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LOAD CARRYING CAPACITY OF Z-PURLINS WITH A.C. SHEET CLADDING

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SUMMARY

Analytical and experimental studies on Z-purlins made of light gauge steel strip were carried out in order to find the load-carrying capacity of these members when cladded with corrugated asbestos cement sheets. The results are presented.

INTRODUCTION

In India, use of cold rolled steel sections as structural load carrying member has not been so popular as in other countries such as USA and UK. This may be due to doubts as regard to mainly stability and corrosion resistance which used to linger in the minds of practicing Engineers. A few firms have recently started manufacturing Z-purlins (cross-section in the form of 'Z') from light gauge steel strips by cold forming. Some of these Z-purlins were tested in the Structural Engineering Research Centre, Madras to study the structural performance and load carrying capacity. The purlins were cladded with asbestos cement sheets (A.C. sheets) being the most commonly used cladding material. The purlins were tested for gravity and wind load conditions. The sizes of purlins tested are given in Fig.1 and the tests carried out are explained in Table 1.

TEST SET UP FOR WIND LOAD

The test set-up consisted of a pair of purlins kept parallel at a spacing of 1.0 m. They were fitted over two continuous spans of 4.0 m each. Sleeves were used for connections over the supports as detailed in Fig.2. The severe case of wind load on roof is wind suction wherein the compression flange of the purlin (bottom flange) under that load condition would be unsupported laterally. To apply upward load to simulate such wind load was rather difficult. So, it was decided to attach the A.C. sheets on to the bottom flange of the purlins after fixing it upside down to the rafters, and then apply downward load. But, under this condition, the self weight of purlin and sheets would also act in the same direction as that of wind load, unlike in the actual conditions, where they would act in opposite directions. However, the effect of downward load due to the self weight of purlins and sheets

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(which are very small compared to the wind load) were taken into account while analyzing the final test results. The loads were applied using hydraulic jacks through tension rods which were attached to the J-bolts connecting the roof cladding and purlins. (it may be noted here that in the actual case of wind suction also the load will be acting through the J-bolts only). Strain gauges were fixed at selected points for measurement of strains on the purlins. Semi-automatic electronic strain indicator of 48 channel was used for recording the strains. Dial gauges of least count 0.01 mm and 50 mm travel were fixed to measure the vertical and horizontal deflections at various points. The test set-up is shown in Fig.3 and Fig.5.

TEST SET UP FOR GRAVITY LOAD

To test the purlins under the gravity load condition, rafter inclination of 23° was chosen as it is common. A pair of parallel purlins were kept over two continuous spans of 4.56 m each and at a spacing of 1.40 m between them. The purlins were connected at the supporting rafters using cleats and sleeves as shown in Fig.2. Asbestos cement sheets of 2.5 m length were fixed to the purlins using J-bolts. Instrumentation used were the same as described for the wind load tests. Cast iron bricks were used for gravity loads. The test set-up may be seen in the Fig.4 and Fig.6.

PROCEDURE FOR WIND LOAD TEST

Purlins of section 125200 were arranged as described **earlier** and shown in Fig.5. The loads were applied through jacks connected to a central hydraulic pumping unit. One extra jack was connected in series to a separate proving ring and a dummy test frame to evaluate the uniform load applied to the J-bolts through tension rods. The purlins failed by lateral buckling of the compression flange as expected. The test was repeated on another set of purlins.

For purlin section 210200, the test span chosen was 7.5 m. It was not possible to get sufficient space for two continuous spans for the tests. So, it was decided to have a single span of 7.5 m and make one end connection rigid enough so that the test span would behave as if it had an adjacent span of equal length subjected to the same loading as that of the test span. This was achieved by introducing a short span (about 60 cm) continuous to the test span through the sleeve (Fig.7). Purlin section 210200 was used for this short span also so that it would have high rigidity.

PROCEDURE FOR GRAVITY LOAD TEST

Purlins of 125230 were connected on the rafters as shown in Fig.4 over two continuous spans of 4.56 m each. Over the A.C. sheets cast iron bricks were placed to simulate uniform load on the purlins. An overhead crane was used to lift and place the bricks in position. The load was increased gradually upto the failure stage (Fig.6).

