PRE-COMPRESSED CONCRETE-FILLED STEEL TUBE FOR HIGH EARTHQUAKE RESISTING PERFORMANCE OF STEEL COLUMNS

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Abstract

Strength of the circular-shaped concrete-filled steel tubes (CFT) is enhanced significantly due to the confinement provided by the surrounding steel plates. The effectiveness of the confinement depends on several factors such as column slenderness, diameter to thickness ratio, strengths of steel and concrete, the loading method and boundary conditions, and the interface condition between steel and internal concrete. A new technique is introduced in this study to increase the effectiveness of the confinement in order to improve the strength and the ductility of CFT columns. The CFT column used in this study is different from the conventional CFT column in that the concrete is compressed prior to hardening using two circular steel plates placed at both ends of the column.

Keywords: *concrete-filled steel tubes, confinement, strength, ductility*

1.0 Introduction

A great effort is made in seismic design of highway bridge piers made out of steel plates to control the formation of local buckling deformation in plates in order to achieve high ultimate strength and ductility capacity. Concrete infilling, use of stiffened sections, double-skin tubes, tapered plates, low yield strength steel plates, introducing shear walls are few techniques that have been proposed so far for this purpose [1-6]. Among these, concrete-filled steel columns have a widespread application in building and civil engineering structures in areas where severe earthquakes are expected to occur because of the enhanced axial strength and ductility of such members due to the confinement provided by steel plates. The effectiveness of confinement varies with the column slenderness, diameter to thickness ratio, strength of steel and filled-in concrete, the loading method, boundary conditions, and the interface condition between steel and internal concrete [7-10]. An attempt is made in this study to explore the possibility of increasing confinement by pre-compressing filled-in concrete before it get hardened. In addition, the new CFT member is designed so that axial load is applied only to concrete segment. The pre-compressing is to be done using two circular steel plates placed at each end of the tube. The new pre-compressed concrete-filled circular steel tube (PC-CFT) is intended to be placed inside a hollow box or circular steel piers with a special loading device from which axial load from superstructure transfers to the PC-CFT member while lateral loads exerting on piers due to earthquakes will be taken by the main pier. This will greatly enhance the ultimate strength and the ductility of bridge piers when subject to earthquake loads.

2.0 Test of Concrete-Filled steel Tubes (CFT)

Concrete infilling has become increasingly popular in building and bridge pier construction over the past few decades. A large number of experimental and analytical studies has been carried out to investigate the behaviour of concrete-filled steel tubes. The attention has been paid in particular on examining the strength enhancement, ductility improvement, and energy absorption capacity because these are the key factors considered in designing of earthquake resistant structures [11, 12]. It has been well known that the CFTs have excellent earthquake resisting characteristics. These improvements are mainly due to the confinement of concrete from surrounding steel plates. The mechanical behaviour of CFT columns when load applied to: (a) the concrete section; (b) the steel section; and (c) the entire section has been investigated extensively in a past study, and it has been

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revealed that the axial deformation of columns with load applied only to the concrete section was higher than the other two cases [8].

In this study, series of axial load tests of short CFT columns were carried out prior to the testing of PC-CFT columns in order to check the effect of interface condition and the time of concrete compressing (t_i). The axial load was applied only to the concrete through a loading cap. The concrete is slightly compressed at the beginning so that the confinement could be much effective and a significant strength gain could be expected. For this, nine specimens in three sets (i.e., Set-1, Set-2 and Set-3) were prepared. The details of the specimens are presented in Table 1 where t_0 is the thickness of tube, D is the outer diameter, and h is the specimen height. The steel was of grade SM490 having nominal yield strength of about 325 MPa. Since the actual yield strength usually differs from the nominal value, tensile coupon tests were carried out to check the actual yield strength. These tests showed that the yield strength is around 414 MPa, Young's modulus is 208 GPa, and Poisson's ratio is around 0.29. The loading arrangement is shown in Fig. 1.

