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Experimental study of shear strength of cold-formed channels with an aspect ratio of 2.0

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ABSTRACT

Shear behaviour of cold-formed steel beams with an aspect ratio (shear span/web depth) of *1.0* has been studied thoroughly, mainly using central point load tests. However, for beams with longer aspect ratios, the effect of bending causes reduction of shear capacity and alters the failure modes. This paper summarises experiments recently performed at the University of Sydney on channel section members using a new test configuration to minimize bending moments. Shear strength close to pure shear capacity can be therefore reached even at an aspect ratio of *2.0*. The test results were compared with the strength predictions using the current direct strength method (DSM) of design for shear specified in the North American specification for the design of cold-formed steel structural members, AISI S100:2016 and the Australian/New Zealand Standard for cold-formed steel structures, AS/NZS 4600:2018. A good agreement between the experimental results and the predicted values has confirmed the viability of the DSM design rules for structures with aspect ratios up to *2.0*. Numerical models were developed to foresee potential issues prior to the experimental work, and were subsequently calibrated against the tests to produce reliable results.

1. Introduction

Cold-formed steel structures have been used worldwide in the construction industry as a result of its inherent advantages over the conventional hot-rolled steel such as higher strength-to-weight ratio and the ease of assembly. Its applications range from non-structural elements such as infill wall frames to the holistic cold-formed steel mid-rise buildings. The design of cold-formed steel structural members are specified in the North American specification for the design of cold-formed steel structural members AISI S100:2016 [1] and the Australian/New Zealand Standard for cold-formed steel structures AS/NZS 4600:2018 [2]. These codes have incorporated the newly developed Direct Strength Method (DSM) of design which substantially simplifies the design process as compared to the conventional Effective Width Method (EWM). For structures subjected to shear forces, the corresponding DSM design curve was constructed on the basis of *36* shear tests on beams with an aspect ratio of *1.0* conducted by Pham and Hancock [3] using a central point load test setup. The design rules are deemed to be applicable to the shear space of a moment - shear interaction approach to design structures with the aspect ratios up to *2.0*. At this aspect ratio, another series of tests by Pham and Hancock [3] observed combined bending and shear failure modes adjacent to the loading points. Although this method has been proved to be rational, an experimental verification of the shear strength of beams with large aspect ratios is of importance. This could be achievable by searching for a testing apparatus that is able to reduce the bending effects, allowing ultimate shear strength to be reached without premature bending failure at aspect ratios up to *2.0*.

2. Background

2.1. Shear tests on plate girders

In 1960, Basler et al. [4] conducted tests on welded plate girders subjected to a ‘pure shear’, a term used in their publication, using a unique test configuration to minimize the bending effects as seen in Fig. 1. The girder was simply supported at a quarter and three-quarter points along its length, and a pair of equal, opposite forces was applied at two ends. Each girder consisted of a test section with *3/16* in. (*4.76* mm) thick web and two end sections with heavier web plates. The flanges were strengthened at high moment areas by cover plates. Shear panels were formed by transverse web stiffeners welded to the girder. The test section where shear failure was expected to occur was located at the mid-span, and it was subjected to a constant shear force and a small amount of bending moment gradient with the maxima at two ends of the shear span. Experiments with various aspect ratios of the central shear panels including *0.5*; *0.75*; *1.0* and *1.5* were carried out

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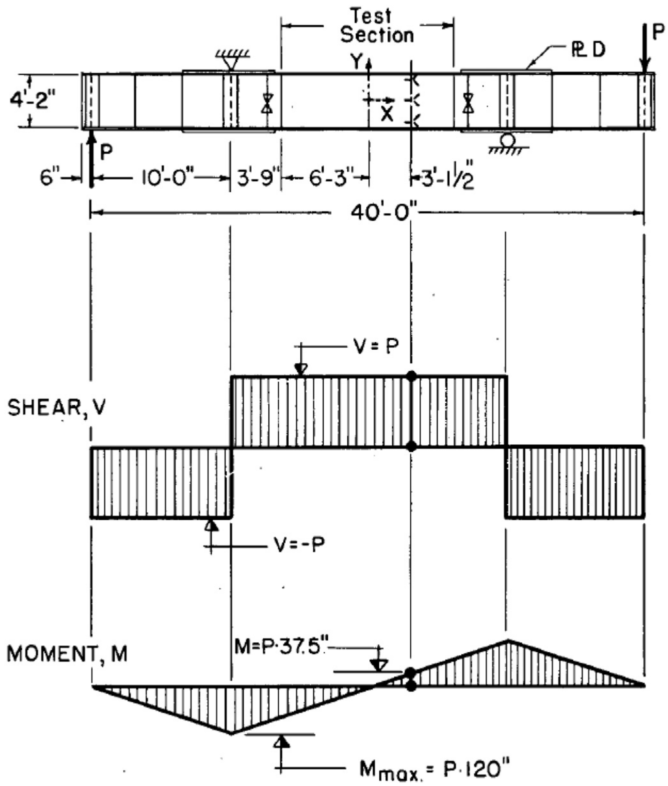

Fig. 1. Diagrams of tests on plate girders subjected to shear (Basler et al. [4]).

with the unique test configuration to minimize the bending effects as seen in Fig. 1.

