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TESTS OF PURLINS WITH SCREW FASTENED SHEETING UNDER WIND UPLIFT

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Summary

The paper describes a test program on purlin-sheeting systems for which the sheeting was screw fastened to the purlins. The test program simulates wind uplift. Z-section purlins were tested in three span and two span continuous lapped configurations. Both C- and Z-section were tested as simple spans. The test purlins were supported by a range of bridging (bracing) members ranging from no bracing to 2 braces per span.

The test results are compared with the design method in the Australian Cold-Formed Steel Structures Standard (AS1538-1988). Tests of unbraced simply supported purlins are compared with the design method of Pekoz and Soroushian. Tests of unbraced continuous Z-sections are compared with the design method proposed by LaBoube et al.

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1 INTRODUCTION

Roof systems composed of high tensile steel profiled sheeting screw-fastened to cold-formed steel purlins of high strength steel are very common in Australia and throughout the world. In Australia, the design of such systems is usually performed according to the Australian Cold-Formed Steel Structures Code (AS1538-1988) (Standards Association of Australia 1988) and is usually governed by wind uplift. Despite their wide use, very little data is available in the public domain on the strength and deflection characteristics of such systems. In 1988, a large vacuum test rig was commissioned in the Centre for Advanced Structural Engineering at the University of Sydney using funds provided by the Metal Building Products Manufacturers Association for the purpose of providing test data on metal roofing systems. The test rig uses a conventional vacuum box to simulate wind uplift.

An extensive test program on purlin-sheeting systems with screw fastening was performed in 1989 in the vacuum test rig. Z-section purlins were tested in three span and two span continuous lapped configurations. Both C and Z-sections were tested as simple spans. The test purlins were supported by a range of bracing (bridging) members ranging from no bracing to 2 braces per span. In addition, a range of section slenderness values was used so as to precipitate both local buckling and yielding failures in the sections. The tests were called the Common Test Program since the purlins, sheeting, screw fastenings, laps, bridging (bracing) and cleats were common to the major manufacturers in Australia.

The purpose of the paper is to compare the test results with design values for purlin sections. The design procedures used are those in the Australian Cold-Formed Steel Structures Standard AS1538-1988 (Standards Association of Australia 1988)) and those proposed for unbridged (unbraced) simply supported purlins (Pekoz and Soroushian 1982) and continuous Z-section purlins (LaBoube et al. 1988). In addition, proposals for improvement in the design procedures are discussed.

2 TEST RIG

The test rig consists of a vacuum chamber of length 21 metres (69 ft), of height 4 metres (13.1 ft) and of width approximately 1 metre (3.3 ft). The front and back planes (21 m × 4 m) consist of purlin and sheeting roofing systems sealed with plastic sheeting located between the purlins and metal roof sheeting. A cross-section of the rig is shown in Fig. 1. The top, bottom and end planes consist of stiffened steel plating with the stiffeners external to the vacuum chamber. The plastic sheeting is attached to the top, bottom and end planes in such a way as not to constrain the roofing system under test.

Transverse support frames, as shown in Fig. 1, support vertical I-section steel members with cleats attached. The vertical members simulate rafters in prototype structures. The purlins are attached to the cleats on the vertical members. The purlins and sheeting are not attached to the vacuum chamber or support frames at any other points.

Air is sucked from the chamber using a Nucon Exhauster with capacity 3600 m^3 per hour (127000 ft^3 per hour). The pressure in the chamber is controlled by an adjustable flap at the northern end which provides a controlled leak. The pressure difference between the inside and outside of the chamber is measured using two pressure transducers, one at either end of the rig.

3 TEST SPECIMENS

3.1 Test Series

The tests on the three span lapped Z-sections are designated Series 1 (S1), the tests on the two span lapped Z-sections are designated Series 2 (S2), and the tests on the simply supported C and Z-sections are designated Series 3 (S3).

3.2 Overall Geometry

The overall dimensions of the Series 1 and 2 lapped test specimens were 21 metres long by 4 metres high as shown in Figs. 2(a) and 2(b) respectively giving spans of 7 metres (23 ft) and 10.5 metres (34.5 ft) respectively. The overall dimensions of the Series 3 simply supported test specimens were 7 metres long by 4 metres high as shown in Fig. 2(c). The 4 lines of purlins were equally spaced at 1200 mm (47.2 in) with the edge purlins 200 mm (7.9 in) from the top and bottom of the sheeting. The ribs of the sheeting were located vertically. The purlins were attached to cleats at 7000 mm (275.5 in) centres for Series 1 and 3, 10500 mm (413.4 in) centres for Series 2, and were lapped over the interior supports in Series 1 and 3.

3.3 Purlin Types and Dimensions

Three basic Z-sections were used for the Series 1 tests. These were 150 mm (5.9 in) deep with 1.9 mm (0.075 in) thickness (Z150-19), 200 mm (7.9 in) deep with 1.5 mm (0.059 in) thickness (Z200-15) and 200 mm (7.9 in) deep with 1.9 mm (0.075 in) thickness (Z200-19). One basic Z-section was used for the Series 2 testing. This was 300 mm (11.8 in) deep with 2.5 mm (0.098 in) thickness (Z300-25). One basic Z-section and one basic C-section were used for the Series 3 testing (Z200-24, C200-24). These were 200 mm (7.9 in) deep with 2.4 mm (0.094 in) thickness. The mean measured overall depth, overall flange widths, overall lip depth and total thicknesses including coatings of the sections are summarised in Table 1. A summary of the purlins used in the different tests is given in Table 2.

All purlins were constructed from G450 steel to Australian Standard AS1397-1984 (Standards Association of Australia 1984) of yield stress 450 MPa (65 ksi).

3.4 Sheeting Types and Screw Fastenings

Two different sheeting types were used for the tests. These were Amatek MONOCLAD sheeting and Lysaght TRIMDECK sheeting. The mean measured thickness including coatings was 0.47 mm (0.019 in). Both of these sheetings, although from different manufacturers, had very similar profiles. The particular sheeting used on each test is given in Table 2.

Fasteners for Series 1 consisted of self-tapping 12 mm (0.47 in) diameter screws with a Neoprene washer under the head at every crest. Fasteners for Series 2 Tests 1 and 2 consisted of self-tapping 12 mm (0.47 in) diameter screws with a Neoprene washer under the head at every crest. Fasteners for Series 2 Test 3 consisted of self-tapping 14 mm (0.55 in) diameter screws with cyclone washers under the head at every crest. Fasteners for Series 3 consisted of self-tapping 12 mm (0.47 in) diameter screws with a Neoprene washer under the head at every crest for Test No. 1 and 14 mm (0.55 in) diameter screws with a cyclone washer under the head at every crest for all other tests including Test No. 1R.

After a pressure of 2.6 kPa (54.3 psf) in Series 2 Test 1, an additional line of screw fasteners was included in the pans at points midway between the crests and approximately midway across the flanges of the purlins. These additional fasteners were used on the southern end only for the two inner purlins for a distance up to approximately 6000 mm (236.2 in) from the southern end. They were used after it was observed that the original line of fasteners was close to the web.

The sidelaps were fastened midway between the purlins with 8 mm (0.31 in) diameter self-tapping screws for all tests.

3.5 Bridging

The bridging used for each test is summarised in Table 2. The bridging for the Series 1 tests consisted of 70 mm × 32 mm × 1.25 mm (2.8 in × 1.3 in × 0.049 in) unlipped channels bolted at each end to the webs of the purlins. The positions of the rows of bridging are shown for each test specimen in Fig. 3(a). The bridging for Series 2 consisted of 150 mm × 65 mm × 1.5 mm (5.9 in × 2.6 in × 0.059 in) unlipped channel sections bolted at each end to the webs of the purlins. The positions of the rows of bridging are shown for each Series 2 test specimen in Fig. 3(b). The bridging for the Series 3 tests consisted of 70 mm × 32 mm × 1.25 mm (2.8 in × 1.3 in × 0.049 in) unlipped channels bolted at each end to the webs of the purlins. The positions of the rows of bridging are shown for each Series 3 test specimen in Fig. 3(c).