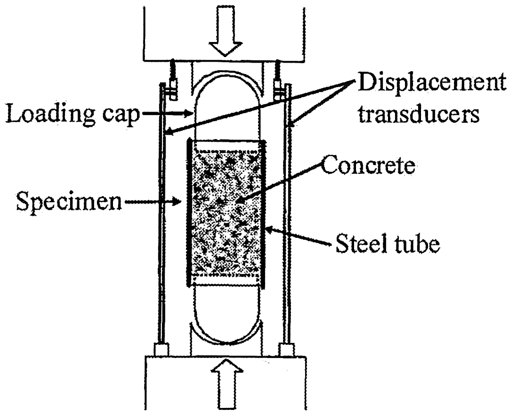

Fig. 1 *Loading arrangement*

Table 1 *Details of specimens (concrete-filled steel tube and concrete cylinders)*

Parameter	Set-1			Set-2			Set-3		
	A1	A2	A3	B1	B2	B3	C1	C2	C3
t_0, mm	6.8	6.9	7.2	7.1	7.1	7.2	7.0[a]	6.9[a]	6.9[a]
D, mm	165.9	165.9	165.9	165.9	166.0	165.6	165.8	166.0	166.0
h, mm	450.0	450.0	450.0	450.0	450.0	450.0	450.0	450.0	450.0
Interface	Paraffin	Paint	Grease	No	No	No	-	-	-
t_i, min	90	90	90	90	180	270	90	180	270

[a] Tube removed after concrete compressing

Axial shortening was measured from displacement transducers. The inner surface of steel tubes in Set-1 was applied with paraffin, grease, and paint and concrete was compressed 90 minutes after pouring. In Set-2, no interface material was used and concrete was compressed after 90, 180, and 270 minutes respectively after pouring. In Set-3, specimens had the same dimensions as those of Set-1 and Set-2 but outer steel tube was removed before concrete get fully hardened. The concrete was compressed after 90, 180, and 270 minutes respectively after pouring similar to those of Set-2.

The results of the specimens in these three sets are shown in Fig. 2. As seen in Fig. 2(a), the paint and grease have the same effect on the strength, but paraffin causes comparatively low stiffness and slightly high strength of concrete. There is no any apparent effect from the time of concrete compressing when tested with the outer tube as seen in Fig. 2(b). The strength of concrete in specimens Set-2 and Set-3 was nearly twice that of Set-3.

