Performance of axially restrained concrete encased steel composite columns at elevated temperatures

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\textbf{A B S T R A C T}

The structural performance of axially restrained concrete encased steel composite columns at elevated temperatures is investigated in this study. An efficient nonlinear 3-D finite element model was presented for the analysis of the pin-ended axially loaded columns. The restraint ratios varied from 20\% to 100\% of the axial stiffness of the composite columns at ambient temperature. The finite element model was verified against published test results on axially restrained concrete encased steel composite columns at elevated temperatures. The columns investigated had different cross-sectional dimensions, different coarse aggregates and different load ratios during fire. The nonlinear material properties of steel, concrete, longitudinal and transverse reinforcement bars as well as the effect of concrete confinement at ambient and elevated temperatures were considered in the finite element model. The interface between the steel section and concrete, the longitudinal and transverse reinforcement bars, and the reinforcement bars and concrete were also considered allowing the bond behaviour to be modelled and the different components to retain their profile during the deformation of the column. The initial overall geometric imperfection was carefully included in the model. The time–temperature relationships, deformed shapes at failure, time–axial displacement relationships, failure modes and fire resistances of the columns were evaluated by the finite element model and compared well against test results. Furthermore, the variables that influence the fire resistance and behaviour of the axially restrained composite columns comprising different axial restraint ratios, different load ratios during fire, different coarse aggregates and different slenderness ratios were investigated in a parametric study. It is shown that axially restrained composite columns behave differently in fire compared to the unrestrained columns since the typical “runaway” failure was not predicted from the finite element analysis. The fire resistances of the composite columns obtained from the finite element analysis were compared with the design values obtained from the Eurocode 4 for composite columns at elevated temperatures. It is shown that the EC4 is generally conservative for all the axially restrained concrete encased steel composite columns, except for some columns with higher load and slenderness ratios.

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1. Introduction

Concrete encased steel composite columns are gaining popularity in tall building construction due to their high strength, full usage of materials, high stiffness and ductility, toughness against seismic loads, significant savings in construction time and mainly good in fire resistance. Experimental investigations were conducted at ambient temperature on unrestrained concrete encased steel composite columns as detailed in [1–3]. Furthermore, analytical studies at ambient temperature on unrestrained concrete encased steel composite columns have been performed in [4–10].

In addition, fire tests were found in the literature on unrestrained concrete-encased steel composite columns as detailed in [11–13].

Looking at a whole building, the behaviour of a heated column under fire conditions is affected by the adjacent cool structural members. The cool structural elements would act as a restraint to thermal expansion. The heated column interacts with the adjacent structural members depending on the restraint’s stiffness and direction. Hence, when a whole building is exposed to fire the common is the restrained condition. However, studying restrained structural elements under fire conditions requires special care to apply restraining actions and to maintain these actions during fire tests. Hence, only very limited number of tests were found in the literature investigating the behaviour of axially restrained concrete encased steel composite columns at elevated temperatures, leading to the present investigation. The fire tests on axially restrained concrete encased I-section steel composite...