New Performance Requirements for Seismic Steel

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Introduction

Amendment 2 of the Steel Structures Standard NZS 3404:1997 released in October 2007 (SNZ, 2007) sets new requirements for steel materials and welding of seismic resisting steelwork that is required to sustain significant plastic deformation under design earthquake events. These changes relate to the selection of steel materials in Table 12.4 and the selection of welding consumables and weld heat input in cl. 2.6.4.5. In some instances these requirements exceed the provisions in the material supply standards for steel sections to AS/NZS 3679 (SAA/SNZ, 1996), plate to AS/NZS 3678 (SAA/SNZ, 1996) and tube to AS1163 (SAA, 1991) A review of steels currently available in the New Zealand market indicates that most will comply with these requirements.

Basis for Changes to the Steel Material and Welding Requirements

Research since the Kobe and Northridge earthquakes in the mid 1990's has led to the conclusion that ductile endurance of structural steelwork is dependant on among other things the control of yield stress, Charpy V-notch characteristics, yield ratio and elongation limits of both the steel and welds in potential plastic hinge zones (Hyland, Ferguson, Butterworth, 2005). As a result the requirements for category 1, 2 and 3 members in seismic resisting steel frames have been reviewed and in some cases tightened in Table 12.4 of the Steel Structures Standard.

Allowable Grade Yield Stress

Category 1, 2 and 3 members are now limited to a specified grade yield stress of 360 MPa. This allows G350 steel to now be used in ductile seismic steelwork rather than previously G300. The grade reference yield stress is set as that for steel thickness range of $12 > t \geq 20$ mm . G350 steel sections have a specified minimum yield stress of 340 MPa in this thickness range in AS/NZS 3679.1, whereas for G350 plate to AS/NZS 3678 this is 350 MPa.

Maximum Actual Yield Stress

The strong column- weak beam design approach embodied in the Steel Structures Standard requires that control is placed on the upper bound yield stress of members that are likely to sustain plastic deformation in an earthquake. This upper bound yield stress will therefore set a limit on the resulting maximum loading on the damaged structure. The upper bound on the yield stress set in the Standard is 133% of the yield stress, which hasn't been changed with Amendment 2. For steel with a grade minimum yield stress of f_Y = 300 MPa an upper limit yield stress recorded on the mill certificate of 400 MPa would therefore be required.

Maximum Yield Ratio

The yield ratio is the ratio of yield stress over ultimate tensile strength of the steel and has a significant effect on the length of plastic hinge zone developed in a plastically deforming structural assembly. A steel assembly with a lower yield ratio will be able to develop a longer plastic hinge than one with a higher yield ratio. The longer plastic hinge will increase the rotational ductility of the assembly. A yield ratio upper limit of 0.80 has therefore been set. Compliance is allowed on the basis of the mechanical properties reported for the particular batch of steel in the mill test certificate.

Minimum Elongation

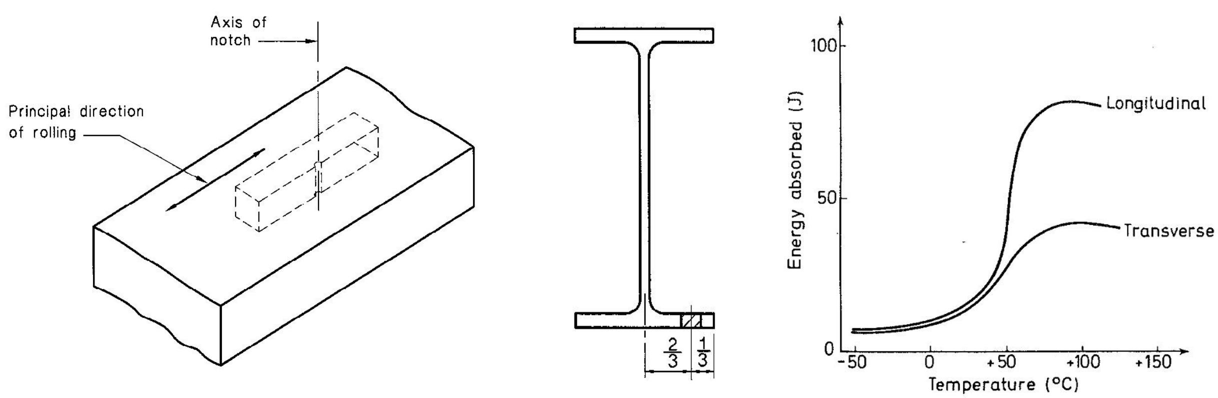
Under cyclic loading plastic deformation accumulates to reduce the available elongation from the steel. The principle is that the greater the initial elongation capability of the steel the greater the accumulated cyclic deformation that the steel can accommodate. Therefore the elongation limit has been lifted to 25%.

