



The University of Sydney

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A Full Section Tensile Tests of a Cold-Formed Rectangular Hollow Section

Sample Report for Civil Engineering Students

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Abstract:

This report describes a full section tensile test on a cold-formed rectangular hollow section. The full section tensile test has shown that the use of the yield stress taken from coupons from the faces of the RHS adjacent the weld underestimates the yield stress of the entire section. A weighted average of yield stresses from coupons around the section closely matches the full section tensile properties.

This is not an official report, it is specifically written as a style guide for civil engineering students for writing a laboratory report. It should be read in conjunction with the "Guide for Writing a Good Report". This report does not necessarily incorporate all the requirements of specific laboratory classes. Students should check with any specific instructions.

Students should pay attention to the format, layout and presentation of this report, as opposed to the actual contents.

Students are not expected to type reports – reasonably neat, hand written reports are sufficient.

1 INTRODUCTION

The aim of the full section tensile test was to determine the yield stress and ultimate strength of a rectangular hollow section by testing the full specimen, rather than coupon tests of small samples cut from the RHS.

The yield stress (f_y) of a steel member is a fundamental parameter in strength calculations. A hot-rolled steel section normally has a clearly defined yield stress which can be observed in tensile tests of coupons cut from the section. Cold-formed hollow sections are formed by forming flat steel strip into a circle and welding the edges together. The rectangular profile is then created from the circular shape by pushing in the circle section. The cold work performed on the section increases the yield stress of the section above that of the original strip. Considerable cold-forming work is done in the corners of the RHS. More work is done on the flat face of the RHS opposite the weld, compared to the two flat faces adjacent to the weld. The different amounts of cold work around the section produce considerable variability of yield stress around the section. The variability of yield stress and tensile strength (f_u) has been observed in many test series on cold-formed RHS (CASE1992a). There is even variability of mechanical properties across each flat face of an RHS (Stranghoner *et al* 1995).

This report describes a full section tension test on cold-formed RHS. The results are compared to the yield stresses obtained from coupons cut from the flat faces and corners of the same specimens obtained from another test series (Wikinson 1999).

2 TEST PROGRAM

2.1 TEST SPECIMENS

A cold-formed RHS, manufactured by Tubemakers of Australia Limited (BHP Structural and Pipeline Products), was chosen for the full section tensile tests. The section was a $150 \times 50 \times 3.0$ RHS, in Grade. The section was labelled as shown in Table D.1.

Specimen No.	Section $d \times b \times t$
FS03D	$150 \times 50 \times 3.0$ C450

Table 1: Section Identification

2.2 FULL SECTION TENSILE TEST PROCEDURE

The full section tensile test was performed to the requirements of ASTM A 370 (ASTM 1989). The test was carried out in a 2000 kN capacity DARTEC testing machine using a servo controlled hydraulic ram. A diagram of the test set-up is shown in Figure 1. Snug-fitting solid steel plugs were inserted into each end of the RHS. The plugs ensured that the hydraulic grips of the DARTEC machine could clamp the specimen without crushing. The plugs extended into the RHS for a length greater than that of the grips, but not into the part of the RHS on which elongation was measured. The relevant dimensions are also shown in Figure 1. The gauge length over which

elongation was measured was 200 mm. A strain rate of $1.0 \times 10^{-4} \text{ s}^{-1}$ was used from zero load until yield. A plastic strain rate of $5.0 \times 10^{-4} \text{ s}^{-1}$ was then employed until failure.

Longitudinal strain gauges were placed on each of the wider faces (the webs) of the RHS. Fine scribe marks were made at 10 mm intervals on the specimens to determine the percentage elongation over the gauge length. Load, extension, and strain gauge readings were recorded by a SPECTRA data acquisition system.

