For an unstiffened web, the interaction equation is a circular formula as shown in Fig. 6.5(a). This interaction formula is based upon an approximation to the theoretical interaction of local buckling resulting from shear and bending as derived by Timoshenko and Gere (Ref. 3.6). As applied in AS/NZS 4600, the interaction is based on the design section moment capacity ($\phi_b M_s$) which includes post-local buckling in bending. Hence the justification for the use of the circular formula is actually empirical as confirmed by the testing reported in Ref. 6.5.

For a stiffened web, the interaction between shear and bending is not as severe, probably as a result of a greater postbuckling capacity in the combined shear and bending buckling mode. Consequently a linear relationship, as shown in Fig. 6.5(b) with a larger design domain, is used to limit the design actions under a combination of shear and bending.

6.5 Web Stiffeners

The design clauses for the web stiffener requirements specified in Clause 3.3.8 are based on those introduced in the 1980 AISI Specification. The clause for transverse stiffeners (3.3.8.1) has been designed to prevent end crushing of transverse stiffeners (Eq. (3.3.8.1(1)) and column type buckling of the web stiffeners (Eq. (3.3.8.1(2)). It is based on the tests described in Ref. 6.6. The capacity reduction factor (ϕ_c) for transverse stiffeners is the same as that for compression members.

The clause for bearing stiffeners (3.3.8.2) in channel section flexural members is new and was based on the work of Fox & Schuster (Ref. 6.7) which investigated the behaviour of stud & track sections.

The clause for shear stiffeners (3.3.8.3) is based mainly upon similar clauses in the AISC Specification for the design of plate girders (Ref. 6.8) although the detailed equations were confirmed from the tests reported in Ref. 6.6.

6.6 Web Crippling (Bearing) of Open Sections

6.6.1 Edge Loading Alone

In the design of cold-formed sections, it is not always possible to provide load bearing stiffeners at points of concentrated edge loading. Consequently a set of rules is given in Clause 3.3.6 of AS/NZS 4600 for the design against web crippling under concentrated edge load in the manner shown in Fig. 6.6. The clauses in AS/NZS 4600 have been empirically based on tests as summarised in Beshara and Schuster (6.9, 6.10).

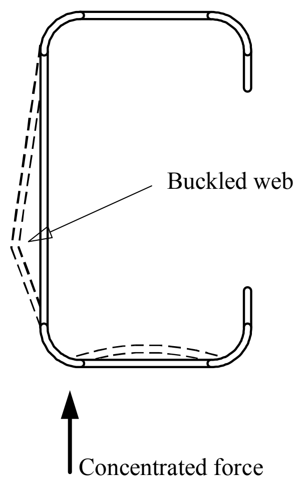

Fig. 6.6 Web crippling of an open section

The nominal capacity for concentrated load or reaction load (R_b) has been found to be a function of the following parameters as shown in Fig. 6.7, 6.8 and 6.9. These are:

