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SEISMIC PERFORMANCE OF POST-TENSIONED SLAB-COLUMN CONNECTIONS

C. Liu [(1)], Y. Zhou [(2)]

[(1)] *Graduate student, Changsha University of Science and Technology*
[(2)] *Associate professor, Changsha University of Science and Technology, yan.zhou@csust.edu.cn*

Extended Abstract

Post-tensioned (PT) concrete slabs are a common system for commercial and residential buildings where post-tensioning limits cracking to allow thinner slabs or longer spans. This leads to reduced floor system weight and reduced demands on vertical structural members. Past earthquake damage has shown that slab-column (SC) frames are not a suitable main lateral-force-resisting system (LFRS) in regions of high seismic risk because of their relative flexibility and potential for brittle punching shear failures. SC frames are commonly used as “non-participating” gravity systems in regions of high seismic risk where they are not designated as part of the seismic-force-resisting system (SFRS), and moment frames or shear walls are provided as the SFRS. In such cases, the SC connections must still maintain sufficient strength and ductility to resist gravity loads under the presence of inelastic deformations.

The tendency for the drift capacity of SC connections to decrease as the gravity shear ratio (*VR*) increases potentially limits the application of flat-plate structures in high seismic regions, as well as buildings with high gravity loads. One approach to enhance the shear resistance and drift capacity of SC connections is to add shear reinforcement. Typical shear reinforcement includes bent-up bars, closed stirrups, shearheads, and shear studs. Shear studs offer a superior reinforcement solution, providing reliable shear transfer paths and ductility while avoiding the reinforcement congestion associated with traditional stirrups. Tests of reinforced concrete (RC) SC connections from the University of Minnesota raised questions about the adequacy of current slab shear reinforcement requirements for lateral demands in the ACI 318 code. However, comparable tests for shear reinforced PT SC connections are not available. Only limiting testing has been conducted for post-tensioned (PT) SC connections, particularly to verify their performance when minimum two-way shear reinforcement is provided to enhance their lateral ductility. Thus, two full-scale interior PT SC connection specimens were constructed and tested in this study to investigate the seismic performance under different gravity

load levels. It is a critical step towards filling a gap in the current understanding of the lateral response of PT SC connections with shear stud rails.

The specimens represented a prototype PT flat plate structure designed according to GB50010-2010 and ACI 318-19. The primary experimental variable was the *VR*, defined as the ratio of the factored gravity shear force (V_g) to the nominal two-way concrete shear strength (V_c). Specimen PT-L was designed with a lower *VR* of approximately 0.42, and Specimen PT-H had a higher *VR* of 0.59. Both specimens were unbonded post-tensioned two-way slabs reinforced with shear studs in an orthogonal layout. The experimental configuration involved the application of the constant distributed vertical load to simulate gravity effects, combined with the reversed horizontal cyclic loading at the column top.

The hysteresis loops of the specimens are presented in Figure 1. Both specimens exhibited the pinching effect characteristic of reinforced concrete structures. Neither specimen displayed a sudden strength reduction, even at large drift ratios, indicating that the shear studs effectively transformed the brittle punching failure into a more ductile mode. The failure of specimen PT-L was induced by a high level of unbalanced moment transfer at the connection, resulting in the yielding of longitudinal reinforcement and subsequent punching shear failure. Further, PT-H exhibited a typical punching shear failure mode, confirmed by the absence of longitudinal reinforcement yielding prior to failure, increased stress levels in the shear studs, and limited cracking within the slab. The displacement ductility coefficients for specimens PT-L and PT-H were determined to be 3.06 and 2.81, respectively. Due to the higher gravity load, PT-H experienced premature stiffness degradation, resulting in a slightly reduced deformation capacity compared to PT-L.

The test demonstrated that (1) both specimens experienced a final punching shear failure mode, whereas the specimen with a higher gravity shear ratio exhibited earlier stiffness degradation and reduced energy dissipation capacity; (2) the shear studs effectively improved the lateral stiffness and ductility of the connections, neither specimen displayed a sudden strength reduction, indicating good ductility, with ductility coefficients reaching 3.06 and 2.81, respectively. It is recommended that the code includes strength calculation methods for shear studs in seismic design and require that the shear studs extend to at least four times the slab thickness from the column face. This study provides an important reference for revising the strength and detailing requirements of slab-column connections with shear studs in Chinese code.

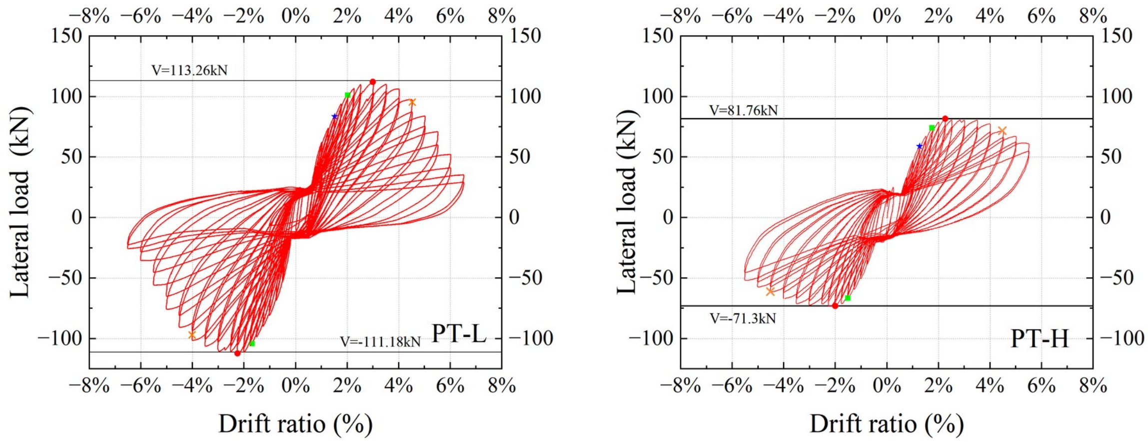

Figure 1- The hysteresis loops of tested specimens.

Keywords: *slab-column connection; punching shear failure; post-tensioned concrete; shear studs; seismic performance.*