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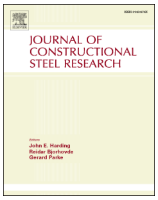

Behaviour of continuous concrete filled steel tubular columns loaded eccentrically in fire

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ABSTRACT

Concrete filled steel tubular (CFST) columns used in multi-storey buildings are generally designed as continuous members all over the world. This research has focused on the behaviour of eccentrically loaded continuous columns in fire, through the standard fire furnace testing of twelve CFST square columns of 3.2 m length. The tests covered three different types of infill; plain concrete, bar reinforced concrete and steel fibre reinforced concrete, with the columns subjected to compressive load levels ranging from 0.33 to 0.41. The result shows that, the significant initial expansion of the steel tube relative to the concrete reported by many researchers did not eventuate, due to the restraining effect of the unheated column between the furnace and the end supports. This represents a typical continuous column in a multi-storey building where the column above and below the floor on fire remains cooler. The use of conventional reinforcement increased the FRR of the column compared to using steel fibre or plain concrete infills.

Using the experimentally measured fire resistance rating, the axial capacity in fire was calculated in accordance with DR AS/NZS 2327 and EN 1994-1-2 and it was shown that the code is too conservative for all continuous column loaded eccentrically.

1. Introduction

The use of concrete filled steel tube (CFST) column for construction increases the axial capacity of a column and reduces its perimeter when compared to a bare steel column. The hollow steel tube acts as formwork for concrete pouring which helps reduce the time and labour required to place and remove conventional concrete formworks. This method of construction also increases the fire resistance ratings (FRR) of a column. The heat sink effect of the concrete slows down the temperature rising of the steel tube and also the steel tube acts as a radiation shield to the concrete. A large number of laboratory tests have been carried out on concrete filled steel tube columns loaded eccentrically in fire by Grimault [1]; Romero et al. [2,3]; Moniler et al. [4] and Chung et al. [5] covering a wide range of parameters. Finite element analysis has also been reported [6] which cover CFST columns filled with normal strength and high strength concrete loaded axially with high utilization factor in fire. The finite element analysis studies, however, have not covered continuous columns in fire.

The Eurocode 4 EN 1994-1-2 [7] design guide made provisions for three different methods to calculate the axial capacity of a concrete filled steel tube column; Tabulated data method, Simple calculation method and an Advanced calculation method. The tabulated method provided in the design guide does not give a method to calculate the axial capacity of an eccentrically loaded column however; this was covered in the simple calculation method provided in annex H of the design guide. There are limitations given for applying the simple calculation method given EN 1994-1-2 [7]. This method can only be used for a column having buckling length less than 4.5 m, relative slenderness λ less than 0.5 and the ratio of eccentricity to diameter of the steel tube (e/D) less than 0.5. Recently, Mago & Hicks [6] computed an advanced numerical analysis to cover columns outside the limits given in annex H.5 of Eurocode 4 part 2. It was observed that the FRR reduced significantly as the columns bending moment and utilization was increased. Therefore, it was suggested that a review should be done for the tabulated method to provide a guide for calculating the capacity of a column when subjected to combined bending and compression.

The laboratory experiments presented in this paper focuses on the axial capacity of a twelve square CFST columns having the ratio of eccentricity to breadth of the steel tube e/B ratio ranging from 0.11 to 0.25 and normalized slenderness from 0.49 to 0.59. The tests covered

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Nomenclature

$A_{s,T}$	cross-sectional area of steel profile at the temperature °c
$A_{c,T}$	cross-sectional area of concrete at the temperature °c
$A_{r,T}$	cross-sectional area of reinforcement at the temperature °c
Am/V	section factor m^{-1}
$E_{s,T}$	modulus of elasticity of steel
$E_{c,T}$	tangent modulus of concrete at the temperature °c
$E_{fi,Exp}$	design effect of actions in fire situation for laboratory experiment
$E_{fi,Rd}$	design effect of actions in fire situation for design code
$E_{c,sec},T$	secant modulus of concrete at the temperature °c
$E_{r,T}$	modulus of elasticity of reinforcement at the temperature °c
$(EI)_{fi}$	effective flexural stiffness in fire situation
F-P	Fixed – Pinned
f_c	compressive cylinder strength of concrete at room temperature
f_r	yield strength of reinforcement at room temperature
f_s	yield strength of structural steel at room temperature
$I_{c,T}$	second moment of area of concrete at the temperature °c
$I_{s,T}$	second moment of area of steel profile at the temperature °c
$I_{r,T}$	second moment of area of reinforcement at the temperature °c
k	effective length factor
$L_{e,T}$	buckling length of column in fire situation
$N_{b,fi,Rd,t}$	design axial buckling load of column in fire situation
R	structural fire resistance
t	steel tube thickness
α_c	member slenderness reduction factor
T	Temperature
T_c	temperature of concrete
T_s	temperature of steel
T_r	temperature of reinforcement
λ_r	relative slenderness of column at room temperature
$\lambda_{,T}$	relative slenderness of column in fire situation
η_{fi}	design load level in fire condition
δ	steel contribution ratio

three commonly used types of infill [2–4,8] namely; plain concrete, bar reinforced concrete and steel fibre reinforced having measured compressive strength ranging from 80 MPa to 95 MPa. Compressive load levels ranging between 0.33 and 0.41 were applied, with the loads determined in accordance with DR AS/NZS 2327 [9]. This paper presents a more realistic boundary condition of a partially continuous column, used in multi-storey building where the intermediate floor is on fire. The bottom floor has a fixed base and the top floor is pinned (see Fig. 2).

