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# Estimating the local buckling capacity of structural steel I-section columns at elevated temperatures

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ABSTRACT

This paper presents and analytical study to investigate the local buckling behaviour of structural steel I-section columns at elevated temperatures. An inelastic stability model is developed that accounts for the reduction in stiffness and strength of the steel when subjected to elevated temperatures. Using the model, a comprehensive parametric study is conducted to investigate the effect of each of the parameters of the column. Based on the results of the parametric study, expressions for the local buckling capacity of steel I-section columns are given in which all the parameters are reflected including the interaction between the flange and the web.



## 1. Introduction

Structural steel columns may experience either global or local buckling depending on their dimensions. Local buckling is generally controlled by the width to thickness ratios of the elements of the section and limitations for these ratios are set by different structural steel design codes [1–3] to classify it with regards to local instability. The width to thickness ratio limitations and the buckling capacity equations given in these codes are usually expressed in terms of the modulus of elasticity $E$ and the yield strength $f_y$ of steel. When the structural steel is subjected to elevated temperatures, its strength and stiffness deteriorate significantly and the question is always raised about the validity of using the same code equations do deal with the elevated temperature cases. The lack of enough research to provide a clear answer has recently attracted a number of researchers to investigate the issue of the local buckling behaviour of structural steel columns at elevated temperatures. Hirashima and Uesugi [4] reported the results of an experimental investigation on H-shaped steel sections under pure compression. Based on their test results, an equation for the stress-strain curve was proposed considering the local buckling. Their equation is limited to the local buckling of the flange and ignores the effect of the other elements of the section. Yang et al. [5] conducted an experimental program on H-steel columns subjected to elevated temperatures focusing on local and global buckling. They concluded that sections with width to thickness ratios that satisfy the ambient temperature non-compact section limits were able to reach the yield strength at the elevated ones. They also noted that failure of some of the tested columns was changed from global buckling at ambient temperature to local buckling at the elevated ones. Heidarpour and Bradford [6] analytically investigated the local buckling of flange outstands at elevated temperatures by modeling the flange alone as a plate and used the finite strip method to estimate the local buckling capacity of the plate. They considered either a simply supported or a clamped case for the plate supports and therefore the interaction with the web was not included. One of their important findings was that the residual stresses have a negligible effect on the local buckling at elevated temperature except in very slender sections. Quiel and Garlock [7] used a finite element model to analyze the buckling behaviour of steel plates at elevated temperatures using shell elements. The stress-strain relations of the steel at elevated temperatures were based on the Eurocode [8]. Their study was limited to either stiffened or unstiffened plates and therefore its applicability to structural shapes remains in question as the interactions between section elements are ignored. Selamet and Garlock [9] conducted a finite element investigation on wide flange sections to evaluate the local buckling capacity of the flange and the web at elevated temperatures as isolate members and as parts of the section. They built their finite element model using shell elements and considered the steel as a Von Mises material with isotropic hardening and considering the stress-strain relations given by the Eurocode [8]. They noted that the AISC code [1] overestimates the local buckling capacity of the section at elevated temperatures. Their results showed that the

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interaction between the section elements has a measurable effect on the results, especially in the flange case. However, their study was limited to only one case of section width to depth ratio, which was taken as 0.5. Furthermore, the steel plasticity model adopted was in fact based on the flow theory of plasticity, which is known for predicting unrealistically higher buckling loads than those experienced experimentally [10]. Seif and McAllister [11] reported the results of a parametric study to investigate the stability of wide flange steel columns under elevated temperatures. They used the ANSYS software to build finite element models for the steel columns. Their results showed that the slenderness of the flange and the web has a significant effect on the way the column buckles at elevated temperatures. Wang et al. [12] conducted an experimental study to investigate the local buckling behaviour of axially loaded columns at elevated temperatures. They showed that using the local buckling provisions of the Eurocode [3] could result in non-conservative results.