The first load test on 210200 was carried out to study the diaphragm action of the A.C. sheeting in carrying the component of load acting along the slope. So, a sag rod was just fixed in position between the purlins but the top end of the sag rod was not secured to any rigid point (Fig.8). Now, the component of load acting in the plane of the roof should be resisted mainly by the sheeting acting as a diaphragm between purlins. Right from the beginning of the test, the purlin started sagging badly along the slope pushing the sheeting along with them. The system collapsed after the purlins twisted and sagged completely (Fig.9). The failure load was less than half of the calculated working load on the same purlin with effective sag rods. This result of the test indicates that the A.C. sheeting supported between the two purlins could not play an effective role in carrying and load acting in the plane of the roof.

The test was repeated on a new set of purlins after fixing the sag rod to a rigid point at top. The system failed by buckling of the top flange breaking the A.C. sheets (Fig.10).

EVALUATION OF TEST RESULTS

The Z-purlins were designed as per IS: 801-1975[2]. In the case of gravity load, it was assumed that the compression flanges were braced by the A.C. sheets[1]. But, in the case of upward wind load, the purlins were designed assuming no lateral restraint in the compression flange due to sheeting. The fictitious load concept recommended by Lev Zetlin and George Winter[3] was used for the computation of safe working load. The experimental stresses at the working load is given in Table 2[4]. The failure load and the actual load factor achieved from tests indicated doubts in the stiffening effect of the roofing sheets in effectively bracing the compression flange.

WIND LOAD TEST RESULTS

The roof purlin was loaded until failure. The load factor achieved was much more than the required load factor. The larger failure load that the purlin carried may be due to the partial restraint offered by the loading system through the J-bolts at the tension flange. The vertical deflection at mid span was close to the theoretical deflection calculated from simple beam theory as shown in Fig.11.

Strain variation across the mid span and at mid support are given in Figs.12 and 13. The strain variation behaved in a conventional way as an unrestrained beam about its natural neutral axis. The strain pattern on the top flange of the mid support followed the principal axes of the section. The overall behaviour concurred with the tests reported by Rhodes[5] et. al.

GRAVITY LOAD TEST RESULTS

The actual collapse load is less than predicted load, especially, in Test 4 where the actual factor of safety is 1.42 as against the calculated value of 1.85. Probably the A.C. sheet could not offer sufficient restraint against buckling as assumed.

The strain distribution measured and plotted is shown in Figs.14 and 15. The stress at the junction of top flange and lip is critical. It can be seen from the strain distribution in the flanges that the sheets do not contribute much in carrying the load in the plane of the roof.

The predicted deflection values are compared with actual values in Fig.16 and there is a fairly good agreement in the values.

CONCLUSION

The load carrying capacity of the Z-purlins could be calculated using the fictitious load method. Effective sag rods contribute significantly in improving the performance.

The A.C. sheet cladding fixed using J-bolts does not play an effective role in carrying the load acting in the plane of roof.

ACKNOWLEDGEMENT

APPENDIX.--REFERENCES

1. Djugash, A.C.R., "Buckling Behaviour of Z-beams", Review Report, Structural Engineering Research Centre, Madras, India, 1983.

2. IS:801-1975, "Code of Practice for Use of Cold-formed light Gauge Steel Structural Members in General Building Construction", Indian Standards Institution, January 1976.

3. Lev Zetlin and George Winter, "Unsymmetrical Bending of Beams with and without Lateral Bracing", Proceedings ASCE, Vol.81, August 1955, pp 774-1 to 20.

4. Natarajan, P.R., Djugash, A.C.R., Seetharaman, S., "Experimental Investigations on Z-purlins to Study the Structural Performance and Resistance against Corrosion", Report No.S-004/80, Structural Engineering Research Centre, Madras, India, August 1981.

5. Rhodes, J., et. al. "Tests on a Continuous Purlin Roofing System", Fourth International Speciality Conference on Cold-Formed Steel Structures, June 1-2, 1978, University of Missouri, Rolla, pp 253-282.