For all tests, the bridging only spanned between the purlins and was not connected to external supports.

3.6 Cleats, Laps and Bolts

Standard two-hole cleats were used for all tests. For the Series 1 tests, the standard cleats had nominal section dimensions 75 mm × 200 mm × 8 mm (2.9 in × 7.9 in × 0.31 in). Two M12 Grade 8.8 bolts (0.5 in) were used at each cleat. Two bolts were used in both ends of each lap for all Series 1 tests, one bolt in the web and one bolt in the unsheeted flange. The distance between the bolt centrelines for all Series 1 laps was 900 mm (35.4 in). For the Series 2 tests, the standard cleats had nominal section dimensions 100 mm × 310 mm × 11 mm (3.9 in × 12.2 in × 0.43 in). The distance between the bolt centrelines for all Series 2 laps was 1500mm (59.1 in). Two M16

Grade 8.8 bolts (0.63 in) were used at each cleat. Two bolts were used in both ends of each lap for all Series 2 tests, one bolt in the web and one bolt in the unsheeted flange. For the Series 3 tests, standard cleats had nominal section dimensions 100 mm × 310 mm × 12 mm (3.9 in × 12.2 in × 0.43 in). Two M12 Grade 8.8 (0.5 in) bolts were used at each cleat.

For all tests, all bolts were torqued to 54 N.m (40 ft.lbs).

4 TEST PROCEDURE AND INSTRUMENTATION

4.1 Instrumentation

The tests were instrumented to electronically measure displacements and pressures. Six displacement transducers were used to measure the vertical and horizontal displacements of the purlins at the centre of each of the three spans in the Series 1 tests, at the centre of each of the two spans in the Series 2 tests, and the centre of the single span in the Series 3 tests. Only the bottom three rows of purlins were instrumented. The displacement transducers were connected to the test specimen by long wires so that displacements normal to the direction being measured did not produce a significant alteration in the readings. Two pressure transducers were used, one at each end of the rig. Both displacement and pressure transducers were connected to the data logger which consisted of an HP3054A interfacing to an Apricot microcomputer.

4.2 Test Procedure

The pressure was generally increased in 0.2 kPa (4.2 psf) increments until the vicinity of failure where the increment was reduced to approximately 0.1 kPa (2.1 psf). In several of the tests, the pressure was further increased after initial local failure in the span at one end of the rig or the other until failure occurred at the other end of the rig. Readings of pressure and displacement were taken at all increments. Readings were normally taken after unloading to determine the permanent deformation in the structure.

For Series 1 Tests 4 and 9 and for Series 2 Test 1, where tears occurred in the plastic sheeting, the structure was unloaded and a new test commenced after repair. For Series 2 Test 1, additional screw fasteners were added prior to reloading as described in Section 3.4 above. For Series 3 Test 1, where the sheeting broke away from the purlins after large twisting deformations caused the screws to pull through the crests of the sheeting, the screw fasteners were replaced with 14 mm diameter screws with cyclone washers under the heads. The test was repeated and the test is called Series 3 Test 1R.

5 TEST RESULTS

5.1 Measured Failure Pressures

A complete summary of the measured pressure differences at failure is given in Table

3. The range varied from 1.86 kPa (38.8 psf) for a three span lapped Z150-19 section with no bridging to a value of 4.54 kPa (94.8 psf) for a two span lapped Z300-25 section with two rows of bridging in each span.

5.2 Failure Modes

In all cases, other than Series 3 Test 1, failure involved local buckling of the purlin section at the flange-web junction, the lip-stiffener or across the whole flange. Series 3 Test 1 failed when the sheeting broke away from the purlins after large twisting deformations caused the screws to pull through the crests of the sheeting. For Series 1, all purlins other than Test No. 6 failed in the end span. Series 1 Test 6 failed at the end of the lap in the interior span. In Series 1 Tests 7, 8 and 9 and Series 2 Tests 2 and 3, significant distortion occurred at the end of the lap in the end span. The failure positions and failure types are shown for all test specimens in Figs. 3(a), 3(b) and 3(c).

In the Series 1 tests, the unbridged purlins (S1T1, S1T4, S1T7) generally failed by a single flange-web local buckle occurring towards the centre of each purlin in one of the end spans. The flange-web local buckling mode is shown in Fig. 4. The purlins with one row of bridging (S1T2, S1T5, S1T8) generally had a combination of a flange-web local buckle in the section of purlin on one side of the bridge and a lip stiffener buckle in the section on the other side of the bridge, as shown in Fig. 5. In some instances, the flange-web local buckle or lip-stiffener buckle occurred at the bridging point. The purlins with two rows of bridging (S1T3, S1T6, S1T9) in the end span generally had a failure of the whole flange of the type shown in Fig. 6 or a failure similar to that of the purlins with one row of bridging in the end span.

Distortion of the type which occurred at the end of the laps in Series 1 Tests 7, 8 and 9 and Series 2 Tests 2 and 3 is shown in Fig. 7.

In the Series 2 tests, the unbridged purlins (S2T1) failed by a single flange-web local buckle of the type shown in Fig. 4. The purlins with one row of bridging (S2T2) had a flange-web local buckle in the section of purlin nearer the simply supported end. Section distortion of the type shown in Fig. 7 was also visible at the end of the lap in this test. The purlins with two rows of bridging (S2T3) had a combination failure with a flange-web local buckle between the bridging points and a failure of the whole inner flange at the end of the lap.

In the Series 3 tests, the unbridged purlins with cyclone washers (S3T1R and S3T4) failed by a single flange-web local buckle of the type shown in Fig. 4 occurring towards the centre of the purlins. The Z-sections with one row of bridging (S3T2) had a combination of a flange-web local buckle in the section of lower inner purlin on one side of the bridge and a lip stiffener buckle in the section on the other side of the bridge of the type shown in Fig. 5. The Z-sections with two rows of bridging (S3T3) underwent a flange-web local buckle in the vicinity of the centre of the span. The C-sections with one row of bridging (S3T5) had a general flange failure of the type shown in Fig. 6. The C-sections with two rows of bridging (S3T6) underwent a combination of flange-web local buckles, lip-stiffener buckles and outer flange general failure. It is interesting to observe that in the Series 3 tests, the C-sections with bridging, which twisted less than the Z-sections, underwent outer flange general failure rather than lip-stiffener failure or flange-web local buckling as for the Z-sections.

5.3 Load-Deflection Response

The load-deflection response curves of all specimens are given in detailed reports (Centre for Advanced Structural Engineering 1989, 1990a, 1990b). Several typical load-deflection response curves are given here to demonstrate observed behaviour. They show the deflections normal to the plane of the wall.

Fig. 8 shows the displacement on the inner end purlin for Test S1T2 which had one row of bridging. The readings for all four inner end purlins were almost identical. The values are compared with a simple linear elastic analysis of a continuous beam accounting for the double section in the region of the laps. There is a change in the stiffness at about 0.7 kPa, probably as a result of slipping on the cleat bolts as friction was overcome. The graph is then linear and approximately parallel with the theoretical graph until close to failure.

Fig. 9 shows the displacement on an inner end purlin for Test S1T7 which had no bridging. As for the previous case, the readings for all four inner end purlins were almost identical and so only one has been shown. The values are compared with a linear elastic analysis. The experimental results are more nonlinear for this test as a result of the twisting of the unbridged purlin. The stiffness in the midrange after initial slipping and before significant twisting was close to the theoretical value.

5.4 Determination of Load Ratio in Purlins

One of the main purposes of the deflection measurements perpendicular to the plane of the wall system was to determine the initial flexibilities of the inner (F(INNER)) and outer (F(OUTER)) purlins so that the proportion of the total load carried by the inner and outer purlins could be estimated. The ratios are all summarised in Table 3.

