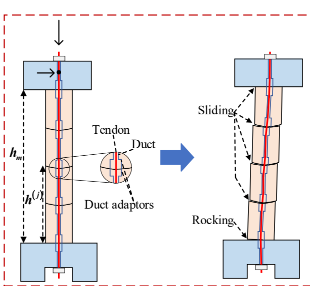

Figure 1-Configuration and response mechanism of the proposed segmental column with hybrid sliding-rocking joints.

The joint configuration, response mechanism, and mechanics-based design concept are first established. Several key design objectives are identified, including control of sliding capacity, prevention of yielding in the post-tensioning tendons, and residual sliding mitigation. Based on an experimentally validated finite element model, three-dimensional nonlinear models are developed to investigate the seismic performance of different segmental column-supported bridge configurations. Comparative analyses are conducted under representative strike-slip and dip-slip across-fault ground motions. Three bridge configurations are considered, including a conventional segmental column-supported bridge (B-SC1), a bridge incorporating duct adaptors only (B-SC2), and the proposed bridge combining duct adaptors with low-friction curved contact interfaces (B-SC3).

The damage patterns shown in Figures 2 and 3 further demonstrate the effectiveness of the proposed joint under both strike-slip and dip-slip across-fault ground motions. For the conventional segmental column-supported bridge (B-SC1), severe damage is mainly concentrated at the top and bottom regions of the columns, indicating that the imposed fault-induced deformation is largely accommodated by local inelastic deformation at the column ends. After the duct adaptors are introduced in B-SC2, the damage at the column ends is noticeably reduced because the inter-segmental joints are allowed to accommodate and release part of the imposed seismic deformation through controlled sliding. However, due to the absence of an effective geometry-induced restoring path, relatively large residual sliding still remains after the earthquake. In comparison, the bridge with the proposed joint (B-SC3) exhibits a more favorable damage distribution under both fault types. The low-friction curved contact interface guides the sliding trajectory and provides a geometry-induced restoring effect, thereby reducing residual sliding compared with B-SC2. Therefore, B-SC3 achieves improved performance in terms of both damage mitigation and residual sliding control.

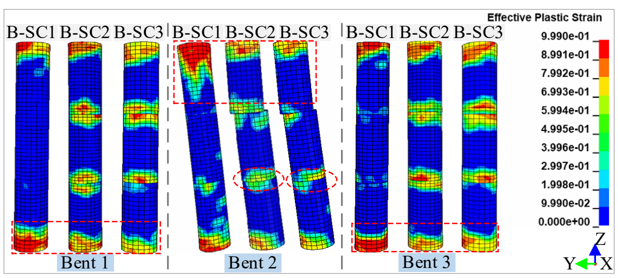

Figure 2-Damage modes of bents in different bridges under strike-slip across-fault ground motions

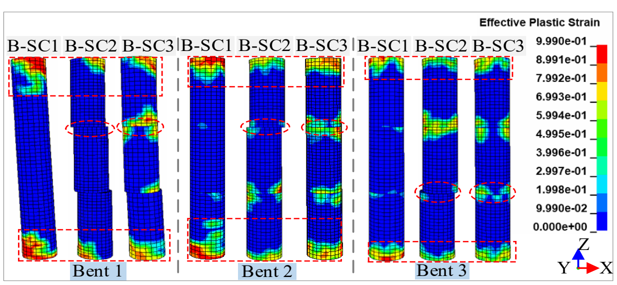

Figure 3-Damage modes of bents in different bridges under dip-slip across-fault ground motions

Keywords: *Segmental columns-supported bridge; Across-fault ground motions; Strike-slip fault; Dip-slip fault; Hybrid sliding-rocking joints*