TABLE 1

DETAILS OF TESTS CARRIED OUT

Test No.	Purlin Section	Simulated loading case	Span Length (m)	Spacing (m)	No. of spans	Sag rods	No. of purlins tested	Slope of rafter
1	125200	Wind Load	4.00	1.00	2	Nil	2	Horizontal
2	125230	Gravity Load	4.56	1.40	2	Nil	2	23°
3	210200	Wind Load	7.50	1.00	One full span with provision for continuity	One	2	Horizontal
4	210200	Gravity Load	7.50	1.40	-do-	One	2	23°

TABLE 2
COMPARISON OF ANALYTICAL AND EXPERIMENTAL RESULTS

Test No	Purlin Section	Simulated loading case	Span (m)	Analysis		Experiment		Load Factor = $\dfrac{\text{Failure load}}{\text{Safe load}}$	
				Safe working load (kN/m)	Calculated stress at safe load (MPa)	Failure load (kN/m)	Measured stress at working load (MPa)	Expected	Actual
1	125200	Wind load	4.0	0.80	57.26	2.49	48.05	1.57	3.10
2	125230	Gravity load	4.56	1.49	122.63	2.74	111.25	1.85	1.84
3	210200	Wind load	7.5	0.68	74.94	1.58	95.16	1.57	2.34
4	210200	Gravity load	7.5	0.91	122.63	1.30	109.19	1.85	1.42
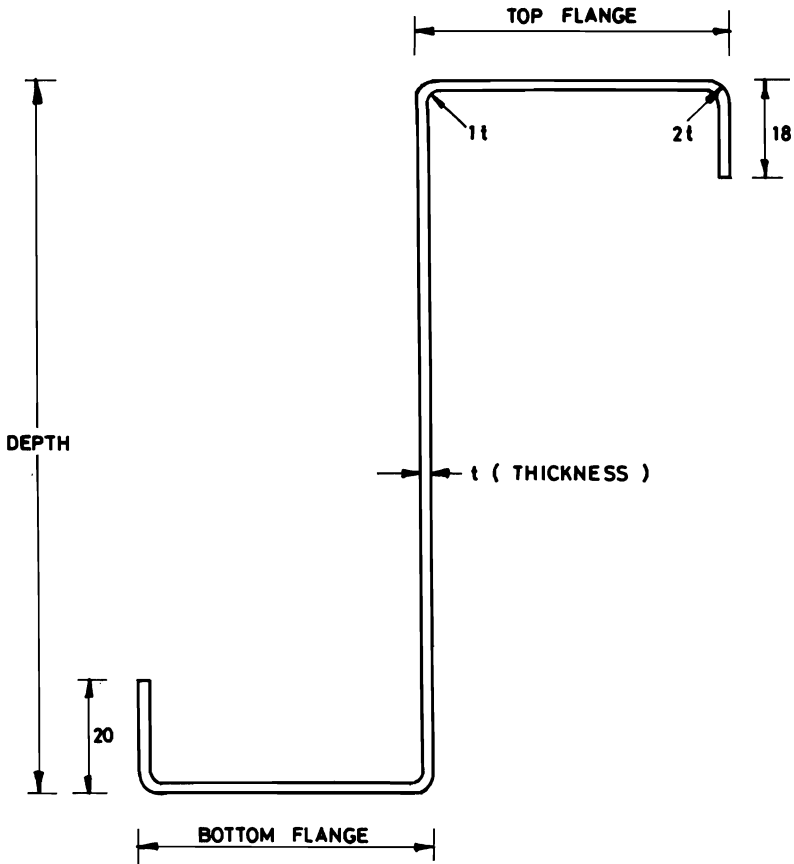
SECTION	DEPTH IN mm.	TOP FLANGE IN mm.	BOTTOM FLANGE IN mm.	THICKNESS IN mm.	AREA IN cm^2.
125 200	125	55	50	2.0	5.08
125 230	125	55	50	2.3	5.81
210 200	210	66	59	2.0	7.19