For the Series 1 tests, the ratios (F(INNER)/F(OUTER)) are based on the secant values at 1.0 kPa (20.9 psf) and 2.0 kPa (41.8 psf). For Tests S1T1 - S1T3, which exhibited some nonlinearity at 2.0 kPa, the mean ratio has been computed at 1.0 kPa as 1.63. For Test S1T4 - S1T6, which exhibited some nonlinearity at 2.0 kPa, the mean ratio has been computed from the values at 1.0 kPa as 1.82. For Test S1T7 - S1T9 , the ratio has been computed at 2.0 kPa as 1.86. For the Series 2 tests, the ratios (F(INNER)/F(OUTER)) are based on the secant values at 2.0 kPa and 3.0 kPa. The mean ratio has been computed as 1.73 excluding the values for the southern end in Test S2T1 at 3.0 kPa where substantial nonlinear response occurred. For the Series 3 tests, the ratios (F(INNER)/F(OUTER)) are based on the secant values at 1.0 kPa and 2.0 kPa. For Test S3T1, which exhibited considerable nonlinearity at 2.0 kPa, the ratio is significantly higher than for all other tests. Hence it has been ignored in computing the mean values. The mean value computed for all tests is 1.71.

5.5 Line Loads on Inner Purlins

If the load is apportioned between the inner and outer purlins based on the assumption that the sheeting is a continuous beam spanning the four purlins which are assumed not to deflect, then the ratio of the load on the inner and outer purlins can be determined from a statically indeterminate beam analysis to be 1.86. However, the inner purlins deflect more than the outer purlins as a consequence of the additional load upon them. In this case, some additional load is transferred to the outer purlins and so the load ratio will be less than 1.86. Assuming that the measured values of the different deflections of the inner and outer purlins are purely a function of the load carried, the ratio of the load on the inner and outer purlins is therefore the ratio F(INNER)/F(OUTER).

The line loads on the inner purlins may be computed from the average line loads on the assumption that the relative deflections are a result of the relative loads, and that the mean value for a certain purlin size can be used for all tests of that size, so that:

$$\text{Computed Line Load on Inner Purlin} = \text{Average} \times \frac{F(\text{INNER})}{F(\text{OUTER})+F(\text{INNER})} \times 2$$

The computed values are set out in Table 3. The percentage increase for the inner purlin based on the measured displacements ranges from 24 to 30 percent depending upon the configuration.

It should be appreciated that the computed line loads are based on several assumptions. These assumptions are:

(a) The average value of all the tests of a certain size purlin has been used to compute the load on each test even though there is a variation from one test to the next.

(b) The values of flexibility are based on the deflections at 1.0, 2.0 or 3.0 kPa and not those at ultimate. There may be a redistribution of loads between the purlins as the ultimate load of the system is approached.
However the nature of the structural response of the bridged purlins, which is almost linear up to the point of localised failure, indicates that this method is fairly sound.

6 DESIGN LOADS

The design of laterally unbraced and intermediately braced beams is set out in Section 3.3 of AS1538-1988 (Standards Association of Australia 1988). The design procedure is based on the computation of the elastic flexural-torsional buckling stress for combination with the yield stress of the steel according to Clause 3.3.2 (Maximum Permissible Stress). The Australian Standard allows an elastic flexural-torsional buckling analysis to be used in place of the formulae given in the standard. For simply supported and continuous beams, a finite element buckling analysis of the type described in Section 5.2.2 of Hancock (1988) can be performed allowing for :

(a) Type of beam support including simply supported or continuous.

(b) Loading position including top flange, shear centre and bottom flange.

(c) Positioning and type of braces (bridging).

(d) Restraint provided by sheeting including the membrane, shear and flexural stiffnesses.

The analysis described applies to sections symmetric with respect to the plane of loading. For the case of C and Z-sections, a model developed by Ings and Trahair (1984) sets out assumptions in relation to the application of the buckling analysis to these sections. The model includes diaphragm shear stiffness but not the flexural stiffness of the sheeting.

The computed design loads based on this model taken in conjunction with the finite element analysis are set out in Table 3. In all cases other than Series 2 Test 3, flexural-torsional buckling controlled the design. For Series 2 Test 3, combined shear and bending in the web at the end of the lap controlled the design. The factor of safety determined by dividing the test line load on the inner purlin by the design load is also given in Table 3.

The computed factors of safety range from 1.65 to 6.05. The mean value for purlins with two rows of bridging (2 in the end span only for Series 1) is 1.96, for one row of bridging is 2.58 and for no bridging is 4.06. Clearly, the model becomes less accurate as the amount of bridging is decreased. This conservatism is most likely a consequence of the fact that the sheeting flexural stiffness provides torsional restraint to the purlins. This torsional restraint is not included in the model and becomes more important for purlins with no bridging where the main resistance to twisting comes from the sheeting restraint. For purlins with two rows of bridging, the bridging is more important in providing torsional restraint and has been included in the analysis. An obvious improvement to the model is to include torsional restraint provided by the sheeting. However, this restraint involves the screw fastener and needs to be quantified. Research in this area is continuing at the University of Sydney.

A design method for unbridged simply supported purlins under wind uplift was presented by Pekoz and Soroushian (1982). A summary of the method is given in Section 5.5 of Hancock (1988). The method is applicable to Test Nos. S3T1R and S3T4 which were both simply supported over 7 metres (23 ft) span and were unrestrained from twisting except by torsional restraint from the sheeting. The method uses a spring stiffness (K) based on a test of a unit length of purlin attached to the sheeting. The K values determined by test for the sheeting/purlin/screw fastening combinations in Test Nos. S3T1R and S3T4 were 0.060 N/mm^2 (9.0 psi) and 0.061 N/mm^2 (8.8 psi) respectively. Using these values of K in conjunction with the purlin dimensions in Table 1, a yield stress of 450 MPa (65 ksi) and assuming no initial imperfections gives failure line loads of 3.60 kN/m (20.6 lb/in) and 3.67 kN/m (21.0 lb/in) for Test Nos. S3T1R and S3T4 respectively. These values are close to the actual failure loads of 3.28 kN/m and 3.63 kN/m given in Table 3.

For continuous Z-section purlins without bridging, a simple design method based on tests was given by LaBoube et al. (1988). The method simply assumes that the design load for unbridged purlins is 70 percent of that for purlins which are completely prevented from twisting. The test results in the current program indicate that purlins without bridging fail at a load which is in the range 66 – 77 percent of those with two rows of bridging which are therefore fairly heavily restrained against twisting. The current test program is therefore in line with the conclusions of LaBoube et al. (1988) for continuous Z-section purlins without bridging.

7 CONCLUSIONS

The results of the purlins tested in the vacuum type purlin test rig are set out in this paper. The test rig appears to have functioned satisfactorily with no apparent difficulties in controlling applied pressure. No restraint was applied to the purlins and sheeting other than that of the cleats attached to the rafters.

Several general conclusions regarding the behaviour of the purlins can be made. These are:

(a) The loads supported by purlins without bridging ranged from 66 to 77 percent of those with two rows of bridging. This is in line with the conclusions of LaBoube et al. (1988) where a value of 70 percent is recommended for design.

(b) Purlins without bridging twisted substantially more than those with bridging and produced a more nonlinear response especially for deflections normal to the plane of the wall. As a consequence, purlins with bridging were stiffer in bending in their plane than those without bridging.

(c) The position of the screw fasteners relative to the width of the flange was found to have a large effect on the nonlinear twisting response of the purlins without bridging and consequently on the ultimate load.

(d) Side lap fasteners were sufficient to transfer membrane forces to the cleats at the ends of the purlins and the need for attachment of the bridging to stiff supports was not apparent during testing.

(e) All test specimens failed suddenly by localised failure of the purlins at the flange-web junction, the lip-stiffener or across the full width of the flange except for the simply supported Z-sections without cyclone washers and bridging which failed by the screw fasteners pulling through the crests of the sheeting after substantial twisting of the unbridged purlins.

(f) The ratio of the loads on the inner and outer purlins varied from 1.62 to 1.86 depending on the flexibility of the purlins. These values can be compared with a value of 1.86 based on the assumption that the sheeting is a continuous beam spanning vertically on unyielding supports.

Several general conclusions regarding the comparison of the design procedure in the Australian Standard (1988) with the test results can be made. These are:

(a) The Ings/Trahair model based on a finite element analysis is fairly accurate for purlins with two rows of bridging but is overly conservative for purlins with one row of bridging and extremely conservative for purlins with no bridging.

