CERIS Civil Engineering Research and Innovation for Sustainability

Fire resistance of composite columns made of concrete filled double-tube and double-skin square sections

PhD student
Rúben Filipe Rosa Lopes

PhD program
Fire Safety Engineering (FCT, University of Coimbra)

Supervisor
João Paulo Rodrigues (FCT, University of Coimbra; CERIS)

Co-supervisor
António J. P. Correia (ISEC, Coimbra School of Engineering)

Period
2017-2024

Funding
PCIF/MOS/0129/2018 – InduForestFire – Interdisciplinary Methodologies for Protection of Industrial Sites to Forest Fires

Summary

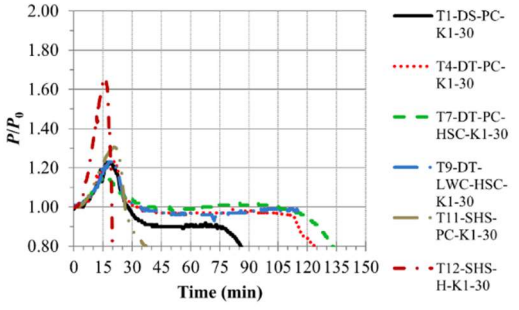
The use of concrete-filled steel hollow section composite columns has grown over the years due to several advantages. These columns have a large load-bearing capacity while allowing the use of slender sections. Also, this type of column cross-section does not require formwork in the construction process, increasing execution speed when compared to reinforced concrete ones. In this cross-section type, the constituent materials have an optimized work: the steel hollow section has excellent structural behaviour and does concrete core confinement, increasing its strength and columns' loadbearing capacity; the concrete core filling prevents the steel hollow section from local buckling, that is a concerning problem for this type of steel section. Furthermore, due to concrete high heat capacitance, the core increases the column's fire resistance to some extent, exempting this type of column cross-section from using external steel fire protection to achieve a 30-minute fire resistance rating. A double-tube composite column consists of a cross-section with two concentric tubular steel sections. The inner section has a width/diameter smaller than the outer section, and the entire inner hollow space is filled with concrete. A double-skin composite column also has two concentric steel sections. However, only the space between the two sections is filled with concrete (concrete outer ring), leaving the interior of the smaller width/diameter steel section (concrete core) empty.

This experimental and numerical work intends to evaluate the behaviour of square double-skin and double-tube composite columns subjected to ISO 834 standard fire curve and thermal axial elongation and rotational restraint. In the experimental part of this work, restrained fire behaviour evaluation of composite double-tube and double-skin columns was carried out. For this evaluation, several parameters were considered: axial loading level (30 and 50% of the column's load-bearing capacity at ambient temperature); concrete strength classes used in the column's cores and rings (C30/37, LC30/33, C55/67); axial and rotational restraining levels applied by the surrounding structure K1 (K_a = 30 kN/mm and K_r = 94 615 kN.m/rad) and K2 (K_a = 110 kN / mm and K_r = 131 340 kN.m/rad). The obtained results were compared with values from the steel-concrete composite sections at high temperatures design expressions from part 1-2 of Eurocode 4 and other authors. The adaptation of existing design codes for these cross-sections usually presented conservative fire resistance results due to not considering the concrete confinement strength increase. In the numerical part of the work, a sequentially-coupled analysis of heat transfer and thermomechanical models was performed using Abaqus software. The numerical results were validated with values from the experimental part. To create a high temperature simplified design method for these columns' cross-sections, a parametric study was conducted where the influence of three variables in the columns' fire resistance were studied: column's relative slenderness, load level and axial and rotational restraining level. Columns with relative slenderness higher than 0.5 presented lower fire resistance than short-stub or columns with relative slenderness lower than 0.5.

Keywords

Composite steel and concrete column, square cross-section, double-tube, double-skin, fire resistance, experimental analysis, numerical analysis.

(a) Experimental layout used in fire testing



(b) Restraining force ratio developed during fire testing for 30 LL – K1 combination

Experimental layout and results.