Tests on Precast Concrete Frames with Connections Constructed Away from Column Faces

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A modified assembled configuration is introduced for precast concrete frames in which the connections are constructed on the beam span and kept away from the column faces so as to avoid coinciding with the plastic hinge regions during seismic excitations. An experimental study on the seismic performances of two full-scale precast concrete subframes adopting the aforementioned configuration and a monolithically-cast subframe subjected to quasistatic simulated seismic loading is presented. The variable examined was the connection detail. The performances of the precast concrete frames are evaluated on the basis of ductility, energy dissipation capacity, connection strength, and drift capacity. Based on the test results, the precast concrete frames are capable of matching overall performance of the monolithic connections and thereby providing moment-resisting behavior.

Keywords: ductility; frames; precast concrete; seismic.

INTRODUCTION

Structural systems employing precast concrete elements have proven quite efficient in raising productivity and quality control as well as being cost efficient. In countries such as New Zealand and the U.S., precast concrete systems with various connection details have been widely implemented in the construction of moment-resisting frames to provide adequate earthquake resistance. Nevertheless, the precast concrete industry has not reached its full operating potential due to several problems that have been left unsolved for years. Problems arising from the connections between precast components have become a serious issue confronting the precast concrete industry. Some precast concrete structures have demonstrated failure during earthquakes in the past as a result of inadequate attention to the connection design.

The lack of prescriptive design guidelines has also been an obstruction for the comprehensive use of precast concrete structural systems in the construction industry. Naaman et al.\(^1\) stated that the UBC Code\(^2\) allows considerable freedom in the development of ductile moment-resisting frames but little clarification is given on how the provisions can be applied to precast concrete structures. Design codes in the U.S. generally adopt a requirement of proven reinforced concrete emulsion for precast concrete seismic-resistant structures.\(^3\) Confidence in the use of precast concrete frames in regions of high seismicity is ultimately based on laboratory testing for the validation of their performance. There is also a lack of accepted design methods for areas of low to moderate seismicity in which the ductility demand may be lower. It appears to be impractical and uneconomical to provide the same level of seismic resistance for precast concrete frames in low to moderate seismic areas as those in regions of high seismicity.

Current practice in precast concrete frame construction reveals that the connections between precast beams are usually located at the beam-column joint cores; or at the midspan of a beam. Providing connection in the beam-column joint region is apparently unfavorable because it disturbs the continuity of reinforcement. The congested reinforcement details in the joints always create difficulties during the erection stage. Moreover, the beam-column joints can be vulnerable under seismic actions as they are subjected to reverse bending moments and shear forces. The induced shear forces in the joint region can typically be in the order of five times the column shear force.\(^4\) A precast beam is normally seated on the column edges, thus coinciding with the inherent plastic hinging region. This situation would probably be most disadvantageous under seismic actions if the connections are not properly designed for strength and ductility. On the other hand, for frames adopting midspan beam-to-beam connections, Park\(^5\) noted that the precast components of this system can be very heavy and difficult to transport due to their relatively large dimensions. This transportation difficulty would then hinder the choice of precasting the cruciform members for frames with long beams.

French et al.\(^6,7\) had looked into the issue of moving the connections away from the column face. In their research, the connections were relocated to the beam span at a distance away from the column faces. Such a configuration implies that a beam-column joint core with short, protruding beam stubs would be cast as part of the precast column, while the beam spanning in between columns would form another precast member. The connections between these precast components were established through the lapping of hooks at the precast beam ends, which were then encased within cast-in-place concrete. Figure 1 schematically illustrates the aforementioned system. With such a frame configuration, the beam-column joint core, in which the reinforcement details are complicated, can be prefabricated precisely under factory conditions. The reinforcement continuity will further enhance the integrity of the joint and prevent premature failure. Most importantly, the coinciding condition between the inherent plastic hinge locations and the connection regions can be avoided. On the other hand, this system allows precast components with longer horizontal members to be mobilized efficiently.

RESEARCH SIGNIFICANCE

The research is relevant to the use of precast concrete systems for gravity-dominated frames in countries located in...