It can be concluded from the literature reviewed above that the reported analytical investigations are either on single plates or conducted on the whole section but without considering all the parameters of the section i.e., the interaction between section elements was not adequately studied. On the other hand, some of the reported experimental investigation showed that using current code provisions may overestimate the compression capacity of the steel columns under elevated temperatures and more accurate expressions are needed. This paper presents a comprehensive study to investigate the local buckling behaviour of steel I-sections loaded in compression at elevated temperatures. The main objective herein is to investigate the effect of all the parameters of the problem. This includes the geometric parameters and the steel type. Furthermore, the paper is directed to propose new equations to estimate the local buckling capacity of I-section columns under elevated temperatures that take into consideration all the parameters of the problem.

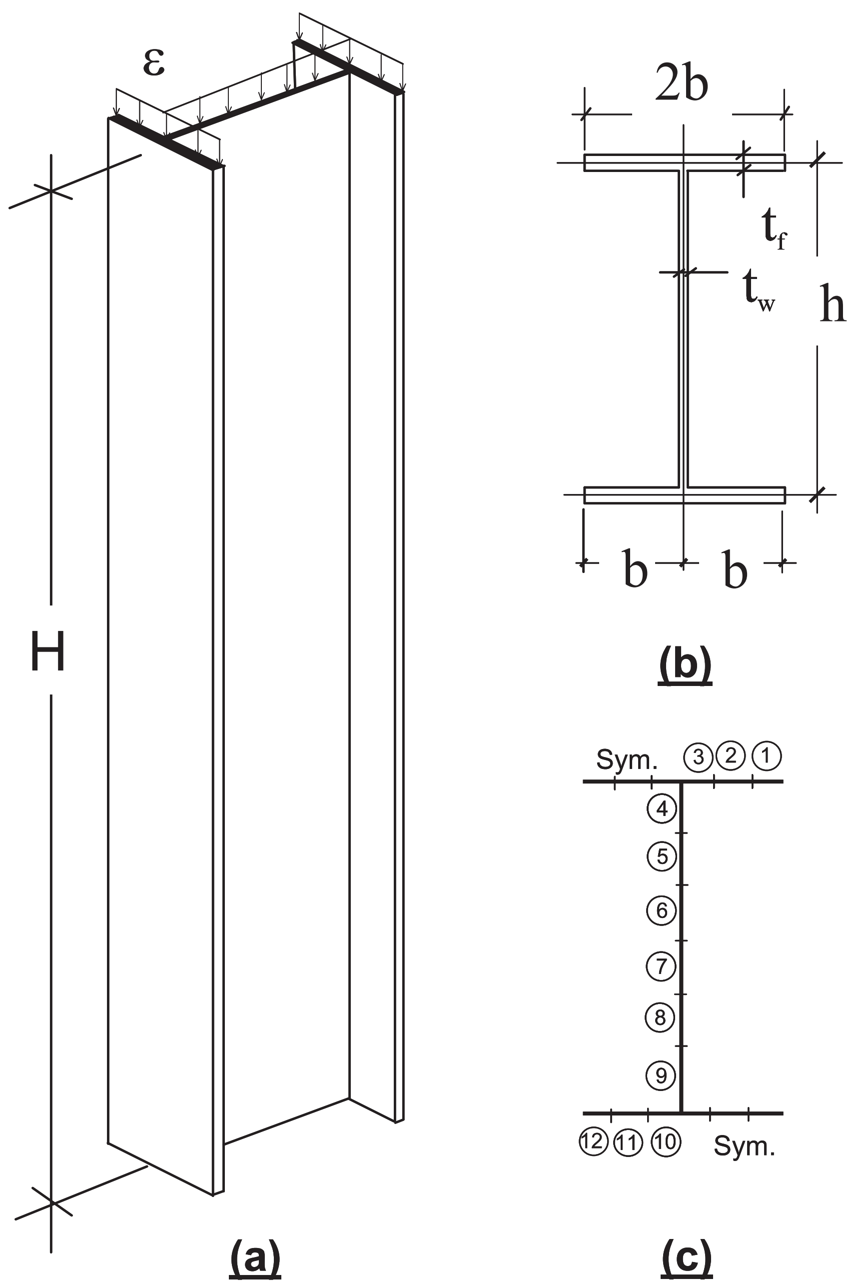


**Fig. 1.** Modeling of an I-section column (a) Loading pattern (b) Cross section dimensions (c) Modeling of the section as connected plates.