FIG. 1. Z-PURLIN DIMENSIONS
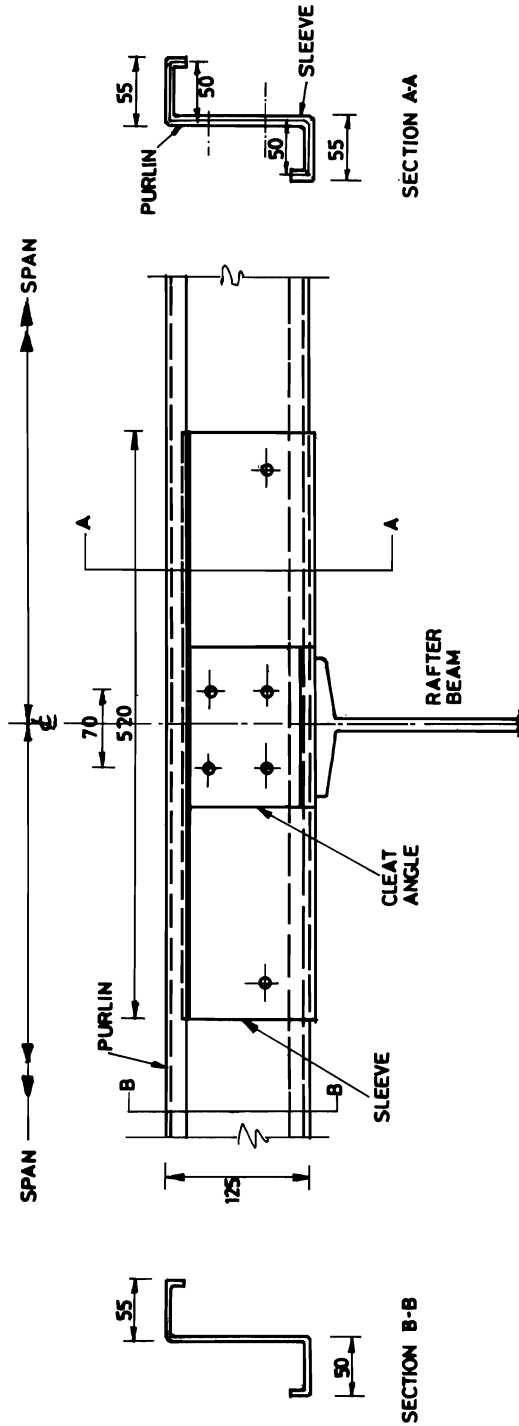
FIG. 2. SLEEVE AT THE MID-SUPPORT
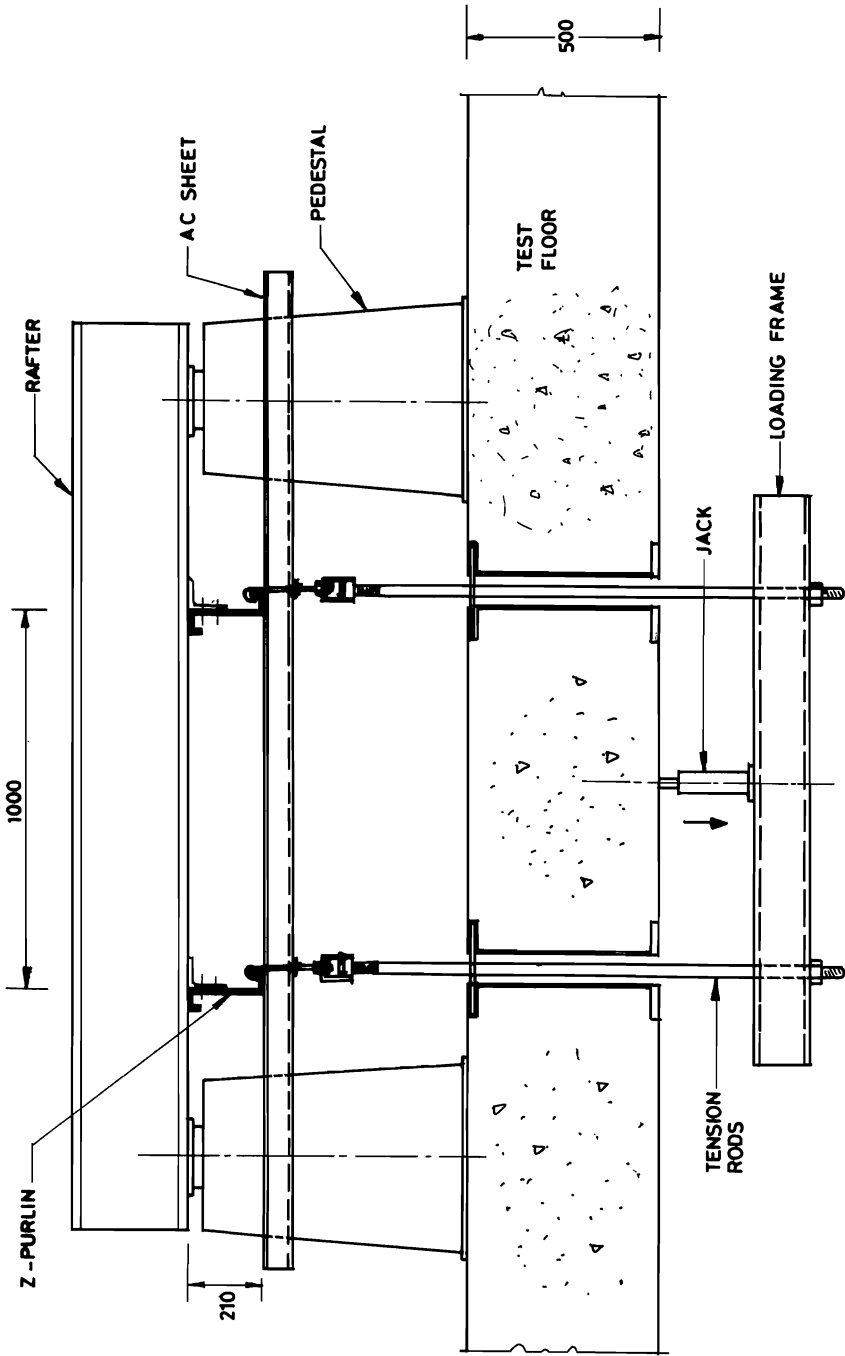
FIG. 3. TEST SET UP FOR WIND LOAD
