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Review

Web crippling behaviour and design of cold-formed steel sections

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ABSTRACT

Cold-formed steel sections are used in many different shapes based on their applications. Recently, a new C-section known as SupaCee was introduced in Australia with higher flexural capacities compared to traditional channel sections. However, all cold-formed steel sections are vulnerable to web crippling failures due to their higher plate slenderness. Australian/New Zealand (AS/NZS 4600) and North American (AISI S100) Standards use a unified web crippling design equation with four coefficients while Eurocode 3 Part 1.3 uses different design equations to predict the web crippling capacities of cold-formed steel sections. The web crippling coefficients were developed based on the experimental studies undertaken since the 1940s. These experimental studies utilised different test set-ups and specimens lengths and hence the accuracy of predictions using these coefficients may be inadequate. No coefficients are available for unlipped channel sections with fastened supports and high strength SupaCee sections while the same coefficients are used for lipped channels with fastened and unfastened supports. To address these shortcomings, the web crippling behaviour of unlipped and lipped channel and SupaCee sections was experimentally investigated based on recently developed AISI S909 web crippling test guidelines. Finite element analyses were then performed to extend the range of cold-formed steel sections. Using the web crippling capacity results from both experiments and finite element analyses, new equations were proposed to determine the web crippling capacities of lipped and unlipped channel and SupaCee sections. Suitable direct strength method based web crippling design equations were also developed. This paper presents the important details of several detailed web crippling studies undertaken recently including a suite of web crippling design equations that can be adopted in relevant cold-formed steel standards.

1. Introduction

Cold-formed steel unlipped and lipped channel sections are commonly employed as joists and bearers in floor systems due to their high flexural capacities. Recently, a new C-section known as SupaCee section was introduced in Australia, with enhanced flexural capacities compared with traditional unlipped and lipped channel sections (Fig. 1). These SupaCee sections are modified lipped channel sections with four longitudinal web stiffeners and curved lips. Although all cold-formed steel sections possess many advantages such as enhanced strength to weight ratios and dimensional accuracy, the main shortcoming is their vulnerablity to web crippling failure under transverse concentrated loads or support reactions as shown in Fig. 1, if the webs are unstiffened at the load transfer points. Theoretical development of suitable web crippling capacity equations has not been possible due to involved complexities such as non-uniform stress distribution and localised yielding and large deformations, inelastic behaviour of the web element and plate imperfections. Therefore the web crippling behaviour of many cold-formed steel profiles has been mainly investigated experimentally since the 1940s.

Current cold-formed steel standards such as North American Specification (AISI S100) [1], Australian/New Zealand standard (AS/NZS 4600) [2] and Eurocode 3 Part 1–3 [3] and AISI S909 web crippling test methods [4] classify web crippling failures into four groups (load cases): End-One-Flange (EOF), End-Two-Flange (ETF), Interior-One-Flange (IOF) and Interior-Two-Flange (ITF) based on the failure location and loading conditions as illustrated in Fig. 2. The load case is referred to as end loading for the failure within $1.5d_1$ from the edge of the specimen. Otherwise, it is referred to as interior loading. Two-flange loading is the case when the distance between the edges of the bearing plates of opposite adjacent two loadings is less than $1.5d_1$. Otherwise, it is one-flange loading, where d_1 is the height of the flat web portion.

Many series of experiments have been performed since the 1940s to investigate the web crippling behaviour of different shapes (C-, Z-, hat and built-up sections) of cold-formed steel sections [5–14]. Using all the available web crippling capacity data until 1994, Canadian researchers [9,10] developed a unified equation to predict the web crippling capacity (R_b) as shown in Eq. (1) based on web thickness (t_w), yield

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