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Fire resistance of concrete filled circular hollow columns with restrained thermal elongation

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ABSTRACT

The filling of circular hollow sections (CHS) with concrete is a good solution for strengthening columns since such procedure increase their load bearing capacity at room and high temperatures. However, in the event of a fire, restraining to thermal elongation may change their mechanical behavior. This paper presents the results of a large series of fire resistance tests on CHS columns with restrained thermal elongation. Parameters such as the slenderness of the column, its load level, the stiffness of the surrounding structure, the percentage of steel reinforcement and the degree of concrete filling inside the column, were tested. The results obtained show that the critical time of the columns was less than 46 min. The use of a concrete ring around the internal surface of the column's wall is of no advantage in terms of its behavior under fire conditions because this concrete ring suffers extensive spalling and cracking due to overheating of the steel tube. The main failure mode of the columns was global buckling. However in several cases local buckling also occurred.

Notation

EA_{eff}	Effective axial stiffness
EI_{eff}	Effective flexural stiffness
$f_{cu,j}$	Compressive cube strength of concrete at room temperature at "j" days
f_{sy}	Yield strength of construction steel at room temperature
f_{su}	Ultimate strength of construction steel at room temperature
f_y	Yield strength of reinforcing steel at room temperature
f_u	Ultimate strength of reinforcing steel at room temperature
K_{as}	Axial stiffness of the surrounding structure
K_{rsi}	Rotational stiffness of the surrounding in "i" direction
K_{ac}	Column's axial stiffness
K_{rc}	Column's rotational stiffness
L_e	Buckling length of the column
$N_{b,rd}$	Design value of the buckling load at room temperature
$N_{pl,Rk}$	Characteristic value of the plastic load to compression at room temperature
N_{cr}	Elastic critical load for the relevant buckling mode at room temperature
α	Degree of axial restraint
B_i	Degree of rotational restraint in "i" direction
$\bar{\lambda}$	Relative slenderness
η	Load level

1. Introduction

The use of circular hollow steel columns (CHS) filled with concrete in building construction is increasing due to several advantages, such as, for example, the higher load-bearing capacity, the possibility of using columns with smaller cross-sections, shorter erecting times due to avoiding formworks and good fire performance. Therefore, CHS columns seem to be an adequate construction solution in terms of load-bearing capacity at room and high temperatures.

The behavior of CHS columns when subjected to fire has been studied by several authors for years [1–16], but most of these studies do not consider the restraining to their thermal elongation. The response of these columns when inserted in a building structure is different than when isolated. Restraints on the thermal elongation of the column, provoked by the building surrounding structure, plays a key role on column's stability, since it induces different forms of interaction between the heated column and the cold adjacent structure. The increase in the stiffness of the surrounding structure to the column subjected to fire increases not only the axial but also the rotational restraining, while the former reduces the critical time (also the critical temperature) of the columns, the latter increase them [17–20].

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