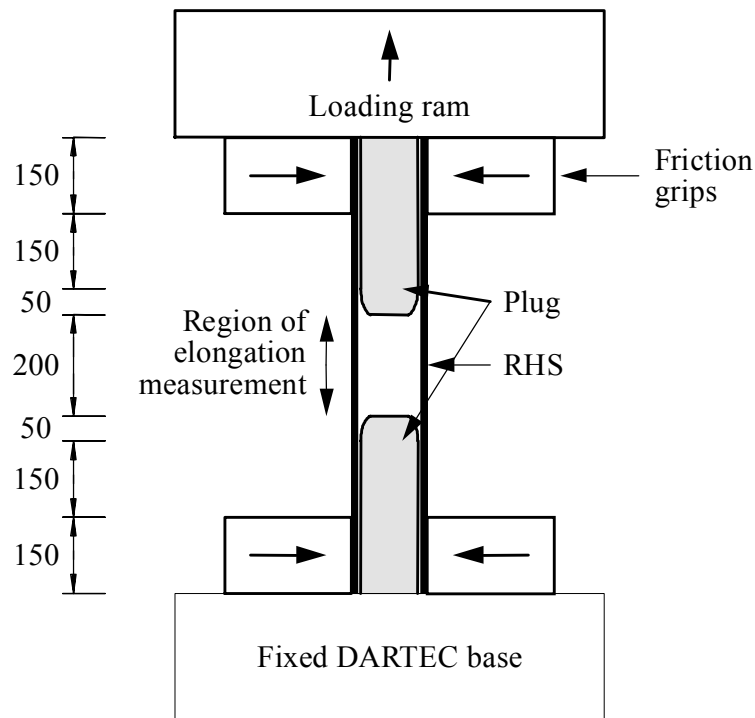


Figure 1: Schematic Detail of Full Section Tensile Test

3 TEST RESULTS

The RHS was tested until failure. Specimen FS03D ($150 \times 50 \times 3.0$ C450) failed by fracture initiated in both of the adjacent faces (the webs). Fracture was sudden. The line of fracture across the web was at an angle of 45° to the direction of loading. The specimens failed at the approximate mid-length of the sample.

Values of the yield stress, ultimate strength and percentage elongation after failure (e) on various gauge lengths were obtained from the RHS. As the yielding was gradual, the yield stress quoted is the 0.2% proof stress. The stress-strain curve was linear only for small strains. The Young's modulus of elasticity (E) was calculated by averaging the slope of the curve over this initial region. The specimen dimensions are listed in Table 2, and the results are given in Table 3. Note that all stresses quoted are *static* values. Static values are obtained by stopping the test machine for about one minute near the yield and ultimate loads. These values are often considerably lower than dynamic values (measured when the test machine is moving).

The stress - strain curve for the full section tensile test is shown in Figures D.2 and D.3. The curves from the individual coupons cut from the faces and the corners are included in Figures D.2 and D.3.

Specimen	Cut from section	d (mm)	b (mm)	t (mm)	r_e (mm)	A_g (mm ²)
FS03D	150 × 50 × 3.0 C450	150.37	49.89	2.95	6.0	1125

Table 2: Section Dimensions for Full Section Tensile Tests

Specimen	Cut from section	E (GPa)	f_y (MPa)	f_u (MPa)	Percentage elongation over gauge length			
					10 mm ^a	20 mm ^a	50 mm ^a	30 mm ^b
FS03D	150 × 50 × 3.0 C450	208	476	528	45	42	26	6.7

Notes: (a) Elongation measured across the failure plane.
(b) Elongation measured outside necking region.