(b) The torsional restraint provided by the sheeting plays a large part in the strength of the purlin-sheeting system for purlins with little or no bridging, but is not important for purlins with two rows of bridging.

The design method of Pekoz and Soroushian (1988) provides accurate estimates of the failure loads of simply supported purlins without torsional restraint except from sheeting.

8 ACKNOWLEDGEMENTS

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9 APPENDIX - REFERENCES

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TABLE 1 - MEAN SECTION DIMENSIONS

(All dimensions in millimetres)

Purlin	Depth	Flange		Lips	Thickness
		Wide	Narrow		
Z150-19	152.5	65.6	59.3	17.1	1.92
Z200-15	202.0	79.5	70.8	18.1	1.51
Z200-19	200.0	77.8	72.0	18.2	1.93
Z300-25*	300.0	105.5	91.9	31.3 25.9	2.53
Z300-25**	305.5	102.9	96.3	29.4 25.8	2.53
Z200-24	205.0	83.0	74.0	20.0	2.45
C200-24	206.0	77.1	77.1	21.3	2.45

* Tests S2T1, S2T2 ** Test S2T3

(1 in = 25.4 mm)

TABLE 2 - TEST SPECIMEN DETAILS

Series No.	Test No.	Purlin Size	Sheeting	Lap length (bolt centre)	Bridging
1	1	Z150-19	MONOCLAD	900 mm	0 - 0 - 0
1	2	Z150-19	MONOCLAD	900 mm	1 - 1 - 1
1	3	Z150-19	TRIMDECK	900 mm	2 - 1 - 2
1	4	Z200-15	TRIMDECK	900 mm	0 - 0 - 0
1	5	Z200-15	TRIMDECK	900 mm	1 - 1 - 1
1	6	Z200-15	TRIMDECK	900 mm	2 - 1 - 2
1	7	Z200-19	TRIMDECK	900 mm	0 - 0 - 0
1	8	Z200-19	TRIMDECK	900 mm	1 - 1 - 1
1	9	Z200-19	TRIMDECK	900 mm	2 - 1 - 2
2	1	Z300-25	MONOCLAD	1500 mm	0 - 0
2	2	Z300-25	MONOCLAD	1500 mm	1 - 1
2	3	Z300-25	TRIMDECK	1500 mm	2 - 2
3	1,1R	Z200-24	TRIMDECK	-	0
3	2	Z200-24	TRIMDECK	-	1
3	3	Z200-24	TRIMDECK	-	2
3	4	C200-24	MONOCLAD	-	0
3	5	C200-24	MONOCLAD	-	1
3	6	C200-24	MONOCLAD	-	2

0 - 0 - 0 , 0 - 0 , 0 refer to no bridging

1 - 1 - 1 , 1 - 1 , 1 refer to one row of bridging in each span

2 - 2 , 2 refer to two rows of bridging in each span

2 - 1 - 2 refers to one row of bridging in centre span and two rows of bridging in end span

(1 in = 25.4 mm)

TABLE 3 - FAILURE PRESSURES, LOADS AND FACTORS OF SAFETY

Series No. Test No.	Failure Pressure (kPa)	Computed Load Factor on Inner Purlin	Computed Line Load on Inner Purlin (kN/m)	Design Load (kN/m)	Factor of Safety
S1T1	1.86	1.24	2.31	0.63	3.67
S1T2	2.12	1.24	2.63	1.14	2.31
S1T3	2.40	1.24	2.98	1.45	2.06
S1T4	2.00	1.29	2.58	0.80	3.23
S1T5	2.28	1.29	2.94	1.55	1.90
S1T6	3.00	1.29	3.87	2.19	1.76
S1T7	2.70	1.30	3.51	1.07	3.28
S1T8	3.29	1.30	4.28	2.01	2.13
S1T9	3.50	1.30	4.55	2.76	1.65
S2T1	3.41	1.27	4.33	1.30	3.33
S2T2	3.88	1.27	4.93	2.16	2.28
S2T3	4.54	1.27	5.77	2.53	2.28
S3T1	2.10	1.26	2.65	0.67	3.96
S3T1R	2.60	1.26	3.28	0.67	4.90
S3T2	2.93	1.26	3.69	1.58	2.34
S3T3	3.78	1.26	4.76	2.39	1.99
S3T4	2.88	1.26	3.63	0.60	6.05
S3T5	2.88	1.26	3.63	1.41	2.57
S3T6	3.74	1.26	4.71	2.31	2.04

(1 in = 25.4 mm, 1 psi = 6.895 kPa, 1 kPa = 20.9 psf,

1 kN/m = 5.72 lb/in = 477 kip/ft)