According to the specific girder depth (*4′-2″* or *1270* mm) of the test, if the test section, i.e. the central shear panel, has an aspect ratio of *2.0*, the maximum ratio of the moment to shear (*M*/*V*) along the test span would be equal to the girder web's depth. This moment to shear ratio plays a critical role to enforce the shear failure and to prevent a premature bending failure. Therefore, this ratio is computed and discussed for each test configuration mentioned in this paper.

2.2. Shear tests on cold-formed steel beams

Yu and LaBoube [5] used a simply supported beam test set-up, referred to Test Setup A, loaded at the mid-span as seen in Fig. 2(a,b) to investigate the shear strength of thirty six cold-formed lipped channel members with the aspect ratio of *1.0*. The maximum moment to shear ratio (*M*/*V*) experienced by testing members was equal to the shear span and thus the web depth (b). Shear failure was clearly observed as depicted in Fig. 2(c) despite a minor bending failure at the top flange.

For longer shear spans, considerable moments might interfere at an early state and cause premature flexural failure before structures reach the shear capacity. Therefore, two tests on members with an aspect ratio (a/b) of *3.23* were conducted using another test configuration, referred to as Test Setup B shown in Fig. 3 which is, to some extent, analogous to the test configuration employed by Basler et al. [4]. The maximum M/V ratio of the middle test segment reached a value of (L-($a + 3''$)). As the length $L = 2.5a$ was used in those two tests, the *M*/*V* was equal to approximately *4.8b*. This ratio is even larger than that in the Test Setup A which is *b*. No further information regarding the failure modes was found in the record.

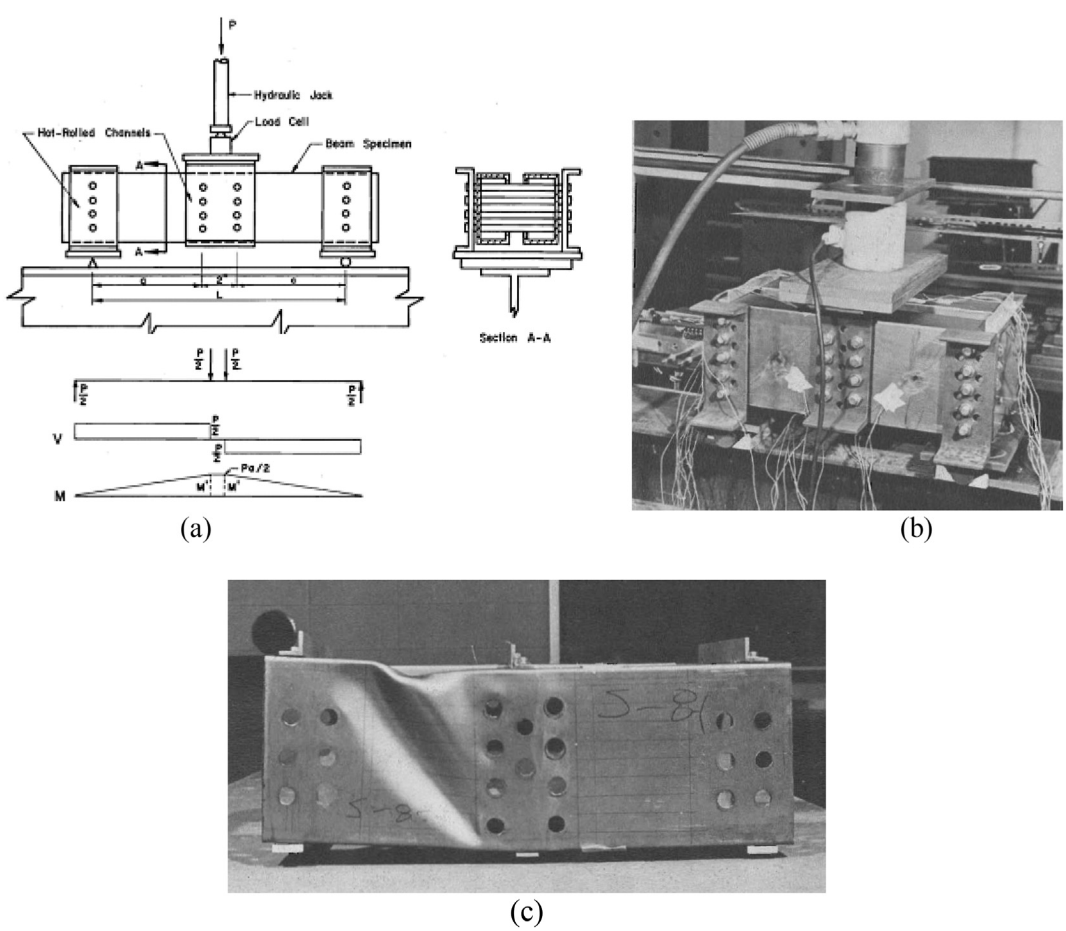

Fig. 2. Test Setup A (Yu and LaBoube [5]).