CONCEPT, ANALYTICAL MODEL AND CYCLIC BEHAVIOR OF UPLIFT-ROCKING TALL DOUBLE-COLUMN BENTS

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Extended Abstract

Girder bridges with tall double-column bents have emerged as a crucial solution to navigate the complex topographic and spatial challenges, especially prevalent in the mountainous and canyon regions. Considering a more favorable moment distribution along the double columns, the link beams are recommended to be strategically arranged between the column in the transverse direction and detailed as ductile components capable of dissipating seismic energy. However, as the irregular bridge system, significant challenges remain in post-earthquake rehabilitation due to substantial residual displacements and extensive damages. In this context, as a critical component of lifeline infrastructure, there is an urgent need for innovative seismic-resistant systems to enhance the seismic resilience of conventional tall bents.

A typology of innovative systems employing rocking self-centering (RSC) has been recognized as a prospective resilience-enhancing solution, attracting considerable research attention in recent years. By releasing the fixed constraints between column bases and foundation, the columns are allowed to exhibit significant rocking behavior, thereby minimizing the earthquake-induced damage, as well as achieving negligible residual deformation. Although these technologies have been successful applied into low and medium-height bridge piers, their application to tall piers, particularly within tall bents, remains limited. More importantly, this bridge configuration tends to exhibit higher sensitivity in terms of seismic resilience, for example, the geometric nonlinearity and the rocking stability induced by the increased slenderness, the balance between the self-centering and energy-dissipation capabilities.

The presentation in this keynote speech is about the proposal of an innovative uplift-rocking double-column bent (UR-TDCB) system, as well as a series of a parametric theoretical, experimental and numerical campaign. The study was funded by the National Natural Science Foundation of China. Figure 1 shows the details of the UR-TDCB system that will be the focus of this presentation. The system comprises the rocking component (i.e., tall bent), the displacement-constraint (DC) devices, and the energy-dissipative (ED) devices. Although the distance between the gravity center of the bent and the pivot point in the proposed system is greater than in the conventional RSC single-column systems, the self-centering stability and mitigated stress concentration at the rocking toe are secured by the increase of the plan dimensions of the tall bent at the bottom ends. In the absence of a monolithic connection, the tall bent was connected to the foundation with the ED devices, composed of triangular steel plates that dissipate input energy via a flexural-yielding mechanism at the uplifting-rocking phase. Two shear grooves were introduced at the foundation top as a simplified alternative to conventional shear-key devices. Under

extreme earthquake ground motion, the expanded base is allowed to undergo excessive uplifting displacement. Since such uplift is particularly critical for slender systems, DC devices were employed to control the displacement induced by uplift. Given the difficulty of replacement, the embedded bolts of DC devices were specified as high-strength steel elements and detailed to remain elastic with a sufficient embedment length, to prevent the potential bond-slip behavior. It is noteworthy that, the post-tensioned (PT) tendons are unnecessary in this proposed system that allows the global uplifting and self-centering, as well as in the additional rocking interface between the double-column and cap beam. This configuration markedly saves the time and cost for construction works, including the retrofit of cap beam, maintenance and replacement of PT tendons etc.

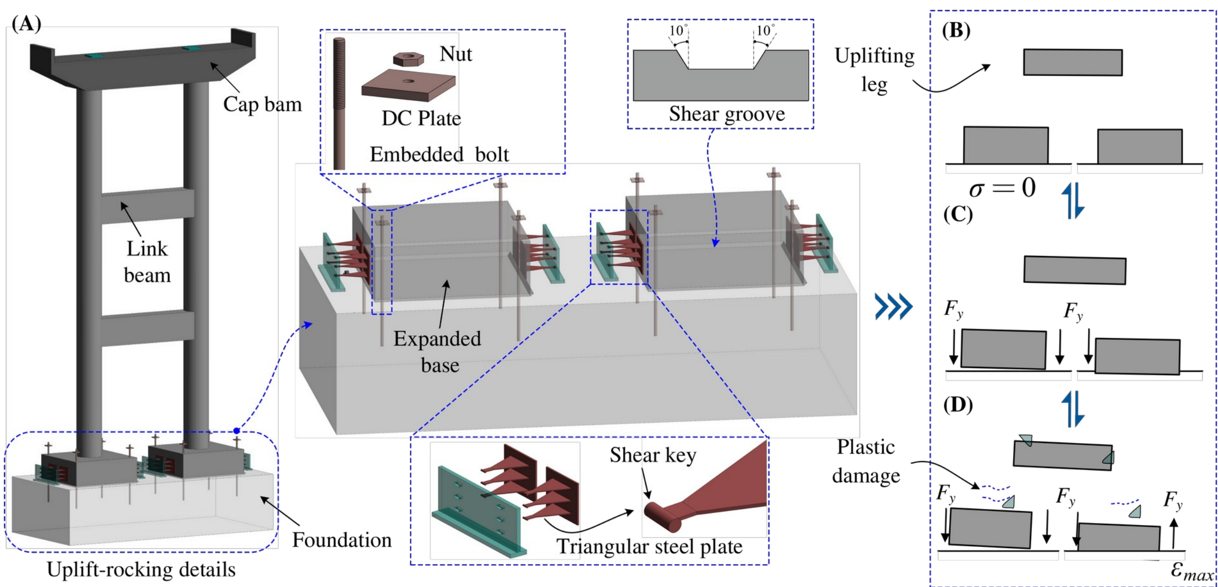

Figure 1- Details of UR-TDCB.

The results showed that the alternating uplift-rocking behavior limited both damage progression and residual deformation in main load-bearing components (i.e., columns and link beams), achieving a 54-87% reduction in the maximum curvature. However, this improvement is achieved at the expense of increased shear damage in beam-column joints. This drawback necessitates the integration of a critical shear-resistant design into the proposed system. Moreover, the energy dissipation (ED) coefficient and the number of link beams play a decisive role in the hysteretic behavior of the system.

***Keywords**: tall double-column bent; seismic resilience; uplift-rocking; theoretical modeling; cyclic behavior.*