Table 3: Summary of Results for Full Section Tensile Tests

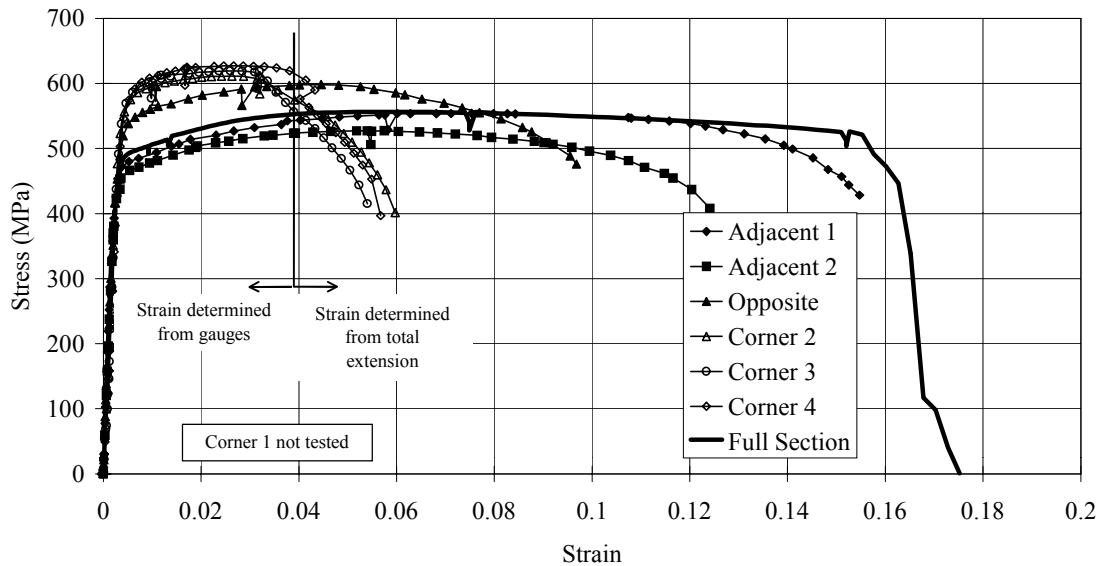


Figure 2: Stress - Strain Curve for Specimen S03

4 COMPARISON OF DIFFERENT METHODS

Table 4 compares the yield stress and tensile strength (in MPa) determined using various methods. The methods are described below. The value in brackets is the difference between the appropriate value and the value obtained from the full section tensile test expressed as a percentage of the full section tensile test result.

Section		Full section	Coupon Tests		
			Ave. of adjacents	Opposite	Weighted average
FS03D 150 × 50 × 3.0 C450	f_y %	476	444 (-6.7)	514 (+8.0)	464 (-2.5)
	f_u %	528	513 (-2.8)	585 (+11)	533 (+0.9)

Table 4: Comparison of Different Methods

The first column of results in Table 4 was obtained from the full section tensile tests. The next three columns are derived from the results of tensile coupon tests. The average of the yield stress of both adjacent faces has been used in this thesis. The yield stress of the opposite face is normally about 10% higher than those of the adjacent faces. The opposite face value has been used by CASE (1992b, 1992c). A weighted average is also given to account for the variability of yield stress about the section. The yield stress of each face and corner is weighted with respect to the proportion of area of the entire section the region contains. Since no coupon was cut from the face containing the weld, this face is assumed to have the same properties as the opposite face.

5 DISCUSSION

The average of the adjacents is slightly lower than the weighted average. This is because the higher strength corners comprise a small percentage of the area, and being a high aspect ratio section the flat area of the adjacents (the webs) is larger than the flange. For thicker sections the influence of the corners would be greater, and for lower aspect ratio sections (eg SHS) the influence of the higher strength opposite face increases. The higher strength in the corners would be more significant under bending, since the corners have a higher lever arm to the bending neutral axis, compared to the web.

The weighted average, adjacent average and full section yield stress are all reasonably close together (10% for C350). Use of the average of the adjacents would probably underestimate the strength of the section.

All results in this thesis have used the average of the adjacents in strength calculations. For in-plane bending, the maximum moment achieved by the compact specimens was, on average, 10 - 20 % higher than the plastic moment based on the average of the adjacents. In stub column tests, the maximum load was, on average, 10 - 20 % higher than the section capacity based on the average of the adjacents. This indicates that the use of the average yield stress of the adjacent faces is slightly conservative to the order of approximately 10 %. Nevertheless, the average yield stress of the adjacent faces provides a useful lower bound for strength design which is not overly conservative.

In plastic bending tests and stub column tests by CASE (1992b, 1992c), the yield stress of the opposite face was used. The conclusion from these tests was that the reliability of strength design,

using the yield stress of the opposite face, was comparable to the reliability of hot rolled steel beams used in the development of AS 4100. This indicates that the use of the yield stress of the opposite face is suitable in strength design

6 CONCLUSION

The full section tensile test has shown that the use of the yield stress taken from coupons from the faces of the RHS adjacent the weld underestimates the yield stress of the entire section. A weighted average of yield stresses from coupons around the section closely matches the full section tensile properties.

7 REFERENCES

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