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ABSTRACT

Seismic Design of Unbonded Post-Tensioned Precast Concrete Coupling Beams

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This paper discusses the design of unbonded post-tensioned precast concrete beams to couple reinforced concrete walls in seismic regions. Different from conventional coupled wall structures with reinforced concrete beams cast monolithically with the walls, the lateral resistance of the new system develops by post-tensioning a precast concrete beam to the wall piers at each floor and roof level (Fig. 1). The post-tensioning force is provided by a multi-strand tendon that runs through the center of the beam and the wall piers. The post-tensioning tendon is placed inside an ungrouted duct and is anchored to the structure only at the outer ends of the wall piers. Thus, the post-tensioning steel is intentionally not bonded to the concrete over its length.

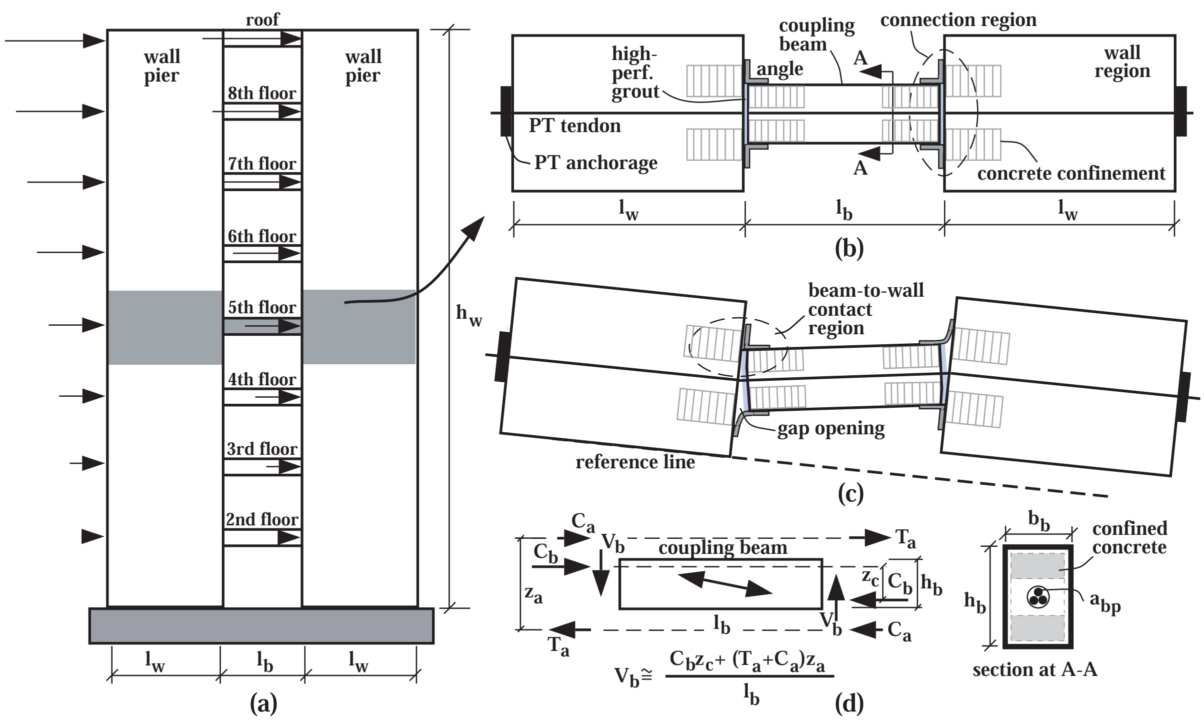

Fig. 1: Coupled wall system: (a) multi-story structure; (b) floor-level subassembly; (c) idealized exaggerated displaced shape; and (d) coupling forces.

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Under lateral loading, the nonlinear behavior of unbonded post-tensioned precast concrete coupling beams is governed by the opening of gaps at the beam-to-wall interfaces. As a result of these gaps, a diagonal compression strut develops along the beam span and the tensile stresses in the beam and the wall piers remain relatively small even under large nonlinear displacements, thus, significantly reducing the amount of bonded mild steel reinforcement needed. Steel top and seat angles are used at the beam-to-wall connections to yield and dissipate energy in the event of a large earthquake and to provide redundancy in support of the beam.

Unbonded post-tensioned precast concrete coupling systems offer important advantages such as simpler detailing, reduced damage to the overall structure, significant self-centering capability (due to the restoring effect of the post-tensioning force), and simpler design and construction for the beams and the wall piers. This paper describes the design of the beams to achieve pre-determined seismic performance objectives to control the amount of damage, including the yielding of the post-tensioning steel, yielding of the angles, and crushing of the concrete. Closed-form procedures that can be used as design tools are developed based on large-scale coupled wall floor-level subassembly experiments to estimate the nonlinear load-deformation behavior of the structure.

The results presented in the paper show that unbonded post-tensioned precast concrete coupling beams having lateral stiffness and strength similar to monolithic cast-in-place reinforced concrete beams can be designed to provide stable levels of coupling without experiencing significant damage over large nonlinear reversed cyclic deformations and with little residual deformations upon unloading. The detailing requirements for the beams (e.g., transverse reinforcement) are considerably reduced as compared with conventional coupling systems. The amount of coupling between the wall piers can be controlled by changing the post-tensioning force.