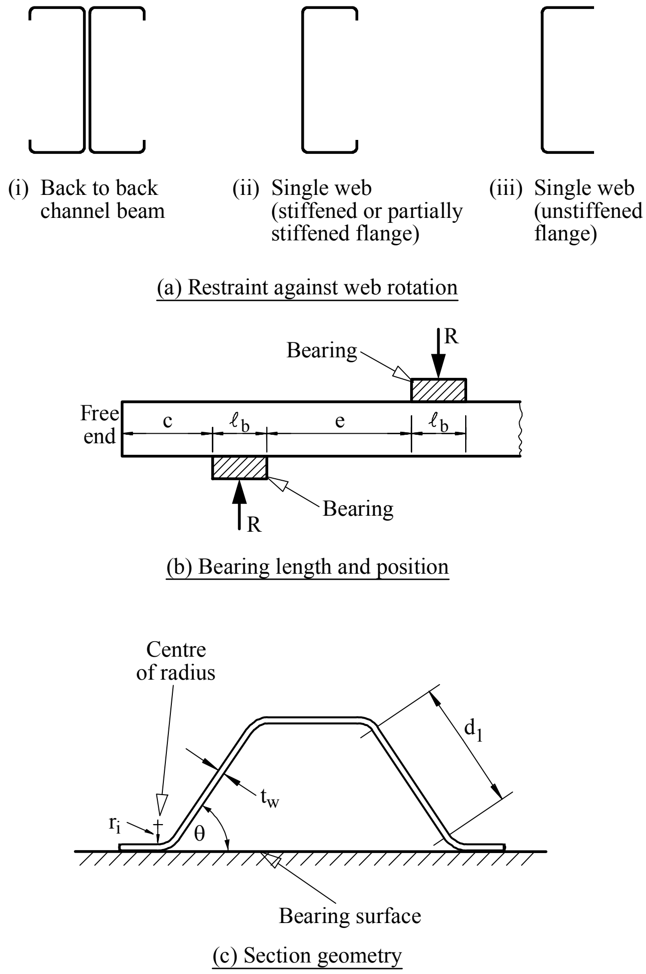

Fig. 6.7 Factors affecting web bearing capacity

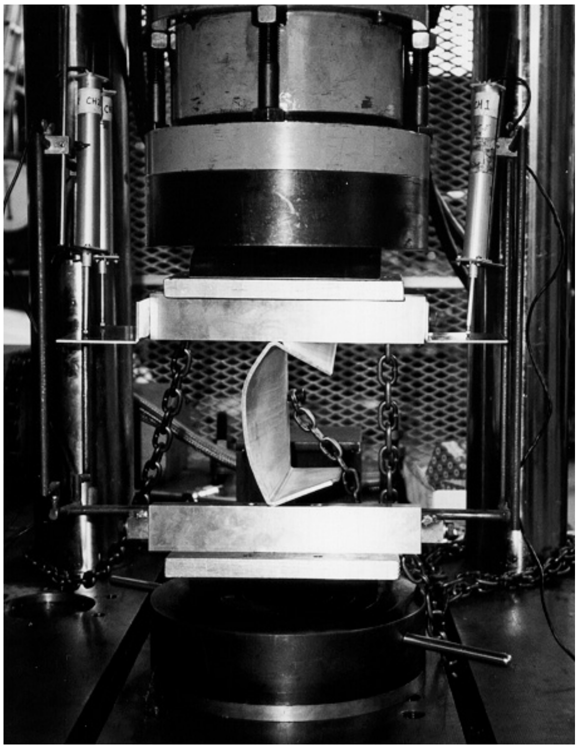

Fig. 6.8 Test of specimen with flanges unfastened

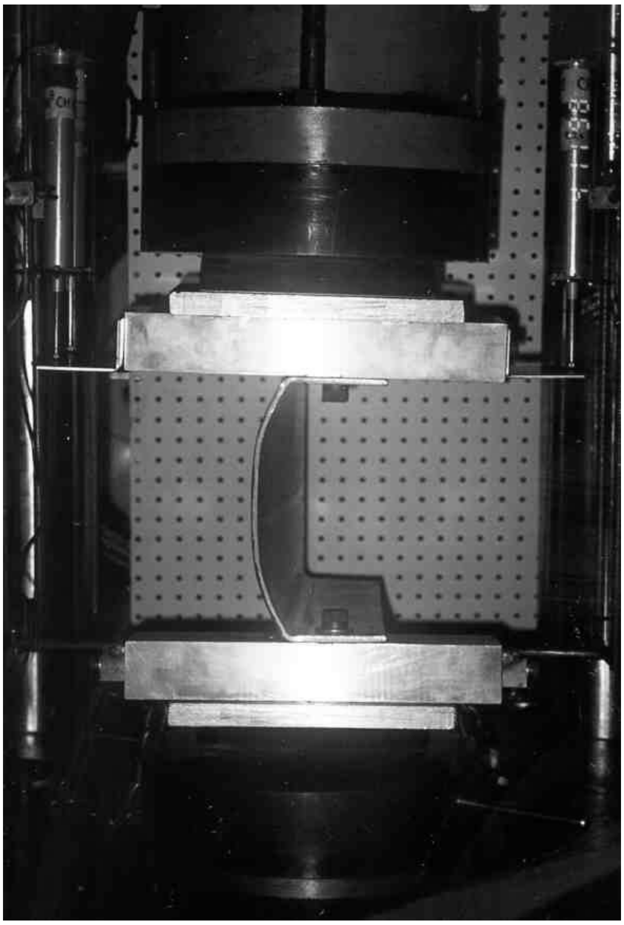

Fig. 6.9 Test of specimen with two flanges fastened

(a) The nature of the restraint to web rotation provided by the flange and adjacent webs as shown in Fig. 6.7(a). The back to back channel beam has a higher restraint to web rotation at the top and bottom and hence a higher load capacity than a single channel. Similarly, the channel with a stiffened, or partially stiffened, compression flange has a higher restraint to web rotation than the channel with an unstiffened web and hence a higher web bearing capacity.

(b) The length of the bearing (lb) shown in Fig. 6.7(b) and its proximity to the end of the section (c). In addition, the proximity of other opposed loads, defined by e in Fig. 6.7(b), is also important. A limiting value of c/d1 of 1.5, where d1 is the web flat width, is used to distinguish between end loads and interior loads. Similarly a limiting value of e/d1 of 1.5 is used to distinguish between opposed loads and non-opposed loads.

