determine whether the net section fracture capacity could be developed at perforated sections. Coupons were taken in the longitudinal, transverse and diagonal directions as described in the preceding paragraph. Circular, square and diamond shaped perforations of varying sizes were placed in the coupons. It was found that despite the low values of elongation measured for this steel as shown in Fig. 2.5, the load carrying capacity of G550 steel as measured in concentrically loaded perforated tensile coupons can be adequately predicted using existing limit states design procedures based on net section fracture without the need to limit the tensile strength to 75% of 550 MPa as specified in Clause 1.5.1.4(b) of AS/NZS 4600 for steel less than 0.6 mm in thickness and 90% of 550MPa for steels greater than or equal to 0.6mm in thickness. These limitations come from the steel in compression as described later in Section 7.5.2 of this book.

2.4 Effects of Cold Work on Structural Steels

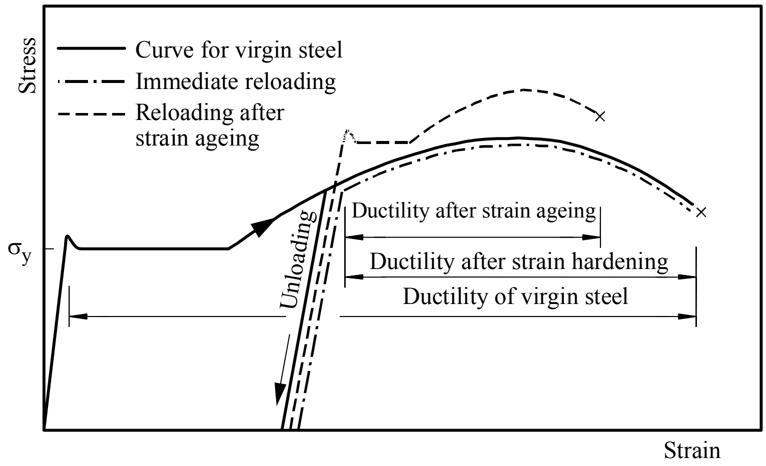
A paper by Chajes, Britvec and Winter (Ref. 2.6) describes a detailed study of the effects of cold-straining on the stress-strain characteristics of various mild carbon structural sheet steels. The study included tension and compression tests of cold-stretched material both in the direction of prior stretching and transverse to it. The material studied included:

1. Cold-reduced annealed temper-rolled killed sheet coil
2. Cold-reduced annealed temper-rolled rimmed sheet coil
3. Hot-rolled semi-killed sheet coil
4. Hot-rolled rimmed sheet coil

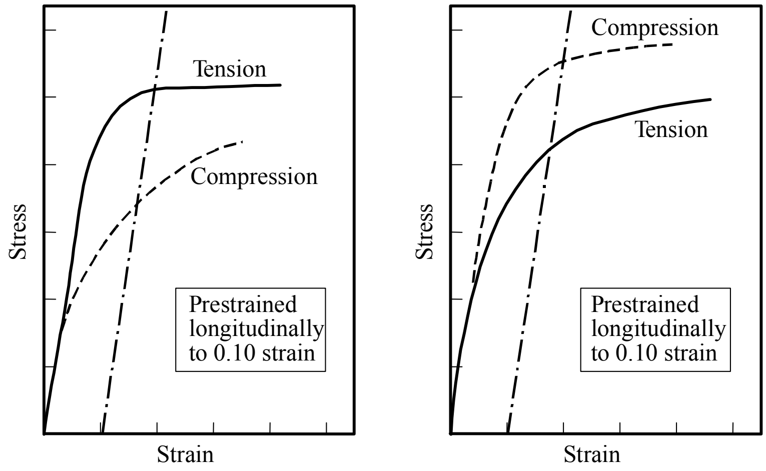
The terms rimmed, killed and semi-killed describe the method of elimination or reduction of the oxygen from the molten steel. In rimmed steels, the oxygen combines with the carbon during solidification and the resultant gas rises through the liquid steel so that the resultant ingot has a rimmed zone which is relatively purer than the centre of the ingot. Killed steels are deoxidised by the addition of silicon or aluminium so that no gas is involved and they have more uniform material properties. Most Australian steels are continuously cast and are aluminium or silicon killed.

A series of significant conclusions were derived in Ref. 2.6 and can be explained by reference to Fig. 2.6. The major conclusions are:

1. Cold work has a pronounced effect on the mechanical properties of the material both in the direction of stretching and also in the direction normal to it.
2. Increases in the yield strength and ultimate tensile strength as well as decreases in the ductility were found to be directly dependent upon the amount of cold work. This can be seen in Fig. 2.6(a) where the curve for immediate reloading returns to the virgin stress-strain curve in the strain-hardening region.
3. A comparison of the yield strength in tension with that in compression for specimens taken both transversely and longitudinally demonstrates the Bauschinger effect (Ref. 2.7). In Fig. 2.6(b), longitudinal specimens demonstrate a higher yield in tension than compression, whereas in Fig. 2.6(c), transverse specimens of the same steel with the same degree of cold work demonstrate a higher yield in compression than in tension.
4. Generally, the larger the ratio of the ultimate tensile strength to the yield stress, then the larger is the effect of strain hardening during cold work.
5. Ageing of a steel occurs if it is held at ambient temperature for several weeks or for a much shorter period at a higher temperature. As demonstrated in Fig. 2.6(a), the effect of ageing on a cold worked steel is to:
    (a) increase the yield stress and the ultimate tensile strength
    (b) decrease the ductility of the steel
    (c) restore or partially restore the sharp yielding characteristic



(a) Effect of strain hardening and strain ageing



(b) Longitudinal specimen

(c) Transverse specimen

Fig. 2.6 Effects of cold work on stress-strain relationships

Highly worked steels, such as the corners of cold-formed tubes which have characteristics such as shown in Fig. 2.3(b), do not return to a sharp yielding characteristic. Some steels, such as the cold-reduced killed steel described in Ref. 2.6 may not demonstrate ageing.

2.5 Corner Properties of Cold-Formed Sections

As a consequence of the characteristics of cold worked steel described in Section 2.4, the forming process of cold-formed sections will result in an enhancement of the yield stress and ultimate tensile strength in the corners (bends) as demonstrated previously in Fig. 1.19 for a square hollow section. For sections undergoing cold-forming as demonstrated in Fig. 1.15, Clause 1.5.1.2 of AS/NZS 4600 provides formulae to calculate the enhanced yield strength (f_{yc}) of the corners. These formulae were derived from Ref. 2.6. A brief summary of these formulae and their theoretical and experimental basis follows.

The effective stress-effective strain ($\sigma - \varepsilon$) characteristic of the steel in the plastic part of the stress-strain curve is assumed to be described by a power function as given in Eq. (2.6).

$$\sigma = k\,\varepsilon^{n} \tag{2.6}$$

where k is the strength coefficient and n is the strain hardening exponent. The effective stress (σ) is defined by the Von Mises distortion energy yield criterion (Ref 2.9) and the effective strain (ε) is similarly defined. In Ref. 2.8, k and n are derived from tests on steels of the types

Design of Cold-Formed Steel Structures

(To Australian/New Zealand Standard AS/NZS 4600:2005)

by

Gregory J. Hancock BSc BE PhD DEng

Bluescope Steel Professor of Steel Structures
Dean
Faculty of Engineering & Information Technologies
University of Sydney

fourth edition - 2007

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