(PURLINS ARE INVERTED AND LOADS AND APPLIED DOWNWARD)
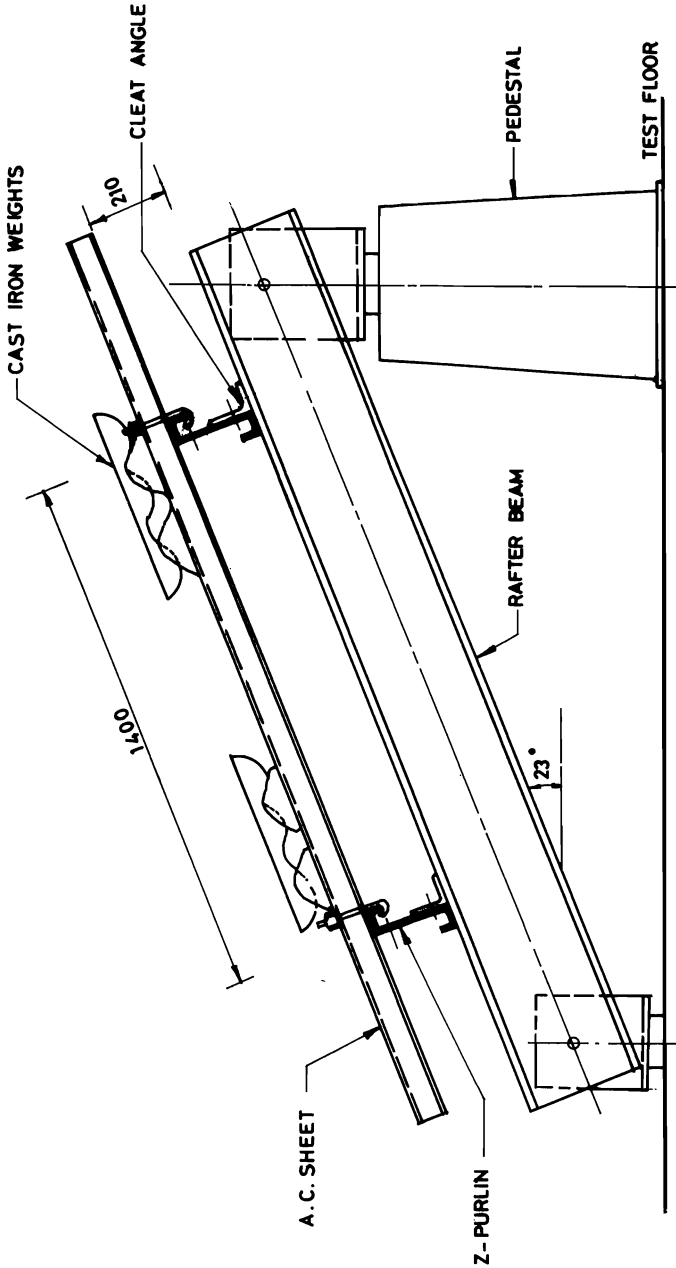
FIG. 4. TEST SET UP FOR GRAVITY LOAD
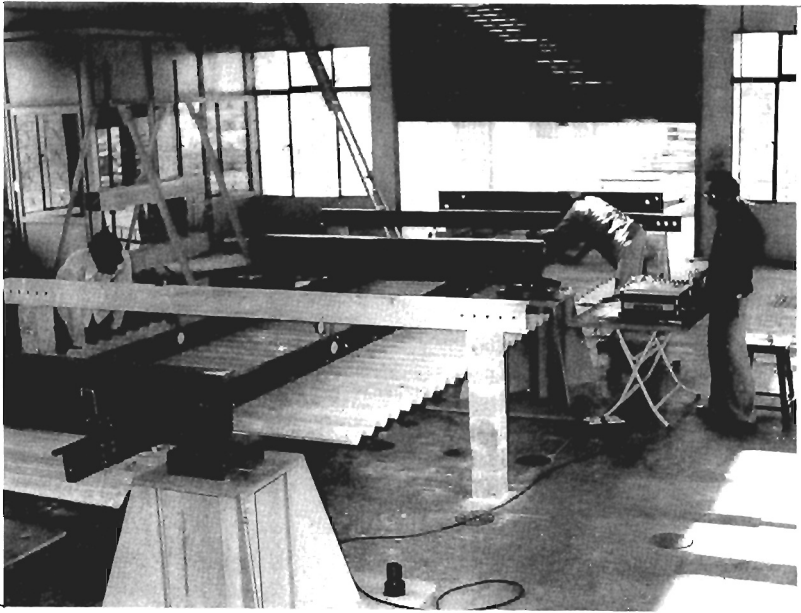
FIG.5 WIND LOAD TEST

