Seismic Performance of Assembled Precast High-Strength Concrete Beams

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Summary

The seismic performance of assembled precast high-strength concrete beams in high-rise buildings is discussed. The proposed various connections, located at beam's mid-span zone, are suitable for precast frames and intended to reduce the amount of cast-in-place concrete as well as construction time. Four half-scale precast beam-specimens are presented. Two beams use transversal bolts. One beam uses sleeved parallel bars and another beam uses sleeved crossed bars. The gap between the assembled precast parts and other voids are grouted with very high-strength cement mortar. Seismic tests, carried out on these assemblies, confirmed their adequacy. They proved to be ductile and failure occurred outside the connection zone similarly to monolithic ordinary beams. Assumed mechanisms were also pictured for the evaluation of the strength of the different connections.

Keywords: High-rise buildings; precast beams; connections; seismic performance; tests.

1. Outline of beams and connections

Despite its potential benefits in terms of construction speed and quality control, precast construction, particularly framed construction, was not used extensively in high-seismic regions due to the lack of appropriate understanding of various parameters, particularly when the connections of precast components are located in sensitive places of structural systems or are of unusual forms, especially in full precast systems. While almost all connections were conceived around the beam-column joint, another concept that shifts the beam connection to the mid-span, uses different mechanical systems and replaces the relatively considerable amount of cast-in-place concrete by a small amount of cement mortar was proposed by the authors and investigated for high-seismic regions.

Four half-scale assembled precast beams, representing interior shallow beams in high-rise buildings, are presented herein. All designed beams were aimed to have a flexural behavior. The detailing and main reinforcement were almost the same in all beams, except at the connection zone. Each beam was cast on half span, as a protruding cantilever from the beam-column joint and intended to be connected at its tip zone. All beams were assembled with a 10mm-gap between the cantilever parts. The gap and other voids were grouted with very high-strength cement mortar to form a rigid connection.

Two beams use transversal bolts for connection. Beam No.1-1 (Fig.1) was composed of two symmetric similarly detailed lap elements and Beam No.1-2 (Fig.2) was composed of two differently detailed lap elements that were intended for a male-to-female connection. Two layers of non-tensioned transverse bolts were used to join the lap elements.

Two other beams use sleeved bars for connection. Beam No.2-1 (Fig.3) was composed of two almost similar two-prong fork-shaped precast elements. The prongs served as lateral forms to cast concrete after lodging the protruding bars from each element in splice grout-sleeves and injecting high-strength mortar into the sleeves to ensure an adequate splicing. Three layers of splice grout-sleeves were used to join the elements. Beam No.3-2 (Fig.4) was composed of two symmetric similarly detailed half-precast elements. The two elements were provided with inclined ducts to pass through headed bars. First the headed bars were lodged into splice grout-sleeves, then the sleeves were injected with high-strength mortar, then the ducts and other voids were filled with high-strength mortar, and finally, concrete was placed on the upper part of the beam to cover the apparent crossed bars.

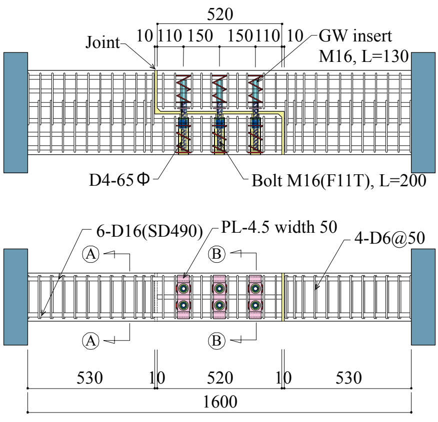

Fig. 1: Outline of Beam No.1-1

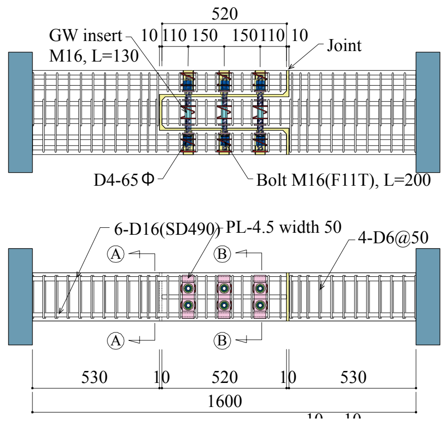

Fig. 2: Outline of Beam No.1-2

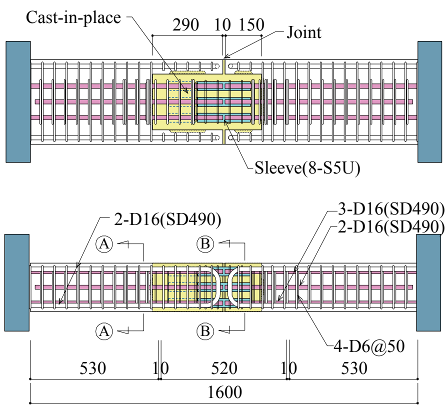

Fig. 3: Outline of Beam No.2-1

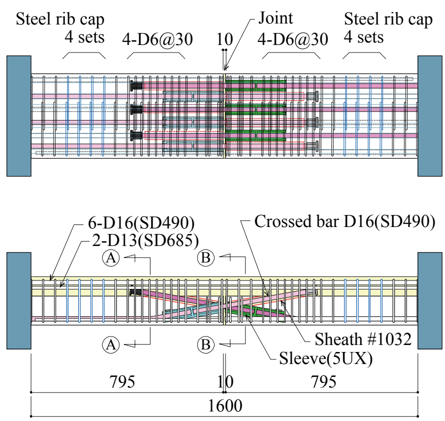

Fig. 4: Outline of Beam No.3-2

2. Performance of tested elements

The test carried out on assembled precast beams confirmed the adequacy of the selected assembles and connection types. The beams proved to be ductile, did not experience any strength deterioration even at large deflection angles and failure occurred outside the connection zone similarly to monolithic beams. The performance of the tested beams, in terms of force-deflection angle relationship, energy dissipation, strains in reinforcement and damage concentration, was relatively comparable. The abrupt variation of cross-sections in Beam No.1-2 with lap elements was the reason of the relatively weak performance when compared to other beams. Furthermore, although test results confirmed the performance adequacy of the connections in Beam No.1-1, Beam No.2-1 and Beam No.3-2, a preference would be toward the bolted Beam No.1-1 due to the simplicity of the connection, the reduced amount of cast-in-place concrete and short time of implementation, thus, resulting in a low erection cost.

The evaluation of the flexural strength of the assembled precast beams was appropriate. The evaluated connection strength values were far higher than the maximum recorded strengths of beams. Therefore, the strength of the connections and the assumed mechanisms could not be checked as long as neither particular damage nor failure mechanism could be observed.