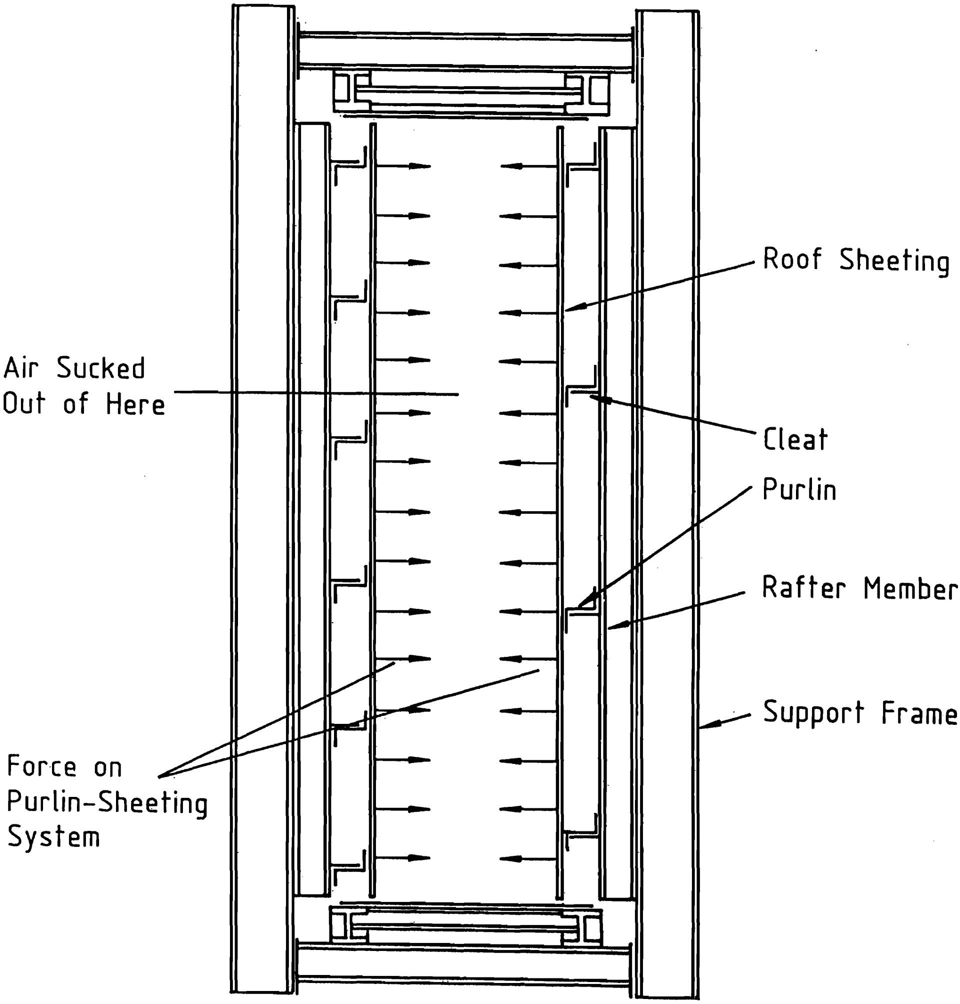


FIG.1 SECTION OF VACUUM TYPE PURLIN TEST RIG

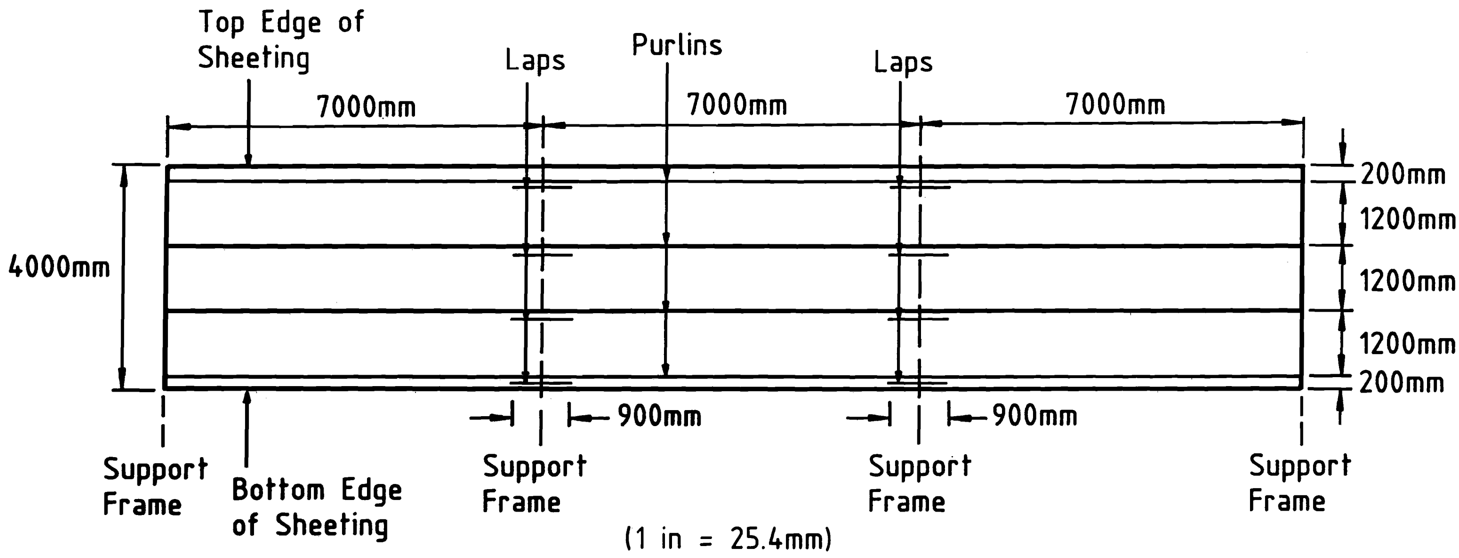
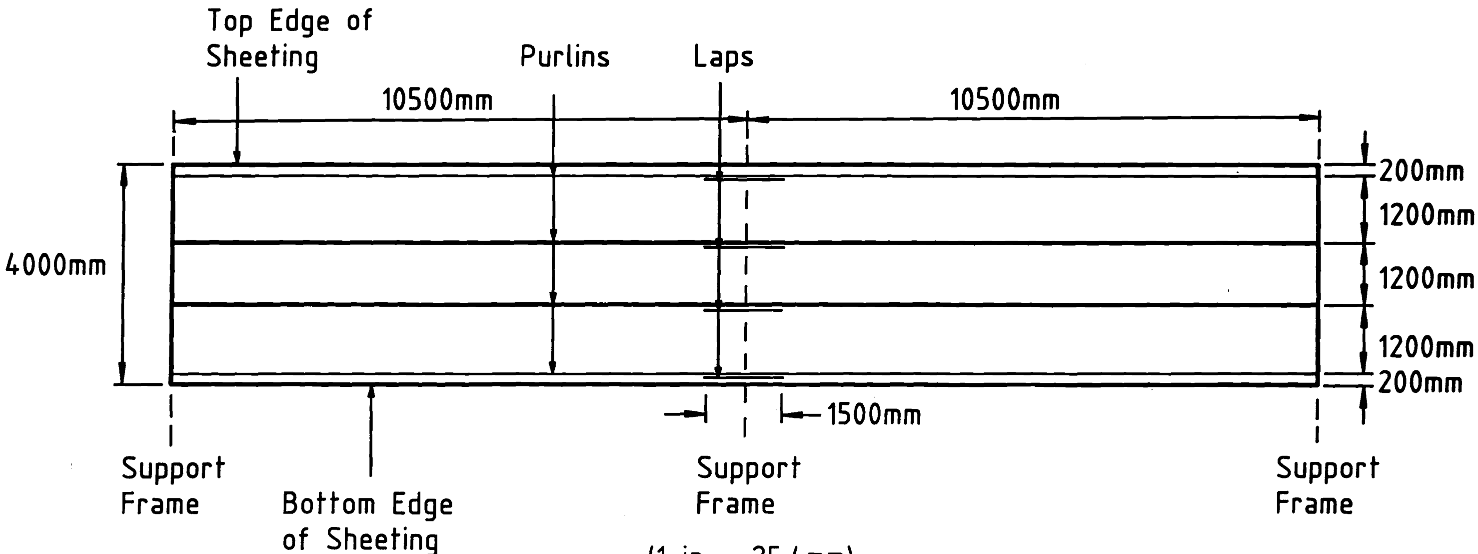


FIG.2(a) TEST SPECIMEN DIMENSIONS - SERIES 1



(1 in = 25.4mm)