2. Experimental investigation

2.1. General

The fire tests were conducted in a furnace having dimensions of 2 m height × 1.5 m length × 1.5 m width, in accordance with EN 1364 – 1: 2012 [10]. The furnace temperature was controlled to match the ISO 834 [11] time-temperature curve. Fig. 1 shows the typical average furnace temperature to the ISO 834 fire curve for a typical test. Axial loads were applied for approximately 30 min before each fire test and were maintained throughout.

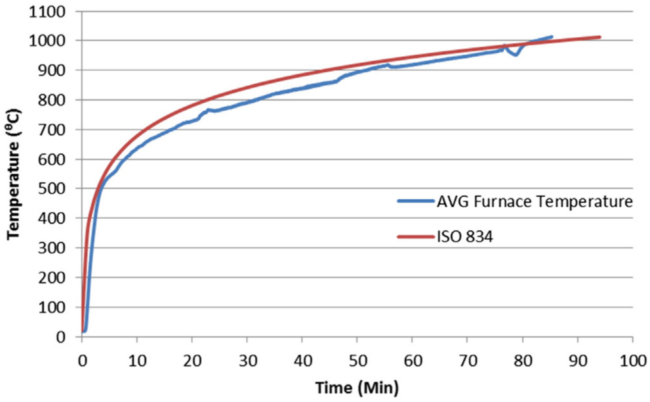

Fig. 1. Measured furnace temperature (ISO 834 shown for comparison).

2.2. Test specimens

Table 1 gives a summary of test specimens, load level and material properties. Two different cross-sectional dimensions of cold formed

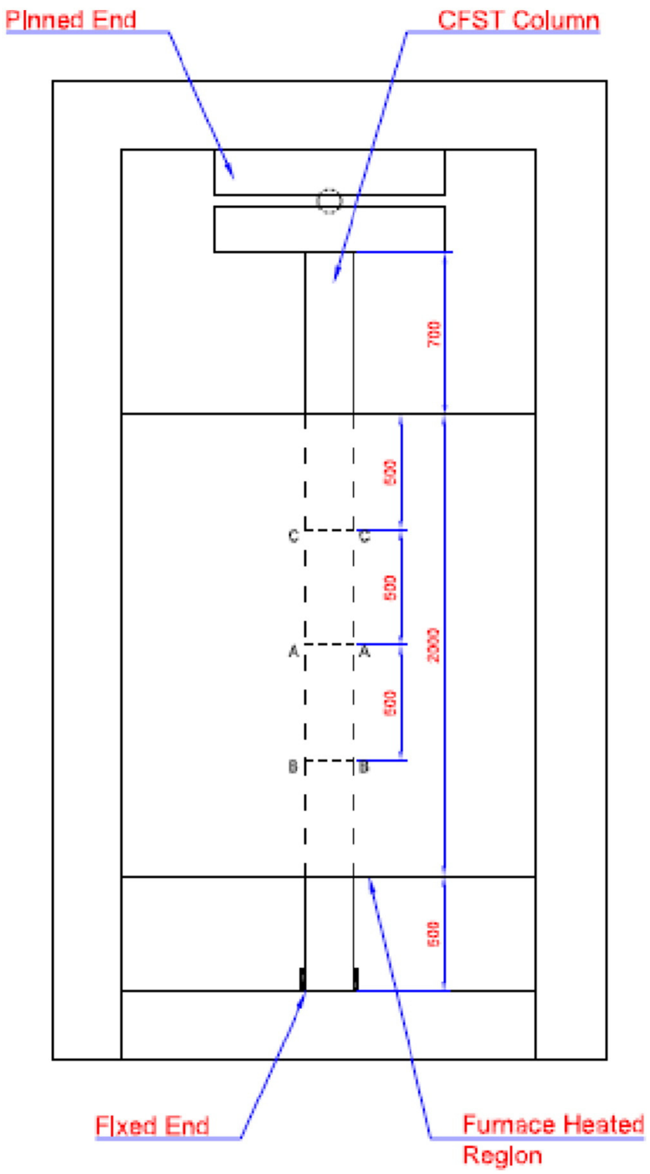

Fig. 2. Fire furnace schematic setup for all columns.