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Effect of Self-Consolidating Concrete on Beam-Column Exterior Joints

H. Shirazi[1] and M. R. Esfahani[2*]

1 [i]Assistant Professor, Ferdowsi University of Mashhad and, [ii]Azad University, Mashhad Branch, Mashhad, Iran
2 Professor, Ferdowsi University of Mashhad, Mashhad, Iran

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ABSTRACT

In this research, behavior of exterior concrete beam-column joints made of normal concrete (NC) and self-consolidating concrete (SCC) is investigated. The variables include the type of beam longitudinal bar anchorage in joint, transverse reinforcement of joint and strength of concrete. Experimental and analytical investigation of joint behavior is carried out. In the experimental part, 10 semi-scale exterior beam-column joints were manufactured and subjected to a constant column axial load and beam quasi-static cyclic load. In the analytical part, the ABAQUS software is used for modeling and analyzing of test specimens. Based on the results, the experimental and analytical joint capacities are in good agreement. Results show that using self-consolidating concrete in joints, apart from easier concrete placement, can increase the workability and ductility of connection and result in a better bond with reinforcing bars. Also, by increasing the concrete strength, the failure mechanism of a connection may change from shear failure in joint to flexural failure in beam.

KEYWORDS

Exterior Concrete Beam-Column Joints, Finite Elements, Self-Consolidating Concrete, Hysteresis Diagram

* Corresponding Author, Email: esfahani@um.ac.ir

1. Introduction

The vibration of concrete in beam-column joints is generally difficult due to the congestion of steel bars in the core zone. Shear capacity and transferring forces across the joint core significantly decrease due to the poor vibration of concrete. This can be the main cause of collapse of many structures subjected to earthquake loads. Self-consolidating concrete (SCC) has become more popular in the concrete industry due to its excellent flowability and ease of performance in heavily reinforced members [1-4]. Although many recommendations have been presented for using SCC to improve the behavior of beam-column joints, experimental studies on the structural behavior of the connections made with SCC are very limited [5]. Regarding the complicated and nonlinear behavior of concrete, it is generally difficult to reach an exact analytical method containing the most effective variables. This problem increases especially in reinforced concrete structures with composite sections in which the interaction of steel and concrete must also be considered. Therefore, it is unlikely to study all effective variables, experimentally. A nonlinear finite element analysis provides a powerful tool to investigate different parameters influencing the behavior of beam-column joints.

2. Experimental Program

In the experimental part of this study, 10 semi-scale exterior beam-column connections were manufactured and tested. Two types of concrete including normal and self-consolidating concrete were used for specimens. Other variables include the type of beam longitudinal bar anchorage in joint, transverse reinforcement of joint and strength of concrete. Experimental and analytical investigation of joint behavior is carried out. Fig.1 shows the reinforcement detailing, the type of concrete of specimens and the dimensions of specimens. Two compressive strengths of concrete were used for specimens including 30 MPa and 45 MPa. All longitudinal and transverse reinforcements used for specimens had similar yield strength of fy=450 MPa. The beam end of the specimens was subjected to a vertical quasi-static load reversal with a double acting 500 kN capacity actuator that simulated earthquake loads (Fig. 2). A constant axial load was also applied to the columns using a 100 kN capacity hydraulic jack during all loading cycles. The applied cyclic load was measured by a 200 kN capacity S-shaped load cell which could record the value of compressive and tensile loads. Appropriate steel bracings were used at the ends of column and beam of specimens to balance them and prevent lateral displacements during the loading cycles. The beam end displacement due to the cyclic load was measured using a linear variable displacement transducer (LVDT). The deformation of a 2-D frame under lateral loads is so that the bending moment in the middle of beam and column spans is approximately zero. To simulate these end conditions, appropriate equipment was used in the test setup. The relationship of load imposed at the beam end versus drift was obtained for different specimens. The drift ratio (DR) was taken as the beam end vertical displacement divided by the distance between the lateral load point and the column center. Fig. 3 shows lateral load versus drift ratio for a specimen.

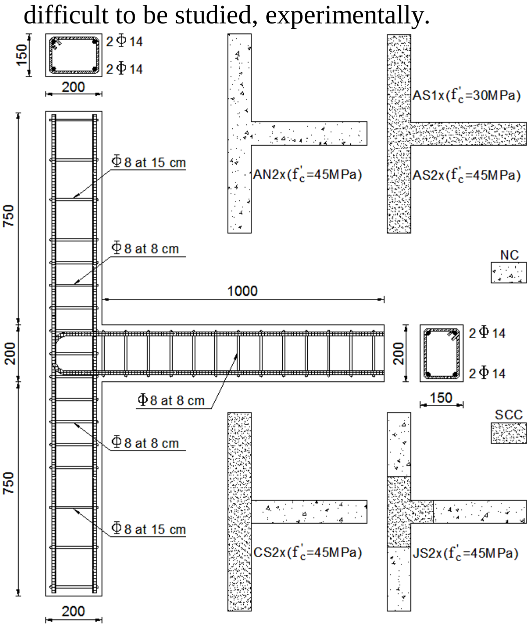
3. Finite Element Analysis

In the present study, the ABAQUS software has been used for analytical investigation of specimens. Due to the application of cyclic load on specimens, the damaged plasticity model was used in this software. The concrete damaged plasticity model assumes that the two main failure mechanisms of concrete are tensile cracking and compressive crushing of the concrete material. In the ABAQUS software, analytical elements C3D8R and TRUSS were used to model concrete and rebar of specimens, respectively.

