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Imperfection sensitivity analysis of lipped channel columns at high temperatures

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Abstract

An imperfection sensitivity analysis is carried out on cold formed lipped channel columns integrated in wall structures. The equations given in Eurocode 3: Part 1.3 and finite element analyses are used to evaluate the flexural buckling strength and ultimate strength of the sections. The analyses are performed at both room and fire temperatures by introducing corresponding material data values obtained from high temperature transient tensile tests into the models. The purpose of the study is to evaluate the possibility of using normal temperature design formulae directly at high temperatures and to evaluate the influence of the choice of initial geometric imperfections on the modelled behaviour of the columns. The analytical estimations are compared to the results of the finite element analyses, which in turn are validated using available test results. It is shown that the magnitude of the modelled types of local imperfections has an effect on the compression stiffness of the members, whereas the magnitude of global flexural imperfections has more influence on the ultimate strength obtained in the analyses. The influence of the choice of buckling curve at high temperatures is discussed.

Keywords: Cold-formed steel; Imperfection sensitivity; Structural fire design; Finite element modelling

1. Introduction

Cold-formed steel members are generally quite sensitive to geometric imperfections. Although this is commonly acknowledged, no general rules exist for the modelling of imperfections, mainly because of lack of extensive and accurate data. The guidelines given in design codes or product standards usually provide only conserva-

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Nomenclature

A_{act}	Actual measured area of cross-section (mm^2)
A_{gr}	Gross area of cross-section (mm^2)
A_{eff}	Effective area of cross-section (mm^2)
b	Width of flange (mm)
E	Modulus of elasticity (mm^2)
F	Axial force (N)
f_y	Yield strength (mm^2)
h	Height of web (mm)
k	Buckling coefficient
L	Member length (mm)
$N_{b.Rd}$	Ultimate compressive load (N)
$N_{cr.local}$	Local buckling load (kN)
T	Temperature (°C)
t	Wall thickness (mm)
u	Axial displacement (mm)
χ	Reduction factor
γ_{M1}	Partial safety factor
ν	Poisson's ratio
σ_{cr}	Critical buckling load (N/mm^2)

tive upper limits for the magnitude of imperfections to be used in design. An alternative approach to the problem is the probabilistic method for the determination of a suitable maximum imperfection presented by Schafer and Peköz [1].

In the use of advanced analysis methods, such as finite element techniques, imperfection sensitivity is often characterised by a large number of very closely spaced eigenvalues representing more or less similar buckling modes. A choice of imperfection mode combinations has to be made in order to continue the analysis into the post-buckling range, where also material imperfections come into play.

The current paper attempts to shed light on the way different imperfection types and their combinations affect the behaviour of cold-formed steel columns by way of finite element analyses with the purpose of finding suitable imperfection magnitudes to be used in further research. The study is part of a larger research project concentrating on the behaviour of cold-formed steel columns and beams at high temperatures. The analyses are performed at both room and high temperatures, which are introduced into the models directly using corresponding material properties obtained from tests [2]. Another objective is to evaluate the basic assumptions needed for the use of Eurocode 3: Part 1.3 [3] formulae also in fire conditions.

The studied column cross-section is C 100×40×15 with wall thickness t=1 mm and length L=2500 mm. The columns are designed to be integrated into a wall structure so that they are attached to wall panels at each flange. The connection is assumed