Compliance is allowed on the basis of the mechanical properties reported for the particular batch of steel in the mill test certificate.

Minimum Charpy V-Notch Impact Energy

The Charpy V-notch (CVN) impact energy characteristic of a steel is a measure of the steel's ability to prevent the development of rapid cleavage type fractures. The characteristic shape of a Charpy V-Notch energy curve of a steel is typically an s-shape, with a relatively flat lower and upper shelf joined by a steeply rising transition portion. As steel is plastically strained the characteristic curve is found to flatten, with the upper shelf reducing in energy absorption and the transition portion of the curve shifting to a higher temperature. This means that the steel has reduced ability to prevent rapid fracture as it accumulates plastic strain. Some common constructional steels on the international market are susceptible to rapid fracture under significant localised cyclic plastic deformation. Therefore the 70J@0^{o}C requirement has been introduced to ensure that an adequate level of upper shelf impact energy is provided to be able to accommodate the degrading effect of cyclic plastic deformation.

Compliance with the provisions for Charpy V-notch impact energy are based on the average of three tests recorded on the mill certificate for the batch or specific end user testing. For example when L0 steel is ordered there will be Charpy results recorded on the Mill Test certificate that will identify the Charpy values achieved when tested at the mill. The average of the three can then be calculated to see if it achieves the 70J limit and the minimum reported value checked as above. When end user testing is required it is important that testing be done in accordance with the requirements of the relevant steel sections, plate or tube supply standard. Particular care being made to ensure that the location within the section that the impact test specimen is taken from is correct. For sections this is the third point of the flange outstand. The impact specimen must also be aligned longitudinally with the rolling direction of the steel and the axis of the notch should be aligned to run vertically through the thickness of the flange outstand, plate or wall of the tube (Figure 1(a)).



(a) (b)

Figure 1 (a)Location and orientation of Charpy V-Notch test specimens in sections in accordance with AS/NZS 3679.1 (SAA/SNZ 1996); (b) Effect of orientation of CVN specimen on CVN curve characteristics of a free machining steel (Knott, 1973)

Orientation and location of CVN samples within the depth of the plate is important and significant variance in the test results can occur if care is not taken, particularly when testing is done at temperatures around the transition region of the steel (Figure 1(b)). Steel forms a "grain" with small non-metallic particles orienting themselves with the rolling direction. In a way analogous with snapping a piece of timber parallel or transverse to grain the CVN test picks up the "grain" effect. The standard tensile test doesn't tend to be so sensitive to the grain effect as its plastic deformation tends to be governed by gross section plastic deformation rather than localised effects that can occur in notched sections.

Changes to the Welding Requirements

In conjunction with changes to the requirements for steel materials to be used in ductile seismic steelwork changes have also been made to selection of welding consumables and weld heat input. High deposition rate welding with poor Charpy V-notch impact energy rated consumables is to be avoided in seismic resisting structures. The updated requirements for selection of welding consumables is covered in section 2.6.4.5 of the Steel Structures Standard. Welding consumables are required to have a Ships Classification Societies Grade 3 approval as would be required for welding grade L15 steel to the Structural Steel Welding Standard AS/NZS 1554.1 (SAA 2004).

References

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