FIG.2(b) TEST SPECIMEN DIMENSIONS - SERIES 2

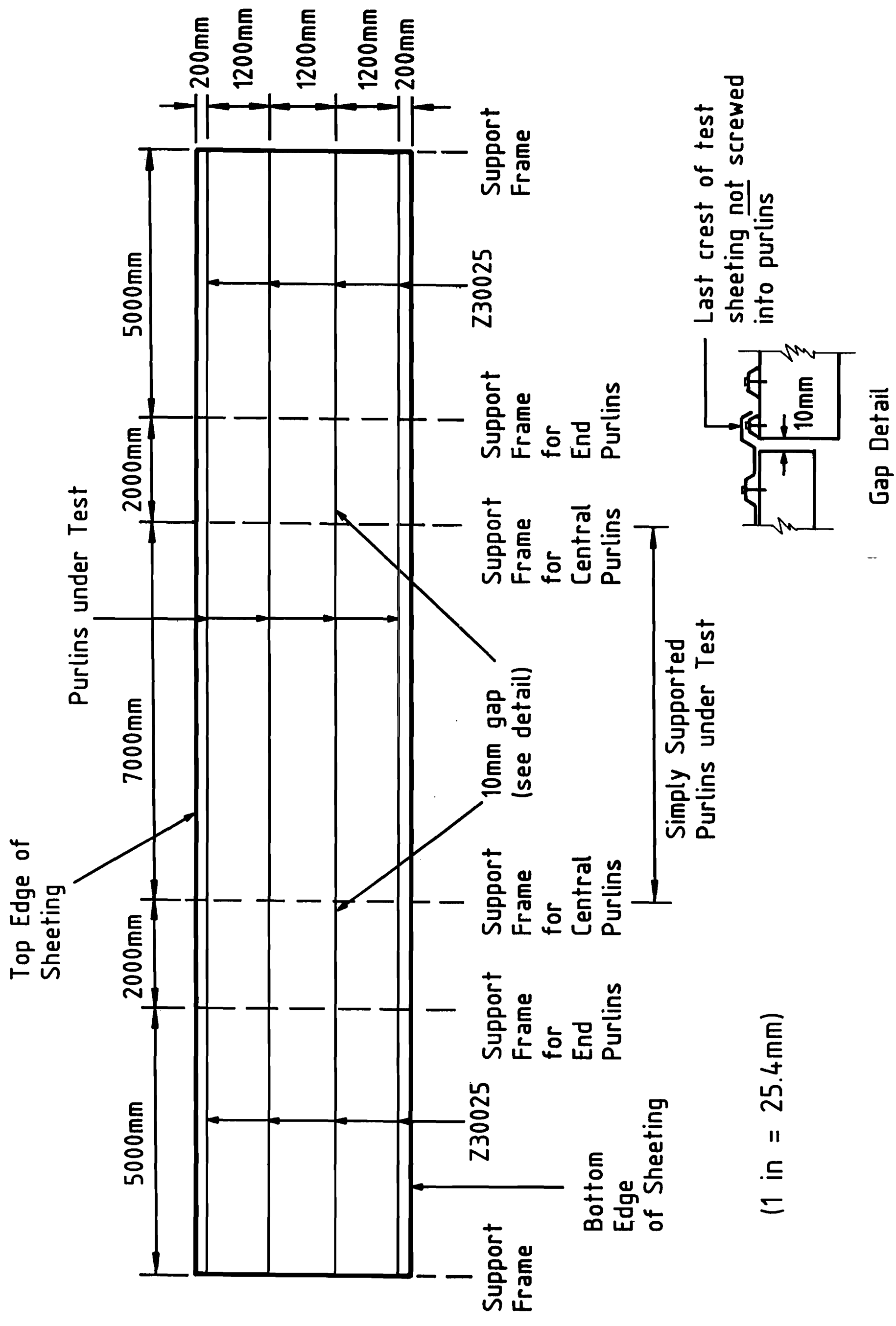
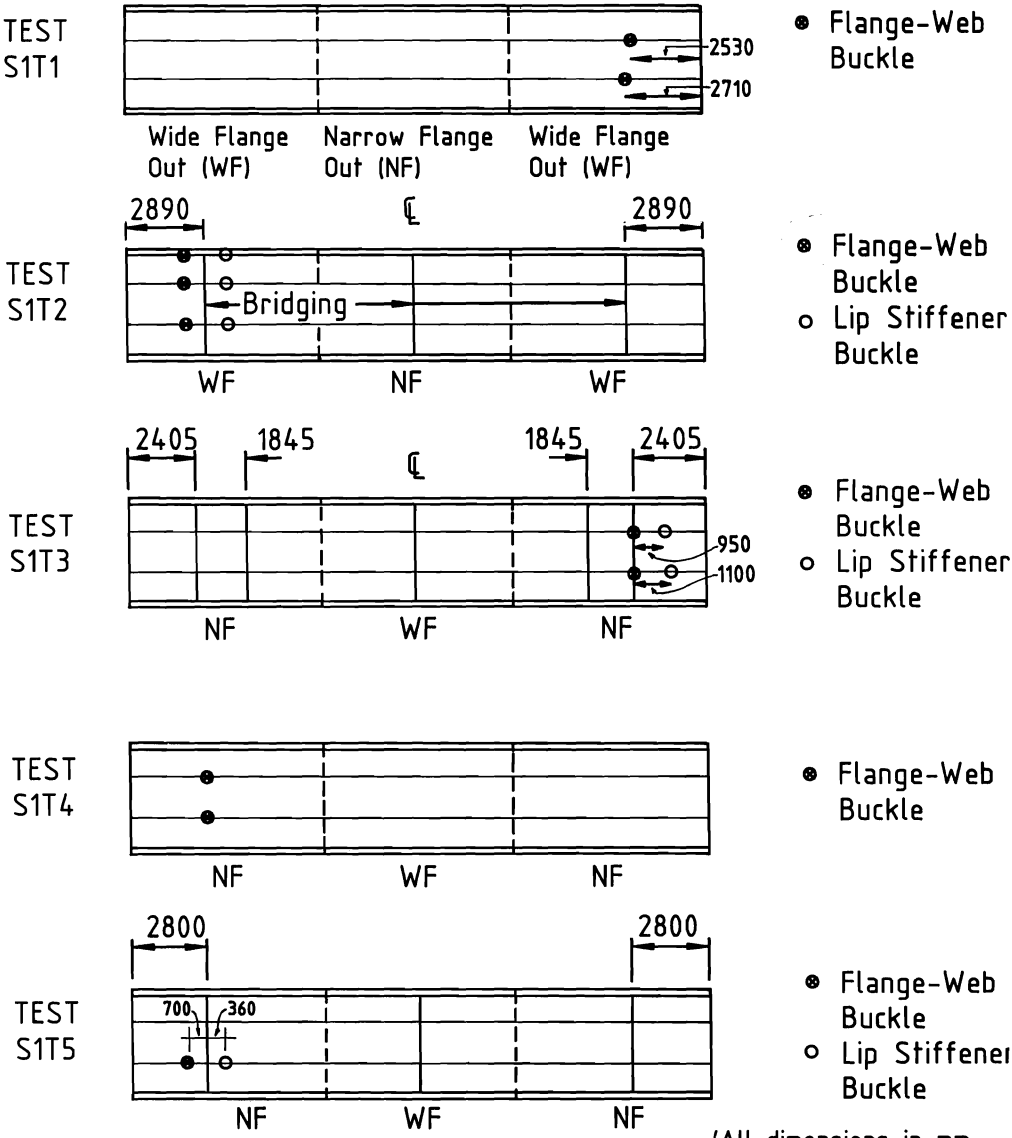


FIG.2(c) TEST SPECIMEN DIMENSIONS - SERIES 3



(All dimensions in mm, 1 in = 25.4mm)

