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Ultimate strength of box section steel bridge compression members in comparison with specifications

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ABSTRACT

Initial distortion and residual stress are well known as the most important initial imperfection factors and have a significant effect in decreasing the ultimate strength of compression members. The present work focuses on predicting the ultimate strength of welded box section steel compression members regarding initial imperfection factors. Beam compared with shell type of Finite Element (FE) models varied in slenderness ratio and initial distortion are used to assess the accuracy of present numerical results. The comparison of result between FE models and design strength formulations in some specifications are used to assess the ultimate strength formulations of bridge specifications according to the behavior of current steel compression members. It can be observed from numerical results that FE models and design strength by JSHB 2012 and AISC 2005/AASHTO 2010 have good agreement each other which means that the specifications have good capability in assessing the ultimate strength of steel compression members. Parametric study of the ultimate strain varied in slenderness ratio and load versus displacement curves of compression members are also introduced in order to perform more detail steel columns displacement behaviour. Finally, present work proposed a flowchart in designing steel compression members with the expectation that it will be helpful as reference for researchers and engineers in practical fields.

Introduction

Initial imperfections factor is an important aspect in determining ultimate strength of steel bridge compression members. Initial distortion and residual stress are most widely used in practical fields. In general analysis, material, boundary and geometry imperfection and also residual stress effects should be included in determining ultimate strength of real steel columns. Many studies in various cross section types of steel columns have proved that initial imperfection has important influence in making the ultimate strength decrease significantly. Schafer and Pekoz [1] have investigated the computational modeling of cold-formed steel members regarding geometric imperfection and residual stress. Study in the impact of global flexural imperfection especially applied in cold-formed steel column curve varied in initial displacement factor is continued project of the previous one [2]. Trahair and Kayvani also explored effects of excessive crookedness on capacities of steel columns using BS950 as basis of column design methods [3].

Some ultimate strength criteria in bridge specifications need to be evaluated and upgraded gradually to maintain the formulations accuracy in real steel members behaviour using recent numerical and experimental study. For example,

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Nomenclature

$\bar{\lambda}$	slenderness ratio
σ_y	yield stress
E	young's modulus
L	column height
R_R	width–thickness ratio
B	flange width
D	web width
t	plate thickness
υ	Poisson's ratio
n	number of panels
w_G	initial displacement in specified node
δ_0	absolute initial displacement
x	distance to specified node
E_{st}	modulus of elasticity in hardening region
ε	determined strain
σ_{cr}	ultimate stress
ε_{ult}	ultimate strain
ε_y	yield strain
ε_{st}	strain in hardening region
σ	determined stress
ξ	constant (for SM490 $\xi = 0.06$)
δ_x, δ_y, δ_z	displacement in x, y and z direction, respectively
θ_x, θ_y, θ_z	rotation in x, y and z direction, respectively
σ_{cr}	ultimate strength
P_e	elastic buckling load
K	effective length factor
F_n^*	nominal buckling stress
F_y	full yield stress
I	moment of inertia about principal axis normal to buckling plane
δ	longitudinal displacement
Δ	lateral displacement
P	load

compression ultimate strength formulation in recent Japan Specification for Highway Bridges (JSHB) 2012 [4]. There are some slight changes in ultimate strength formulations for any slenderness ratio compared to JSHB 2002 version [5]. By various experimental and numerical studies, the newer ultimate strength formulations are considered to have better accuracy in determining real member behaviour.

Previous case study by Ono et al. [6] has introduced ultimate compression strength investigation of welded box section steel columns regarding initial displacement and residual stress in beam models numerical study compared to experimental result. It is continued by numerical case study of Susanti and Kasai [7], where the study used beam and modified shell Finite Element (FE) models. Although it is found that both FE models have good similarity to the previous results, the use of shell models are more suitable in performing global buckling behaviour in coincidence with local buckling. The ultimate strength behavior of beam and shell models indicated good agreement in elastic range but not in non elastic region due to the presence of local buckling in shell models. Parametric study on steel columns using welded box section type is investigated by Imamura et al. [8] and Susanti et al. [9]. The study conducted numerical study in varied slenderness ratio compared to ultimate strength curves of JSHB 2002 and 2012, respectively.

Many engineers in practical fields have difficulties in understanding and performing complicated FE models regarding some initial imperfection factors. Practical simple models neglecting initial imperfection effects are usually chosen in designing a bridge structures, such as simple beam models. It has become very important to introduce many studies in more complex developed models to illustrate the real behavior of structures which can be used as guidance for many practical engineers. On the other side, there are a lot of improvements in factory production technologies that can improve the ultimate strength because some imperfection effects such as initial displacement can be reduced during manufacturing and installation process. New formulations in specifications have to be able to accommodate all of those conditions. According to the explained considerations and some previous studies, the present work investigate compression ultimate strength of welded box section steel columns regarding initial distortion and residual stress using beam and shell FE models in order to develop new formulations in steel columns ultimate strength.