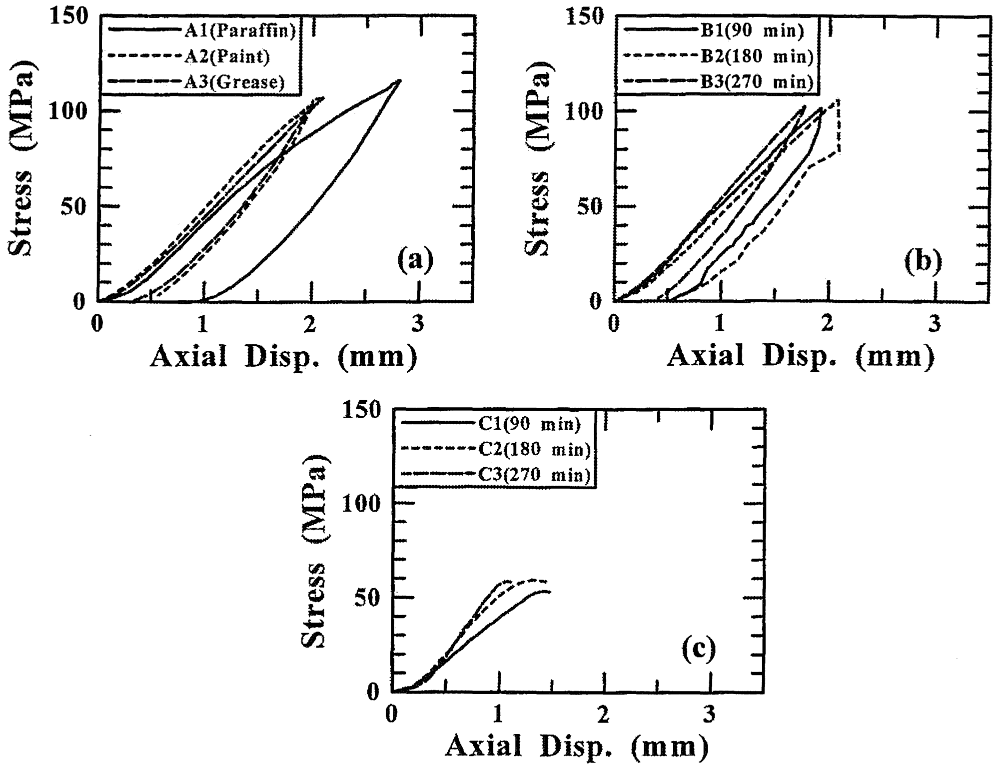

Fig.2 Axial stress versus axial displacement of specimens

3.0 Test of Pre-Compressed Concrete-Filled steel Tubes (PC-CFT)

The proposed PC-CFT column is shown in Fig. 3. The concrete inside the PC-CFT is compressed before getting it hardened, and the standard cylinder tests were carried out simulating the same condition of filled-in concrete. This means that the concrete cylinders were prepared by compressing the concrete after 90 minutes as same as the concrete in PC-CFT. Six cylinders were prepared and tested after 14 days. The average compressive strength was found to be 49.1 MPa. The axial load from the super-structure is directly applied to the concrete core through a loading cap. The inside concrete is compressed from 60 to 90 minutes after pouring, using two steel plates placed at both ends of the tube and a steel rod connecting these two plates. After compressing, the plates are bolted to the steel rod. Thus, the steel rod is in tension and concrete is in compression. The interface between steel and concrete is made as much frictionless as possible by applying paraffin, grease or paint. The air voids inside the concrete

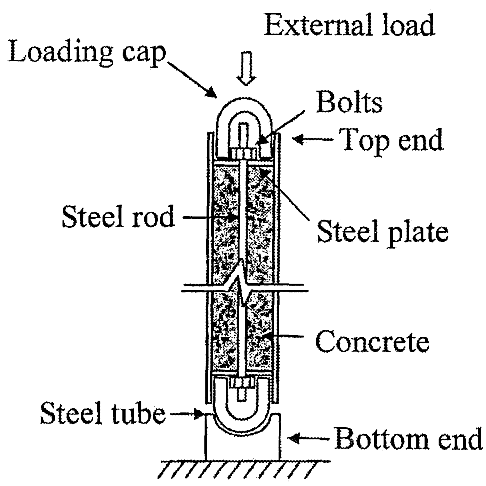

Fig. 3 PC-CFT specimen

wiped out during compressing the concrete. The concrete should be compressed thoroughly so that the fully hardened concrete should have effective confinement from the surrounding steel plates. Some stress will be released when concrete get hardened due to shrinkage.

Nine specimens as described above were prepared in this study to estimate the axial strength of the PC-CFT columns. They were divided into three sets each having three specimens. Each set was tested 14, 21, and 28 days respectively after casting. The average strength of each set was found to be 78.4, 82.6, and 88.5 MPa, respectively. The results implied that the PC-CFT columns have much higher strength than the normal CFT columns.

4.0 Use of proposed PC-CFT

The proposed PC-CFT is intended to be used in a new structural system where PC-CFT is placed inside a hollow box- or circular-shaped steel column of highway bridge pier. The structural system is designed so that only axial load from superstructure transfers to the PC-CFT while main pier is reserved to take lateral loads exerted due to ground acceleration. This could be done using a special loading device.

5.0 Conclusions

Conventional concrete-filled steel tubes are well known for their high axial strength and ductility performance. Concrete confinement has been identified as a key factor that affects the performance of CFT members. Pre-compressing of in-filled concrete was found to be very effective in further improving the confinement. Based on the test results, it has been found that the condition of steel-concrete interface has moderate effect on the axial stiffness of the CFT members. And, the axial strength of pre-compressed CFT was found to have very high strength level such as 88.8 MPa.

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