FIG.6 GRAVITY LOAD TEST
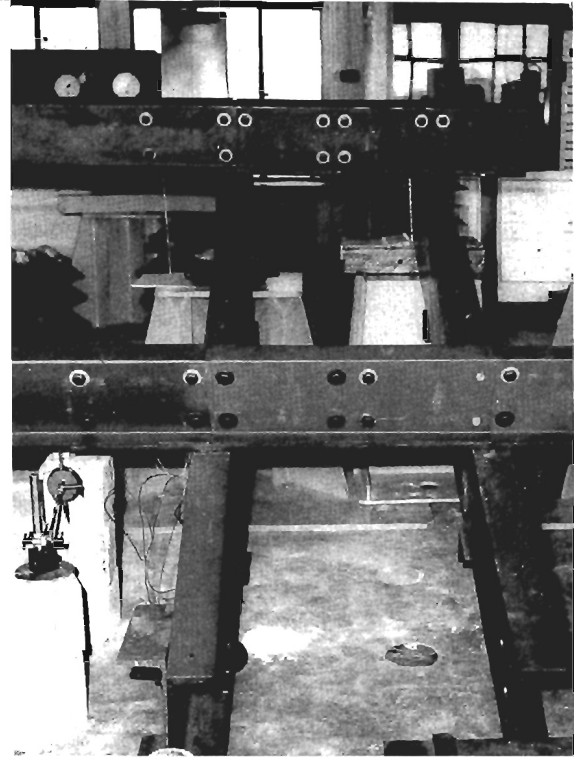
FIG.7 EQUIVALENT CONTINUOUS TWO SPAN ARRANGEMENT
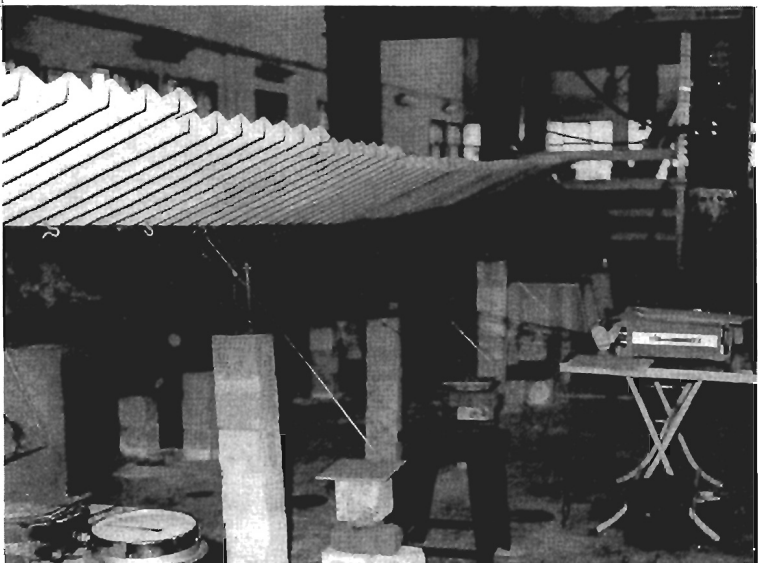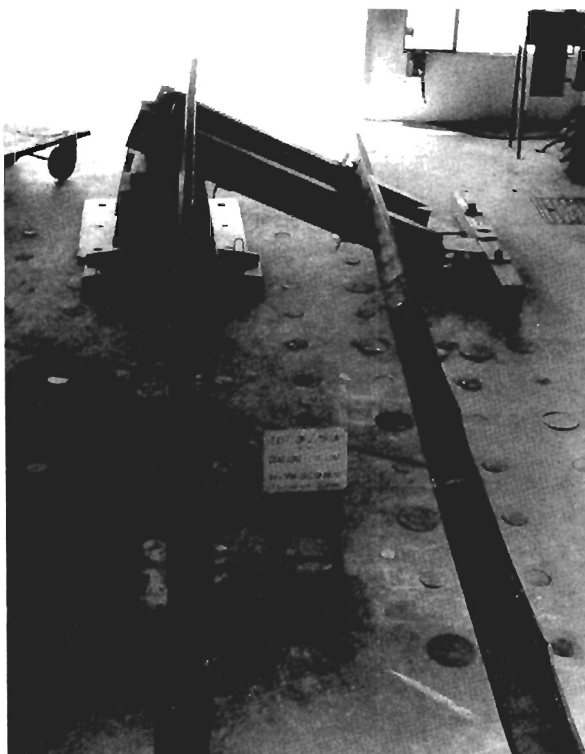