FIG.3(a) BRIDGING POSITION AND FAILURE MODES SERIES 1 - TEST 1-5

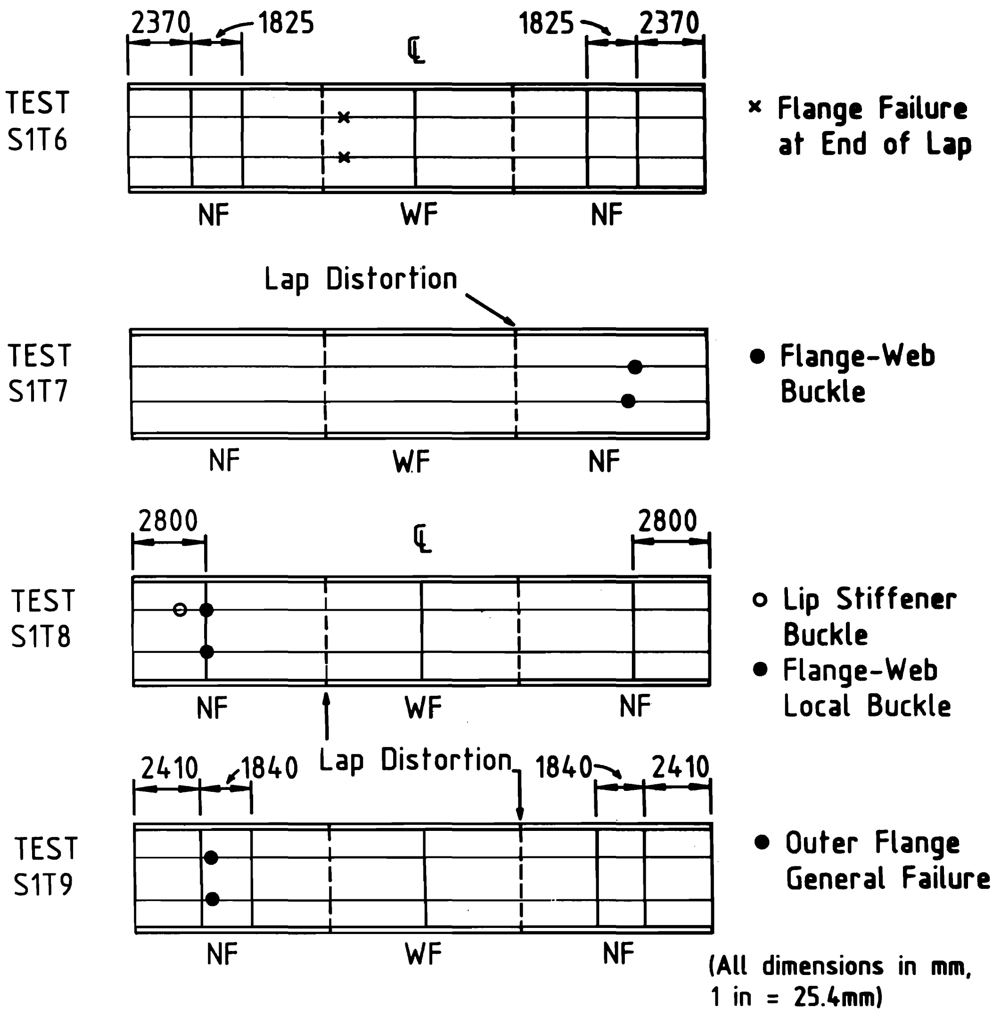


FIG.3(a) continued BRIDGING POSITION AND FAILURE MODES
SERIES 1 - TESTS 6-9

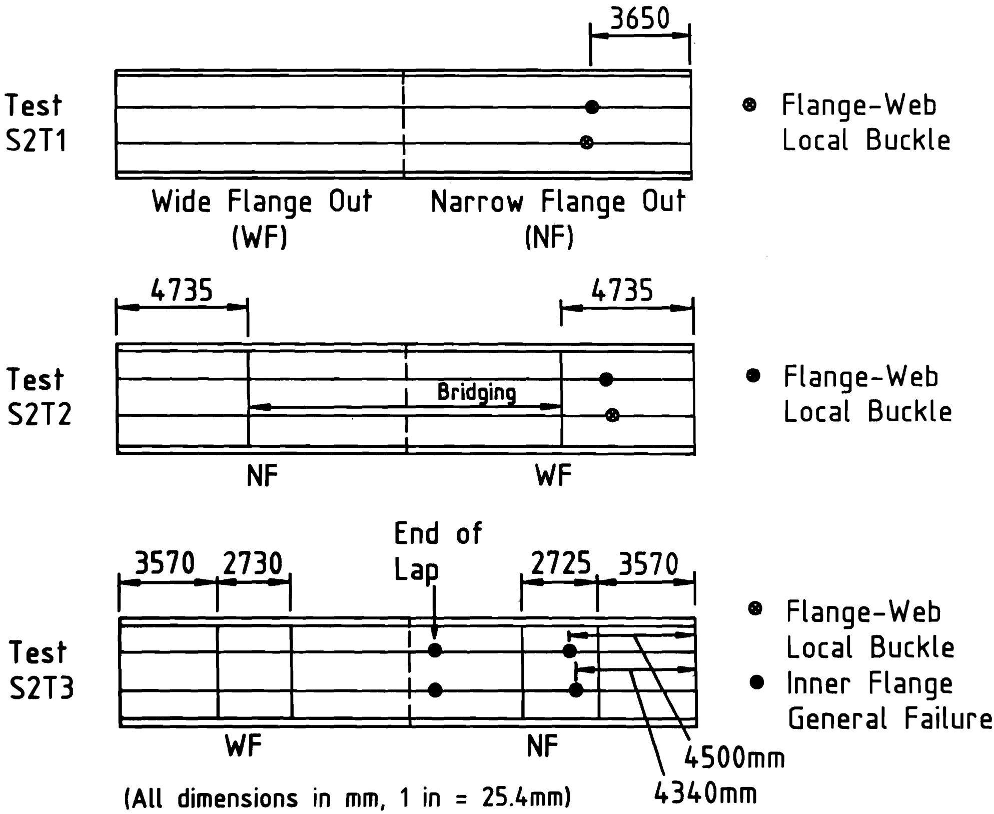


FIG.3(b) BRIDGING POSITION AND FAILURE MODES
SERIES 2 - TEST 1-3

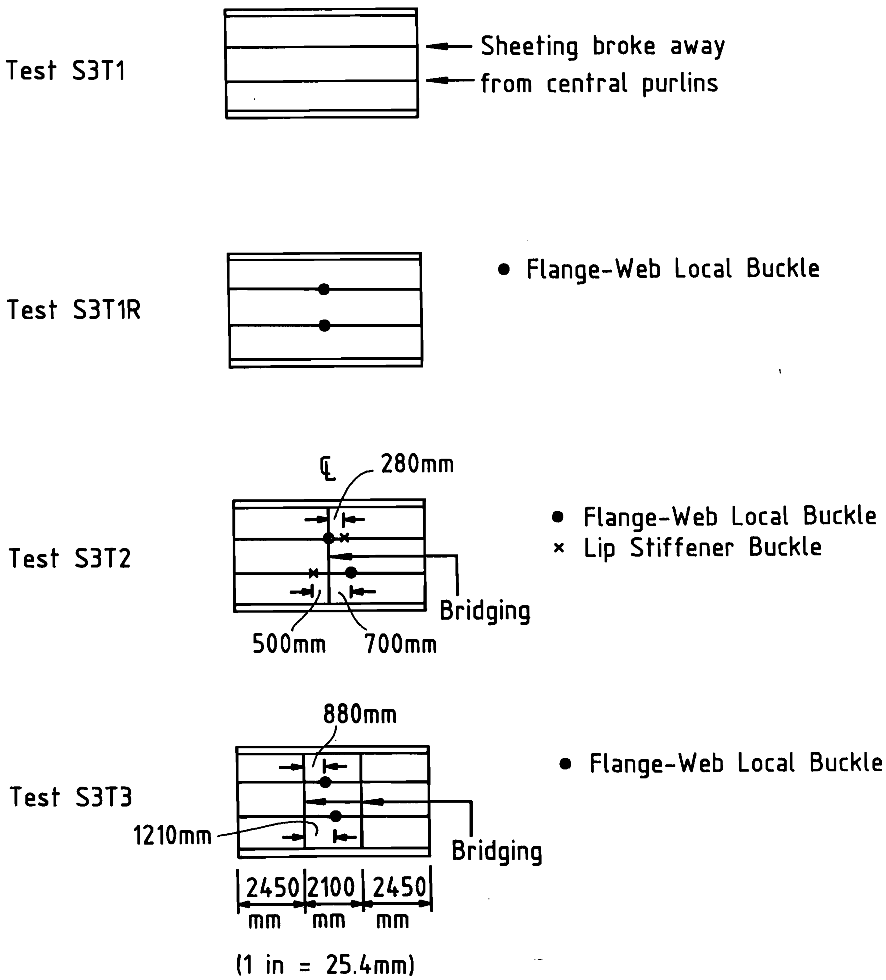


FIG.3(c) BRIDGING POSITIONS AND FAILURE MODES
SERIES 3 - TEST 1-3

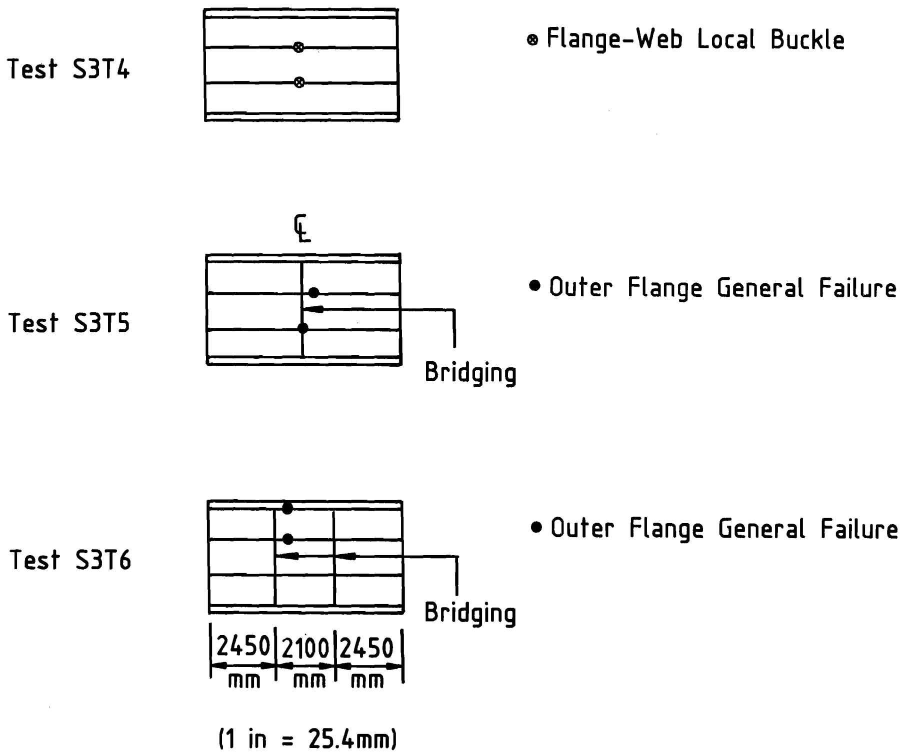


FIG.3(c) continued BRIDGING POSITIONS AND FAILURE MODES
