Benefits of Puddling of Fiber Reinforced UHSC for Enhanced Transmission of Column Loads

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ABSTRACT

This study reports on the structural characteristics of slab-column connections using an ultra-high-strength-fiber-reinforced concrete. Compression tests were performed on two slab-column and four isolated column specimens. During the column load tests were performing on the slab-column specimens, the slab loads were also applied to consider actual confinement condition at the slab-column joint. The main parameter investigated was the "puddling" of ultra-high-strength-fiber-reinforced concrete. This paper also investigates the effects of some parameters on slab-column specimens and isolated column specimens without the surrounding slab for their ability to transmit axial loads from the ultra-high-strength concrete columns through slab-column connections. The beneficial effects of the ultra-high-strength-fiber-reinforced concrete puddling on the transmission of column loads through slab-column connections are demonstrated.

1. Introduction

In a common form of construction, the slab concrete is cast in a continuous fashion through the column-slab joint. As a result, the joint between the slab and the column is made with a lower grade of concrete than is the rest of the column. But if such a construction method is used when the ratio of column concrete strength to slab concrete strength is very high, it cannot make full use of the column's high strength due to weaknesses in the slab-column joint. In such a case, it is desirable to place high-strength concrete in the column-slab joint and further into the slab. This method is called puddling. In these experimental tests, the ultra-high-strength concrete was placed strategically at a distance of only 2d ('d' is the effective depth of the slab) into the slab from the face of the column for one of the slab-column specimens. In addition, steel fibers were added to the puddled concrete. This paper investigates the effects of the ultra-high-strength-fiber-reinforced concrete puddling on the transmission of column loads through slab-column connections.

2. Description of Experimental Program

Two slab-column and four isolated column specimens were tested to failure. Each specimen was subsequently divided into two series, as shown in Fig. 1.

2.1 N series

The normal strength concrete slabs provide the benchmarks with which to compare the responses of slab specimens puddled with ultra-high-strength-fiber-reinforced concrete. Specimen NP1 and NP2 were tested at McGill University by McHarg (2000) and Ghannoum (1998), respectively. Therefore test results of Specimen NP1 and NP2 were analyzed by using the retrospective data. Specimen NT was constructed with ultra-high-strength concrete stub columns extended above and below the normal strength concrete slab. Isolated column Specimen NC is an ultra-high-strength concrete column with a 150 mm thick layer of 40 MPa slab concrete at its midheight. Control column Specimen C1 is a normal strength concrete column, constructed with 40 MPa concrete.

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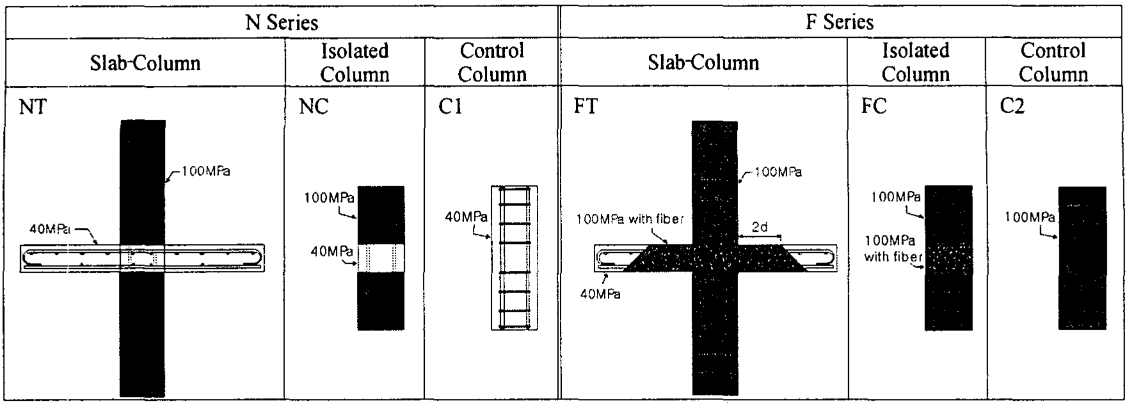