FIG.8 NO SAG ROD AT TOP PURLIN
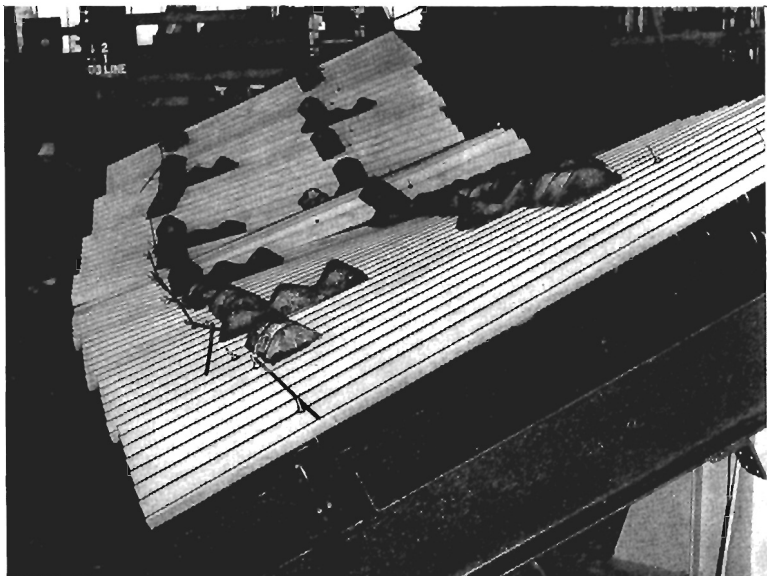
FIG. 9   AT THE FAILURE LOAD