SERIES 3 - TEST 4-6

FIG.4 FLANGE-WEB LOCAL BUCKLE

FIG.5 FLANGE-WEB LOCAL BUCKLE AND LIP STIFFENER BUCKLE

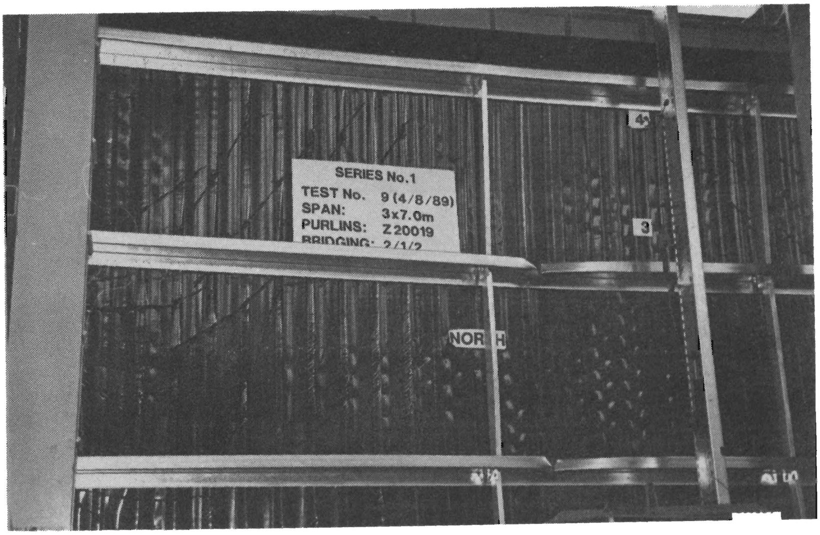


FIG.6 GENERAL FLANGE FAILURE

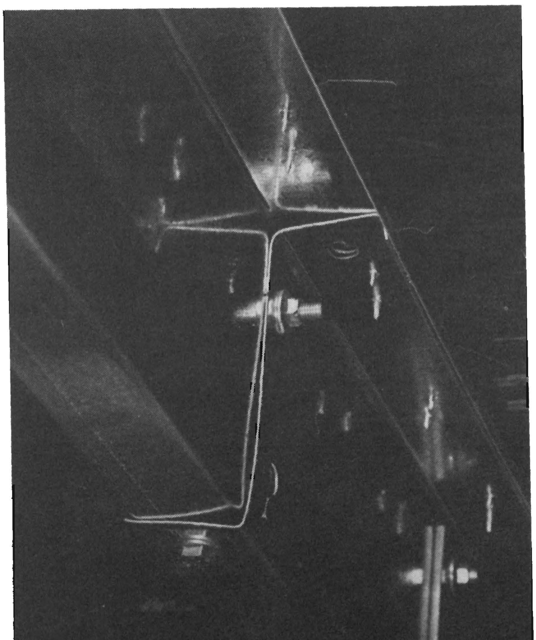
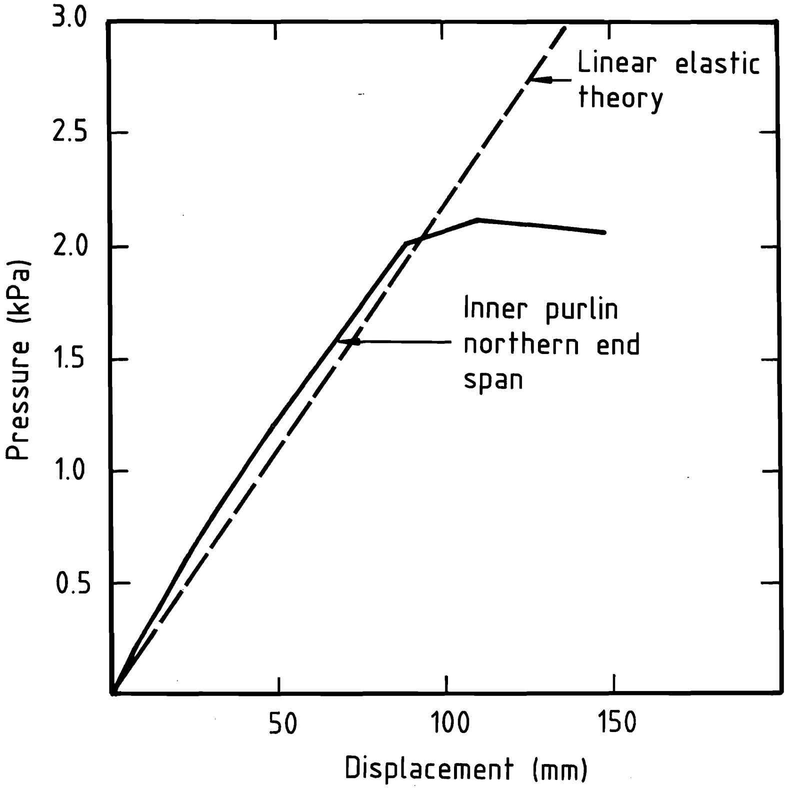


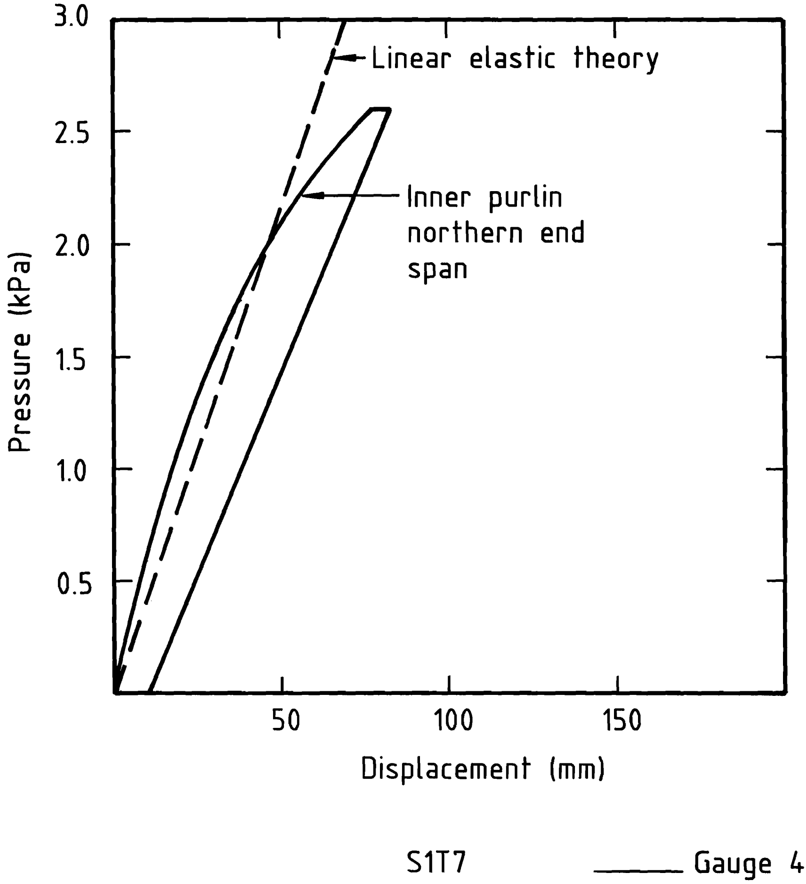
FIG.7 DISTORTION AT END OF LAP



S1T2 ——— Gauge 4

(1 in = 25.4mm, 1 kPa = 20.9psf)

FIG.8 PRESSURE-INWARDS DISPLACEMENT RESPONSE



(1 in = 25.4mm, 1 kPa = 20.9psf)

FIG.9 PRESSURE-INWARDS DISPLACEMENT RESPONSE