TECHNICAL NOTE

LOCAL BUCKLING OF UNIVERSAL BEAM FLANGES

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STATEMENT OF PROBLEM

To study fatigue of defective welds, beam-column joints were cyclically loaded at MWD Central Laboratories. However, local buckling occurred in the beam flanges during the first few cycles at displacement ductilities 2.25-2.6. Despite the buckling, the peak resisted load had a maximum of 15% reduction after 10 cycles at these ductilities, and the hysteresis loops showed little change in shape. Nevertheless, because steel frame structures can be expected to sustain a ductility demand of about 4/SM or 6, there is clearly some doubt as to whether the strength of a system already buckling at a DF < 3 would be maintained under the design earthquake. The 310 UB 40 beam tested complied with the current NZ Steel Code[1], which required no stiffeners in this case.

DISCUSSION

Local buckling is generally only of concern in plastic design[2] and is often coupled with lateral torsional buckling[3]. Because local buckling causes the cross-section to become unsymmetrical, the rate of lateral deformation increases. Thus although there may be little strength degradation with buckling, it may effect local stability. Local buckling can be studied from the theory of "torsional buckling of a restrained plate" which provides an upper limit of the ratio of flange width to thickness for no buckling of[3]:

$$\frac{b}{T} = 3.56 \sqrt{\frac{E}{(3\sigma_y + \sigma_f)(1 + 0.2E/E_{st})}} \qquad (1)$$

= 16.7 for the American steel A36 (σ_y = 400 MPa)

Equation 1 is well verified by experimental results[3] for monotonic loading. As E/Est is high (approximately = 35), Eq (1) indicates that b/T is almost proportional to $\sqrt{E_{st}/\sigma_y}$. Under cyclic loading, E_{st} has little meaning and under the Bauschinger softening, one would expect an effectively lower value of E_{st} and hence a lower allowable b/T ratio.

The New Zealand code[2] (clause 10.8.1) requires b/T to be < 17.5 for a 310 UB 40 with specified yield stress of 260 MPa. The actual value of b/T of the beam was 16.2 (thus satisfying the code) and the measured yield stress was 300 MPa. The code equation is expected to anticipate material over strength.

The code limits for b/T appear to be based on monotonic loading with little safety margin. Shepherd and Spring[4] observed flange buckling at the first cycle to D_F = 2.5 with a high strength UB of b/T = 12.1. Hence it is proposed that the allowable b/T ratios be reduced. Further testing must determine the maximum b/T ratio such that 4 cycles at D_F = 6 should be able to be resisted without buckling. Too much conservation would be unwise however, as a reduction in b/T reduces r_{yy} for a given flange area, and this increases the need for lateral bracing for lateral torsional buckling.

NOTATION:

b	flange width
E	initial elastic modulus of steel
E_{st}	strain hardening modulus of steel
r_{yy}	radius of gyration of UB
T	flange thickness
σ_y	yield stress of steel
σ_f	tensile strength of steel

REFERENCES:

1. NZS 3404:1977, New Zealand Standard "Code for Design of Steel Structures", SANZ, Wellington 1977.

2. Bresler and Lin, "Design of Steel Structures", Wiley p43.

3. ASCE Manual No. 41, "Plastic Design in Steel", ASCE 1971.

4. Shepherd, R., and Spring, K.E.C., "Racking Load Tests on a Steel Beam-Column Joint", NZ Engineering, Volume 30, 1975, pp 326-331.

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