4. Conclusions

Based on the experimental and analytical results, the following conclusions are drawn:

1. Using self-consolidating concrete in joints, apart from easier concrete placement, can increase the performance and ductility of connection and results in a better bond with reinforcing bars. In specimens with SCC, the load capacity of the connection increased by approximately 8%.
2. It is possible to use SCC in the column or in the joint zone instead of all the connections without degradation in load capacity or performance of connection.
3. Finite element analysis of specimens using the ABAQUS software with the concrete damaged plasticity model showed good agreement with the experimental results. The verified model can be used for investigation of various parameters that are difficult to be studied, experimentally.



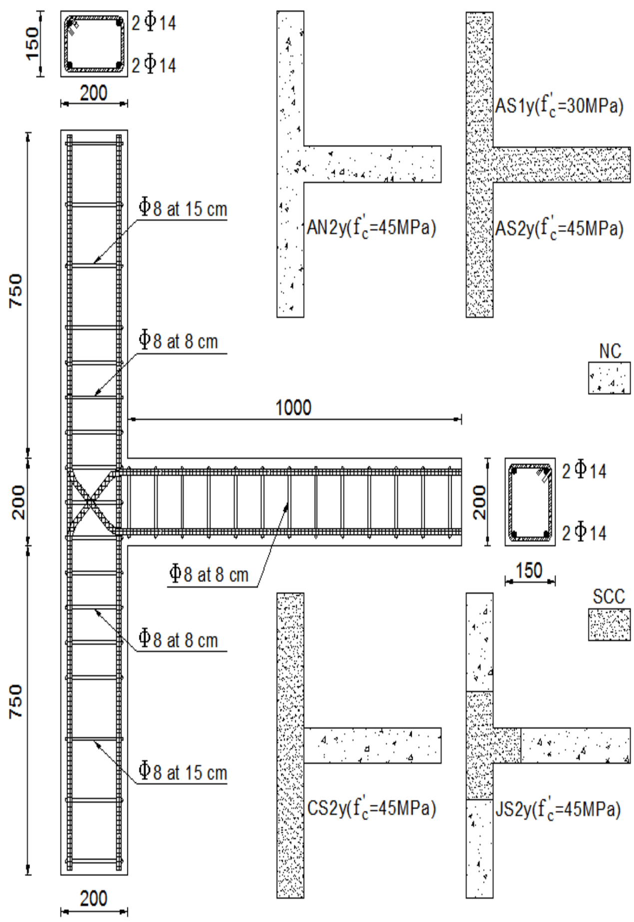


Figure 1: Test specimens and reinforcement

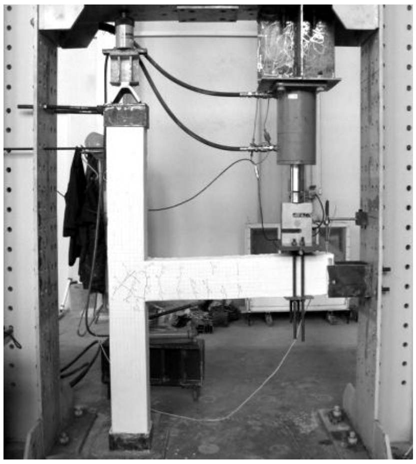


Figure 2: Test setup

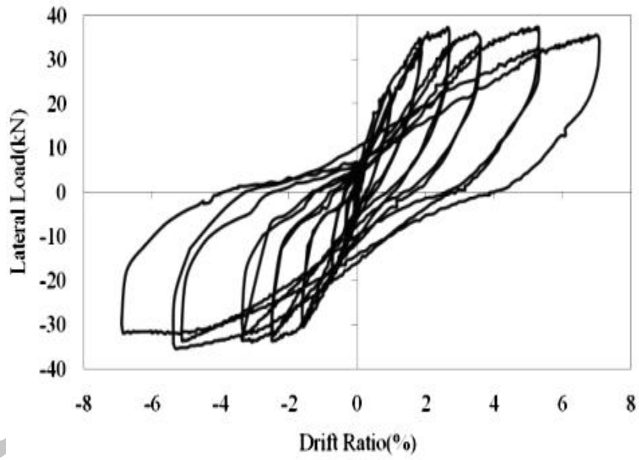


Figure 3: Lateral load versus drift ratio for a specimen

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