WEB CRIPPLING STRENGTH OF COLD-FORMED STEEL CHANNELS SUBJECTED TO INTERIOR TWO-FLANGE LOADING

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ABSTRACT: Cold-formed steel (CFS) members typically have thin, slender, and unstiffened webs, making web crippling a critical limit state under concentrated loading. The web crippling strength is influenced by several parameters, including web slenderness (*h/t*), bearing length (*N*), inside bend radius (*R*), yield stress (f_y), flange restraint, and the presence of flange edge stiffeners (lips). Existing design guidelines, such as ANSI/SDI AISI S100:2024 and BS EN 1993-1-3:2024, recommend a design equations with distinct sets of empirical coefficients depending on cross-section [e.g.: lipped channel (LC), and unlipped channel (ULC)], fastening condition [i.e., fastened(F), and unfastened (UF)] and loading [interior two-flange (ITF), end two-flange (ETF), interior one-flange (IOF), and end one-flange (EOF)]. These equations provide inconsistent predictions of web crippling strength, and ANSI/SDI AISI S100:2024 does not provide specific coefficients for the ULC-F configuration. Recent direct strength method (DSM) provides alternative means of predicting web crippling strength which is a function of yield load (P_y) and critical buckling load (P_{cr}). There are many DSMs reported in the literature which are functions of cross-sections, fastening conditions and loading type. The present study presents a comprehensive experimental, and numerical investigation of CFS channel sections (LC-F, ULC-F, LC-UF, and ULC-UF) subjected to ITF loading, with particular emphasis on the effects of key geometric and material parameters such as *h/t*, *N/t*, *R/t*, and f_y. Based on the experimental and numerical results, a unified design equation is proposed for web crippling strength under ITF loading that is applicable to cross-sectional configuration and flange boundary condition.

The web crippling behaviour of flange-fastened CFS channel sections was first investigated through experiments comprising 42 LC-F and 14 ULC-F specimens subjected to ITF loading, covering $30 \leq h/t \leq 265$ and approximately $16 \leq N/t \leq 205$. The experimental results showed that the specimens primarily failed by flange crushing (FC), web buckling (WB), or an interaction between these modes (FC+WB). For LC-F sections, lower *N/t* predominantly resulted in FC, whereas higher *N/t* generally led to WB, with FC+WB observed for selected specimens with relatively low *h/t*. The web crippling strength of FC-dominated specimens was largely independent of *h/t*, while that of WB-dominated specimens was largely independent of *N/t*. To further investigate the influence of the flange edge stiffener, nonlinear finite element (FE) models were developed and validated for both LC-F and ULC-F sections, followed by an extensive parametric study comprising 506 LC-F and 506 ULC-F simulations. The combined experimental and numerical results demonstrated that the presence of the lip has a limited influence on web crippling strength when FC or FC+WB governs, whereas its influence becomes significant for WB-dominated behaviour, particularly at higher *N/t*.

The web crippling behaviour of flange-unfastened (UF) CFS channel sections was subsequently investigated through experiments comprising 13 LC-UF and 13 ULC-UF specimens subjected to ITF loading. The experimental results showed that both LC-UF and ULC-UF sections predominantly exhibited web buckling (WB) and combined flange crushing and web buckling (FC+WB), with comparable web crippling strengths despite the difference in cross-sectional configuration. Nonlinear FE models were developed and validated against the experimental results, followed by an extensive parametric investigation comprising 501 LC-UF and 501 ULC-UF simulations. The numerical results confirmed the experimentally observed similarities between LC and ULC sections under UF conditions and enabled systematic investigation of the influence of web slenderness, bearing length, and flange restraint over a wider range of parameters. Comparisons between the fastened and unfastened configurations demonstrated that the influence of flange fasteners is strongly dependent on the bearing-length-to-thickness ratio (*N/t*): their effect is negligible at lower *N/t*, where FC or FC+WB governs, but increases with *N/t* as the behaviour becomes increasingly dominated by WB.

The experimental and numerical databases were subsequently used to assess the accuracy and reliability of existing web crippling design provisions and recently developed DSM-based approaches. Based on extensive database comprising of 267 experimental results and 2014 finite element analysis results, a unified design equation for web crippling strength of CFS channel members is proposed. The proposed design equation is simple and provides more accurate predictions of web crippling strength than the existing design equations available in the literature.

Key words: Cold-formed steel; web crippling; lipped channel, unlipped channel, and interior two-flange loading.