Finite element analyses of cold-formed steel unlipped channel beam with web openings in web crippling

Kasthuri Selvarajasarma*[a], Sivapalan Vithurshan, Balasubramaniam Janarthanan.

Abstract: In recent years, the use of Cold-formed steel has increased as an economical replacement to hot-rolled steel sections due to its high strength to weight ratio. However, these sections are vulnerable to bearing failures due to their high width to thickness ratio. Unlipped channel sections are conventional sections used as joists and bearers in the floor systems of residential and industrial buildings. Their web crippling strengths are considerably reduced when web openings are included for the purpose of locating building services. The available current cold-formed bearing capacity design specifications such as AISI S100 and AS/NZS 4600 signified capacity reduction factors due to circular web openings only for one-flange load cases. The effects of circular web openings of unlipped channel sections with unfastened supports under two-flange load case are still unknown. Hence a numerical study was undertaken in this research to investigate the effects of centred beneath web openings on web crippling behaviour and capacity of unlipped channel sections under End Two Flange (ETF) load case. Developed finite element models using ANSYS were validated with past researches and further used to conduct the detailed parametric study. The results from finite element analyses were confirmed that available current design equations are inadequate to determine the web crippling capacities of unlipped channel steel beams without web openings. Hence the suitable coefficients were proposed to the current design equations of cold-formed steel sections without web openings. Also, it is unconservative to use these design equations to with web opening sections. Therefore, a reduction factor equation needs to be proposed for unlipped channel sections with centred beneath web openings under ETF load case.

Keywords: Cold-formed steel, Unlipped channel, Web crippling, Web opening, End Two Flange (ETF) load case, Finite element analyses

1. Introduction

Cold-formed steel sections have been introduced as an economical replacement to hot-rolled steel sections due to its high strength to weight ratio. However, these sections are exposed to bearing failures due to their high width to thickness ratio. Web crippling, which is a localized failure, is one of the most significant problem when the members are exposed to concentrated loadings and reactions under different loading conditions. These loading conditions are commonly distinguished as four types based on loading conditions and failure locations as shown in Figure 1, such as End-One-Flange (EOF), Interior-One-Flange (IOF), End-Two-Flange (ETF) and Interior-Two-Flange (ITF) load cases.

The load case is considered as end loading if the failure occurs within $1.5d_1$ from the edge of the specimen. Otherwise, it is considered as interior loading where d_1 is the depth of the flat portion of the web element of the specimen. Two-flange loading is considered if the distance between the edges of bearing plates of opposite adjacent two loadings is less than $1.5d_1$. Otherwise, it is considered as one-flange loading, where d_1 is the web clear height of the specimen.

Three cold-formed steel specifications such as Australian/New Zealand standard (AS/NZS 4600) [1], North American Specification (AISI S100) [2] and Eurocode 3 Part 1-3 (ECS, 2006) [3] have design equations to determine the bearing capacity of the cold-formed steel sections for the above four load cases. AS/NZS 4600 [1] and AISI S100 [2] specifications use the same unified bearing equation as shown in Equation 1. According to the equation, the bearing failure is different based on different flange types (stiffened/ unstiffened) and support conditions (fastened/ unfastened).

$$R_b = ct_w^2 f_y \sin\theta \left(1 - C_r\sqrt{\frac{r_i}{t_w}}\right)\left(1 + C_l\sqrt{\frac{l_b}{t_w}}\right)\left(1 - C_w\sqrt{\frac{d_1}{t_w}}\right) \qquad (1)$$

Miss. S. Kasthuri, *B.Sc. Eng., Instructor, Department of Civil Engineering, University of Jaffna.*
Mr. S. Vithurshan, *Site Engineer, Nuwani construction (pvt) ltd.*
Dr. B. Janarthanan, *B.Sc. Eng., Lecturer, Department of Civil Engineering, University of Jaffna.*