(c) The web thickness (t_w) the web slenderness (d_1 / t_w) the web inclination (θ) and the inside bend radius (r_i) as shown in Fig. 6.7(c), are the relevant section parameters defining the section geometry. The following limits to the geometric parameters apply to Clause 3.3.6.

Web slenderness, $d_1/t_w \leq 200$

Web inclination, $90^\circ \geq \theta > 45^\circ$ for multi-web deck sections, 90° for other sections

Bend radius to thickness, $r_i / t_w \leq 6$ depends on section type

Bearing length to thickness, $l_b / t_w \leq 210$ for all sections except hats ($l_b / t_w \leq 200$)

Bearing length to web depth, l_b / d_1 depends on section style

(d) Whether the flange is unfastened as shown in Fig 6.8 or fastened as shown in Fig. 6.9 (Ref. 6.11).

The design equation is:

$$R_b = Ct_w^2 f_y \sin\theta \left(1 - C_r \sqrt{\frac{r_i}{t_w}}\right)\left(1 + C_\ell \sqrt{\frac{\ell_b}{t_w}}\right)\left[1 - C_w \sqrt{\frac{d_1}{t_w}}\right] \qquad (6.8)$$

The parameters C, C_r, C_l, C_w and the capacity reduction factors are given in Tables 3.3.6.2 (A)-(E) in AS/NZS 4600 for built-up sections, channel, zed, hat and multi-web deck section.

Transverse stiffeners must be used for webs whose slenderness exceeds *200*.

6.6.2 Combined Bending and Edge Loading

The combination of bending moment and concentrated load frequently occurs in beams at points such as interior supports and points of concentrated load within the span. When bending moment and concentrated load occur simultaneously at points without transverse stiffeners, the two actions interact to produce a reduced load capacity.

A large number of tests has been performed, mainly at the University of Missouri-Rolla (UMR) and at Cornell University, to determine the extent of this interaction. The test results (Refs 6.12, 6.13) are summarised in Fig. 6.10 for sections with single webs and in Fig. 6.11 for I-Beams formed from back to back channels. In the latter case, the test results only apply for beams which have webs with a slenderness (d_1/t) greater than $2.33/\sqrt{f_y/E}$ or with flanges which are not fully effective, or both. For I-beams with stockier flanges and webs, no significant interaction between bending and web crippling occurs as shown in Ref. 6.8. The data on nested Z-sections is given in Ref. 6.14.

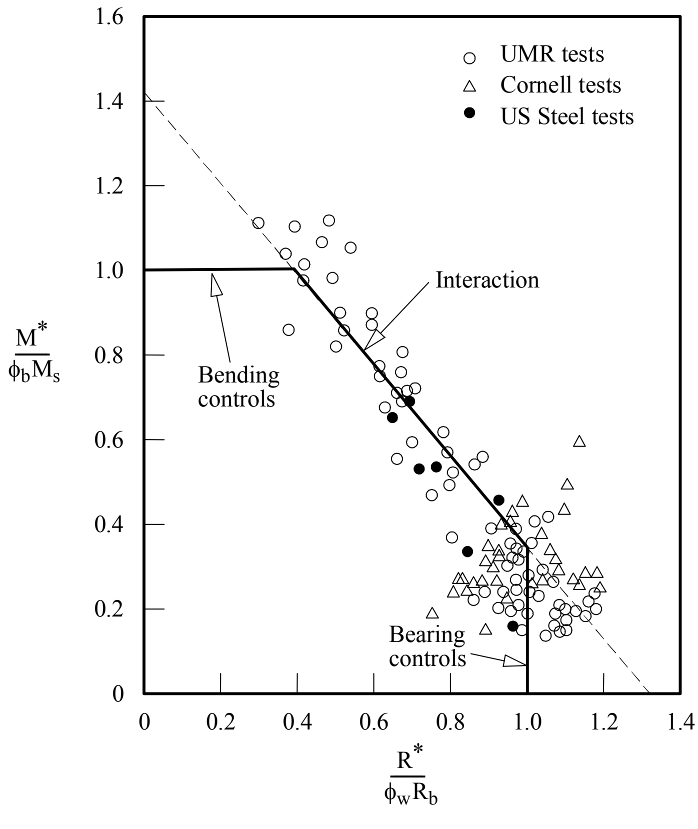

Fig. 6.10 Interaction of bending and bearing for single webs

Design of Cold-Formed Steel Structures
(To Australian/New Zealand Standard AS/NZS 4600:2005)

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