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Predictability of buckling temperature of axially loaded steel columns in fire

Chao Zhang [a], Guo-Qiang Li [b,*], Yong-Chang Wang [c]

[a] College of Civil Engineering, Tongji University, 1239 Siping Road, Shanghai 200092, China
[b] State Key Laboratory for Disaster Reduction in Civil Engineering, Tongji University, 1239 Siping Road, Shanghai 200092, China
[c] School of Mechanical, Aerospace and Civil Engineering, The University of Manchester, PO Box 88, Manchester M60 1QD, UK

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ABSTRACT

In current Eurocode, the buckling temperature of steel columns can be calculated by either using an analytical approach or using a simple closed-form equation. This paper investigates the accuracy and limitations of those two calculation approaches. Test data on steel columns at elevated temperature reported in literature are used for comparison. The two approaches are found to give acceptable prediction for tests with moderate utilization factor, and unacceptable prediction for tests with either high utilization factor ($\mu_0 > 0.83$) or low utilization factor ($\mu_0 < 0.16$). The professional factor for the simple equation has a mean of 0.949 and a COV of 0.016, and can be best described by an extreme value distribution. The professional factor for the analytical approach has a mean of 1.018 and a COV of 0.013, and can be well described by either a normal, gamma or lognormal distribution.

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1. Introduction

In prescriptive codes, to ensure structural fire safety, the fire resistance of a steel column should be not less than the rating specified in building regulations. The fire resistance of a building component is defined as the time when the component exceeds any of the endpoint failure criteria in standard fire tests. In standard fire tests such as BS476-20 [1], the failure of steel column occurs when the test column fails to support the test load, or loses stability. However, standard fire tests are time-consuming and expensive.

As an alternative to test approaches, calculation approaches have been developed to determine the fire resistance of building components [2,3]. In determining the fire resistance of steel columns, the failure temperature of a column, and the maximum temperature of the column reached in potential fires are two key parameters, the calculation of which should be based on reliable approaches. In current Eurocode [4], the analytical approach developed by Franssen et al. [5] is adopted to calculate the buckling capacity of axially loaded steel columns. Also, a simple closed-form equation is provided in [4] to calculate the buckling temperature of steel columns.

When using calculation approaches for fire resistance design, the user should be aware of the accuracy and limitations of the approaches being adopted. Also, in probabilistic analysis, the model error or professional factor of the deterministic approach should be determined. This paper intends to determine the accuracy and limitations of different calculation approaches adopted in Eurocode for predicting buckling temperature of axially loaded steel columns in fire by comparing with test data reported in literature. The probabilistic property of the professional factor of the calculation approaches is also characterized by the test data.

2. Calculation approaches

2.1. Analytical approach

The simple model developed by Franssen et al. [5] is adopted by EC3 [4] for calculating the buckling resistance of axially loaded steel column in fire, which is given by

$$N_{b,T} = \chi_T A f_{yT} \tag{1}$$

where,

$$\chi_T = \frac{1}{\varphi_T + \sqrt{\varphi_T^2 - \overline{\lambda}_T^2}} \tag{2}$$

$$\varphi_T = \frac{1}{2}\left[1 + \alpha\overline{\lambda}_T + \overline{\lambda}_T^2\right] \tag{3}$$

$$\alpha = 0.65\sqrt{\frac{235}{f_{y20}}} \tag{4}$$

$$\overline{\lambda}_T = \overline{\lambda}_{20}\sqrt{\frac{k_{yT}}{k_{ET}}} = \sqrt{\frac{Af_{yT}}{P_{ET}}} \tag{5}$$

* Corresponding author.
E-mail address: 08_chao_zhang@tongji.edu.cn (G.-Q. Li).

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