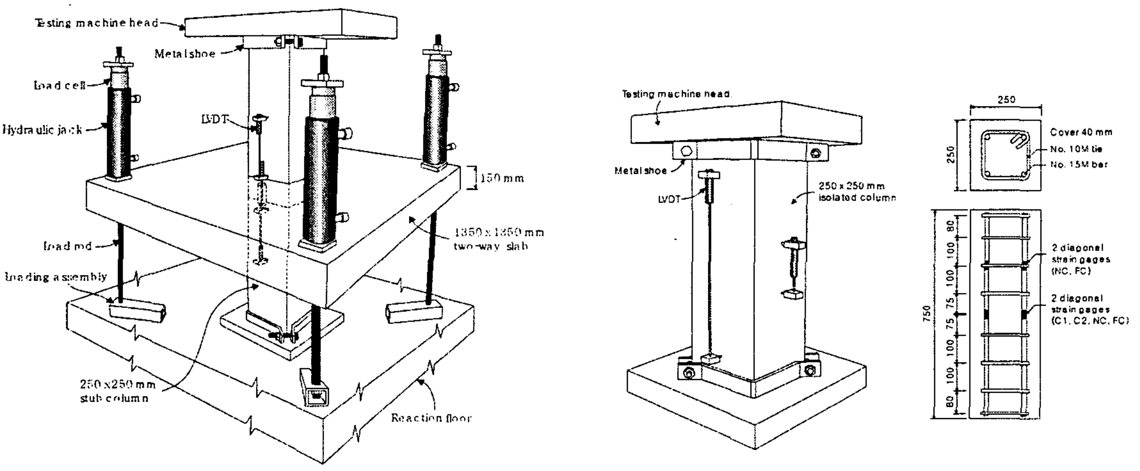
Fig. 1 Classification of test specimens

2.2 F series

The F series contains ultra-high-strength-fiber-reinforced concrete over the entire depth of the slabs, but only in the immediate vicinity of the column, to study the influence of strategically puddle ultra-high-strength-fiber-reinforced concrete on crack control, stiffness, punching shear strength, and transmission of column loads through slabs. Specimen FP and FT contained the ultra-high-strength-fiber-reinforced concrete puddling over the entire depth of the slab in the immediate vicinity of the column. Isolated column Specimen FC is an ultra-high-strength concrete column with a 150 mm thick layer of ultra-high-strength-fiber-reinforced concrete at its midheight. Control column Specimen C2 is an ultra-high-strength concrete column, constructed with 100 MPa concrete.

3. Details of Test Specimens and Test Setup

Test setup and reinforcement layout are shown in Fig. 2. To consider actual confinement condition at the slab-column joint, the slab loads were applied with four center hole jacks connected to a single hydraulic pump (Ospina and Alexander 1998). All specimens were initially loaded with 400 kN to seat the specimen. At this point, the full slab load was applied to the slab. And then, the column load was increased to failure with holding a constant the full slab load. The 250×250×750 mm high column specimens were constructed. Two LVDTs were used to measure the average strain over a 550 mm gage length centered over the height of the column. Two additional LVDTs measured the strain over the middle 150 mm thickness of the slab (Fig. 2 (b)).



(a) Slab-Column Specimen (b) Isolated Column

Fig. 2 Test setup and column reinforcement

4. Test Results

4.1 Load-Strain Responses

Figure 3 compares the behaviors of Specimen NT and FT. It can be seen that providing puddled ultra-high-strength-fiber-reinforced concrete in the slab around the column results in an increase in the axial compressive strength and greater initial loading stiffness. Specimen FT also showed a uniform distribution of strains in the column. While the longitudinal column reinforcement of Specimen NT yielded at the joint when the applied column load reached 63% of the peak load, the longitudinal reinforcement of Specimen FT yielded at 75% of the peak load in the top column stub.

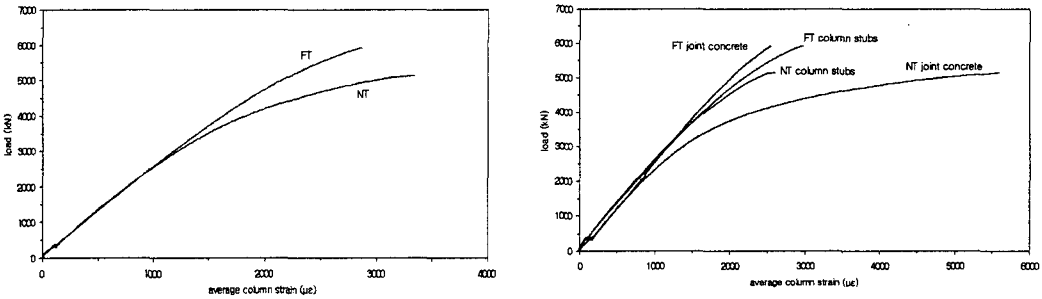
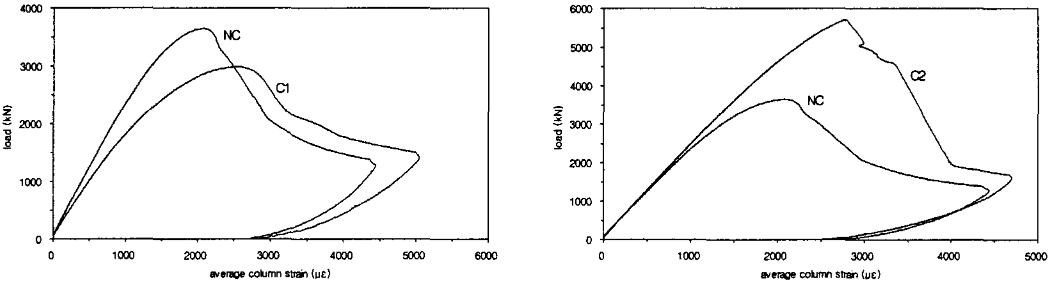


