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Cyclic performance of repaired concrete-filled steel tubular columns after exposure to fire

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Abstract

This paper provides new test data of cyclic behavior of repaired concrete-filled steel tubular (CFST) columns after exposure to fire, the fire-damaged CFST columns being strengthened by wrapping the original columns by concrete and a thin-walled steel tube. The test parameters included the cross-section type (circular, square and rectangular), and the axial load level (0, 0.3, 0.6). It was found that all the test specimens behaved in a ductile manner and testing proceeded in a smooth and controlled way. Based on the experiment measurements, the ultimate lateral strength, flexural stiffness, dissipated energy and ductility of the columns are analyzed and compared. The test results indicate that the ultimate lateral strength and flexural stiffness of concrete-filled hollow structural columns decrease after exposure to fire, however, the ductility of the columns was not adversely affected due to the fire exposure. The test results also indicate that the strength and stiffness of the fire-damaged columns can be restored over the original level of the specimens.

Keywords: Composite columns; Concrete; Fire; Post-fire; Repairing; Residual strength; Hollow sections; Seismic design; Cyclic load; Ductility

1. Introduction

As the use of concrete-filled steel tubular (CFST) columns becomes more widespread, the risk of fire damage to CFST columns increase, it is necessary to develop methods to repair fire-damaged CFST structures.

In recent years, the authors have been engaged in studies to determine the residual strength and seismic behavior of CFST columns after exposure to fire. Both theoretical and experimental studies have been carried out. Han et al. [1] reported results of monotonically loaded stub columns subjected to high constant temperatures, Han et al. [2], Han and Huo [3], Han et al. [4], Han and Lin [5] studied monotonically and cyclically loaded beam-columns with different types of cross-section after exposure to the ISO-834 [6] standard fire; Han et al [7] investigated the behavior of steel beam to CFST column connections after exposure to fire.

This paper provides new test data pertaining to repaired CFST columns that have been exposed to and damaged by the standard ISO-834 fire. Twenty-five specimens, including 9 columns with circular cross-sections, 9 columns with square cross-sections and 7 columns with rectangular cross-sections, respectively, were tested under constant axial load and cyclically increasing flexural load. The fire-damaged CFST columns were strengthened by new concrete and steel tube wrapping as shown in Fig. 1. The test parameters included cross-section type (circular, square and rectangular), and axial load level ($n = 0$, 0.3, 0.6). The axial load level (n) is defined as

$$n = \frac{N_o}{N_u(t)}, \tag{1}$$

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Nomenclature

B_i	width of rectangular inner steel tube, in mm
B_o	width of rectangular outer steel tube, in mm
CFST	concrete filled steel tubes
D_i	diameter of the inner tube or depth of rectangular inner steel tube, in mm
D_o	diameter of the outer tube or depth of rectangular outer steel tube, in mm
E_{ci}	inner concrete modulus of elasticity
E_{co}	outer concrete (sandwiched concrete) modulus of elasticity
E_{si}	inner steel modulus of elasticity
E_{so}	outer steel modulus of elasticity
f_{su}	ultimate strength of steel
f_{sy}	yielding strength of steel
f_{cu}	concrete cube strength
I_{si}	moment of inertia of the inner steel tube
I_{so}	moment of inertia of the outer steel tube
I_{ci}	moment of inertia of the inner concrete section
I_{co}	moment of inertia of the outer concrete (sandwiched concrete) section
K_i	initial section flexural stiffness of the composite column
K_s	serviceability-level section flexural stiffness of the composite column
K_e	flexural stiffness at ambient temperature
K_e (t)	flexural stiffness corresponding to the fire duration time (t)
L	effective buckling length of column in the plane of bending
M	moment
M_u	moment capacity
n	axial load level
N_o	axially compressive load
N_u	ultimate member capacity of the composite columns at ambient condition
N_u (t)	residual member capacity the composite columns corresponding to the fire duration time (t)
P_u	ultimate lateral strength of the composite columns at ambient condition
P	lateral load
P_{ue}	experimental lateral strength
R_k	ratio of flexural stiffness
RFSI	residual flexural stiffness index
t	fire duration time, in minute
t_{si}	wall thickness of inner steel tube, in mm
t_{so}	wall thickness of outer steel tube, in mm
μs	poisson ratio of steel
ϕ	curvature
Δ	lateral displacement
ε	strain

in which N_o is the axial load applied on the specimen; N_u (t) is the axial compressive capacity of the composite column at ambient temperature but after exposure to ISO-834 Standard fire [6] for a duration t. The value of N_u (t) was determined by using the mechanics model described in [8].

Based on the experimental results, the ultimate lateral strength, flexural stiffness, dissipated energy and ductility of the columns are analyzed. Comparisons are also made between the measured flexural stiffness with various design code calculations to assess the feasibility of using an existing design code, i.e. AIJ [9], BS5400 [10], EC4 [11] or AISC-LRFD [12] in the proposed flexural stiffness calculation formulas.

2. Experimental program

2.1. Specimen preparation

Twenty-five specimens, including 9 columns with circular sections, 9 columns with square cross-sections and 7 columns with rectangular sections were tested. The rectangular columns were tested with bending about the strong axis.

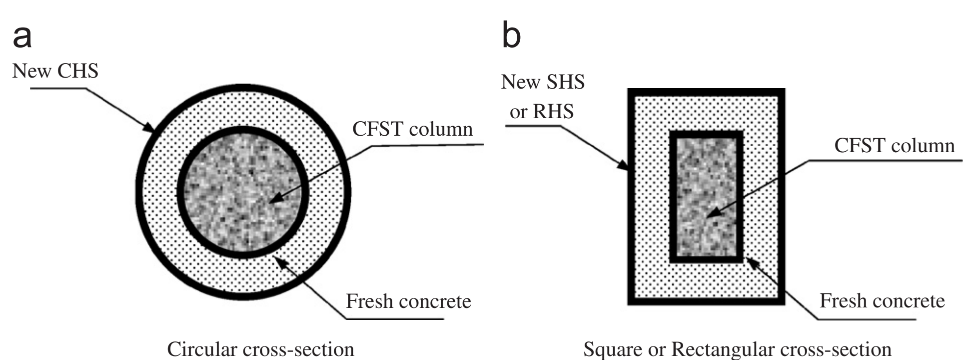

Fig. 1. Repaired CFST column cross-section after exposure to fire.