Fig. 3 Comparison of Specimen NT and FT

4.2 Consideration for Several Parameters

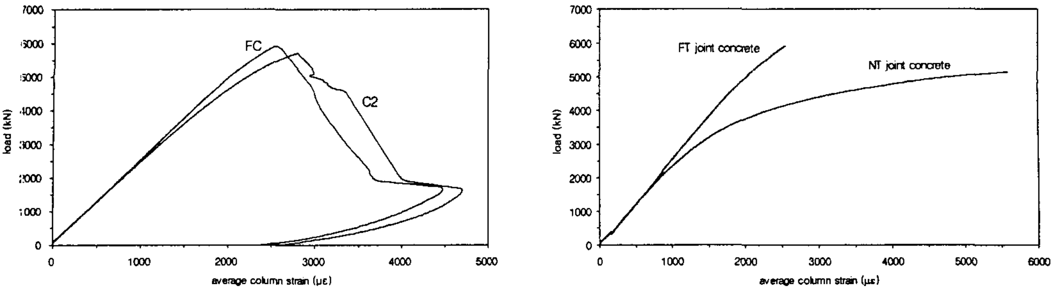
Figure 4 shows the axial load responses of column specimens for several parameters. The isolated column specimen, with a joint of normal strength concrete representing the slab, showed higher strength than the normal strength concrete control column specimen due to the restraint by shear stresses at the interfaces between the ultra-high-strength column concrete and the lower strength joint concrete (Fig. 4(a)). The weaker joint of slab concrete reduced the strength of the isolated column specimen compared to the control column constructed entirely with ultra-high-strength concrete (Fig. 4(b)). But the isolated column showed slightly more ductile behavior in the post-peak performance. Figure 4(c) compares Specimen C2 and FC. Though Specimen FC constructed with 8% lower strength concrete than Specimen C2, Specimen FC exhibits a 4% higher strength than Specimen C2 due to the addition of fibers through the slab thickness. Figure 4(d) illustrate the influence of ultra-high-strength-fiber-reinforced concrete puddling on the behaviors of the slab-column specimens at the joint. It is evident that the presence of puddling of ultra-high-strength-fiber-reinforced concrete increased both the strength and the initial loading stiffness. Figure 4(e) and (f) show the effect of the confinement provided by the surrounding slab for the maximum capacity. Specimen NT with the additional confinement provided by the slab surrounding the weak slab layer had an approximately 45% improved effective strength of the column. However, Specimen FT with puddling of ultra-high-strength-fiber-reinforced concrete had no slab confinement effect.



(a) Interfaces between the column and joint

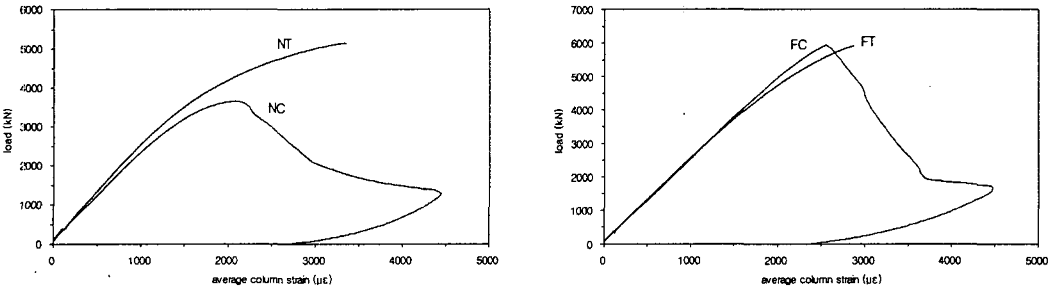
(b) Weaker joint concrete

Fig. 4 Comparison of column specimen responses for several parameters



(c) Fibers in joint concrete

(d) Effect of the puddling



(e) Slab confinement of Specimen NT

(f) Slab confinement of Specimen FT

Fig. 4 Comparison of column specimen responses for several parameters (Continued)

5. Conclusion

1) Providing puddled ultra-high-strength-fiber-reinforced concrete in the slab around the column for the distance of 2d (that is, 240 mm for Specimen FT) from the column face results in a significant improvement in performance. This includes an increase in the axial compressive strength, greater initial loading stiffness, a uniform distribution of strains in the column, smaller cracks in the slab at all levels of loading, and smaller transverse strains at the slab-column joint. The ultra-high-strength-fiber-reinforced concrete puddling near the column of the slab-column specimen resulted in an increase of 16% in the effective concrete strength of the column.

2) The addition of steel fibers to the specimens resulted in an increase of 4% in the effective concrete strength of the column.

3) The confining effects of the slab around the column increased the axial compressive strength and ductility for the specimen having the weak joint concrete. The additional confinement provided by the slab surrounding the weak slab layer increased the effective strength of the column by approximately 45%. But it is note that the specimen with puddling of ultra-high-strength-fiber-reinforced concrete had no slab confinement effect.

Acknowledgements

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