FIG.10   FAILURE PATTERN WITH SAG ROD AT TOP
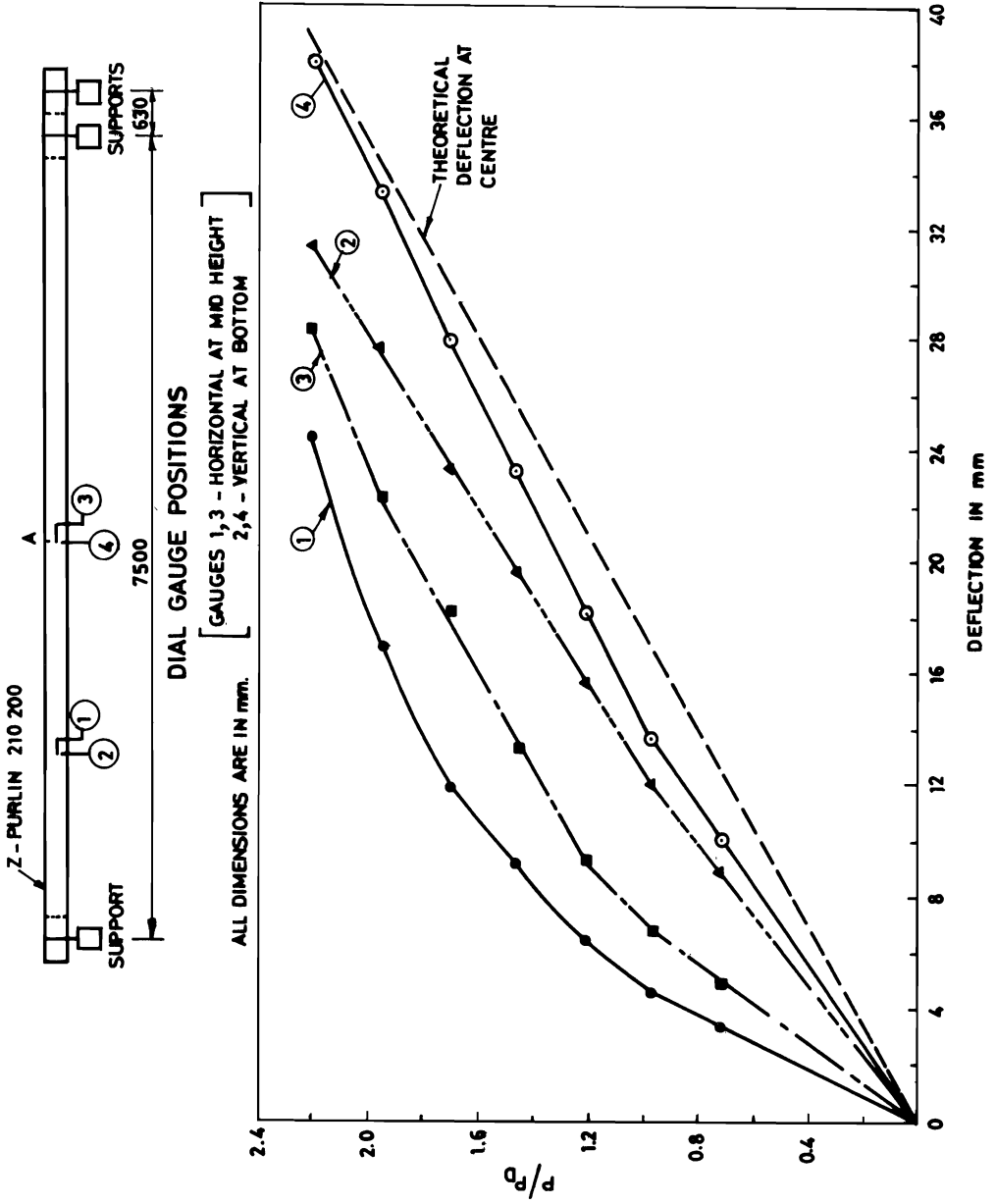
FIG. 11 PURLIN DEFLECTION FOR WIND LOAD

STRAIN SCALE :
  1 DIV. = 100×10^{-6} m/m
EQUIVALENT STRESS SCALE :
  1 DIV. = 20.3 MPa

LINE 1	LOAD	0.54 P_D
2		0.74 P_D
3		0.93 P_D
4		1.13 P_D
5		1.32 P_D
6		1.52 P_D
7		1.71 P_D
8		1.91 P_D
9		2.10 P_D

PURLIN 125200

SCALE AND LINE LOADS
ARE COMMON TO
FIGS. 12 AND 13.

ALL DIMENSIONS ARE IN mm.

STRAIN GAUGE POSITIONS
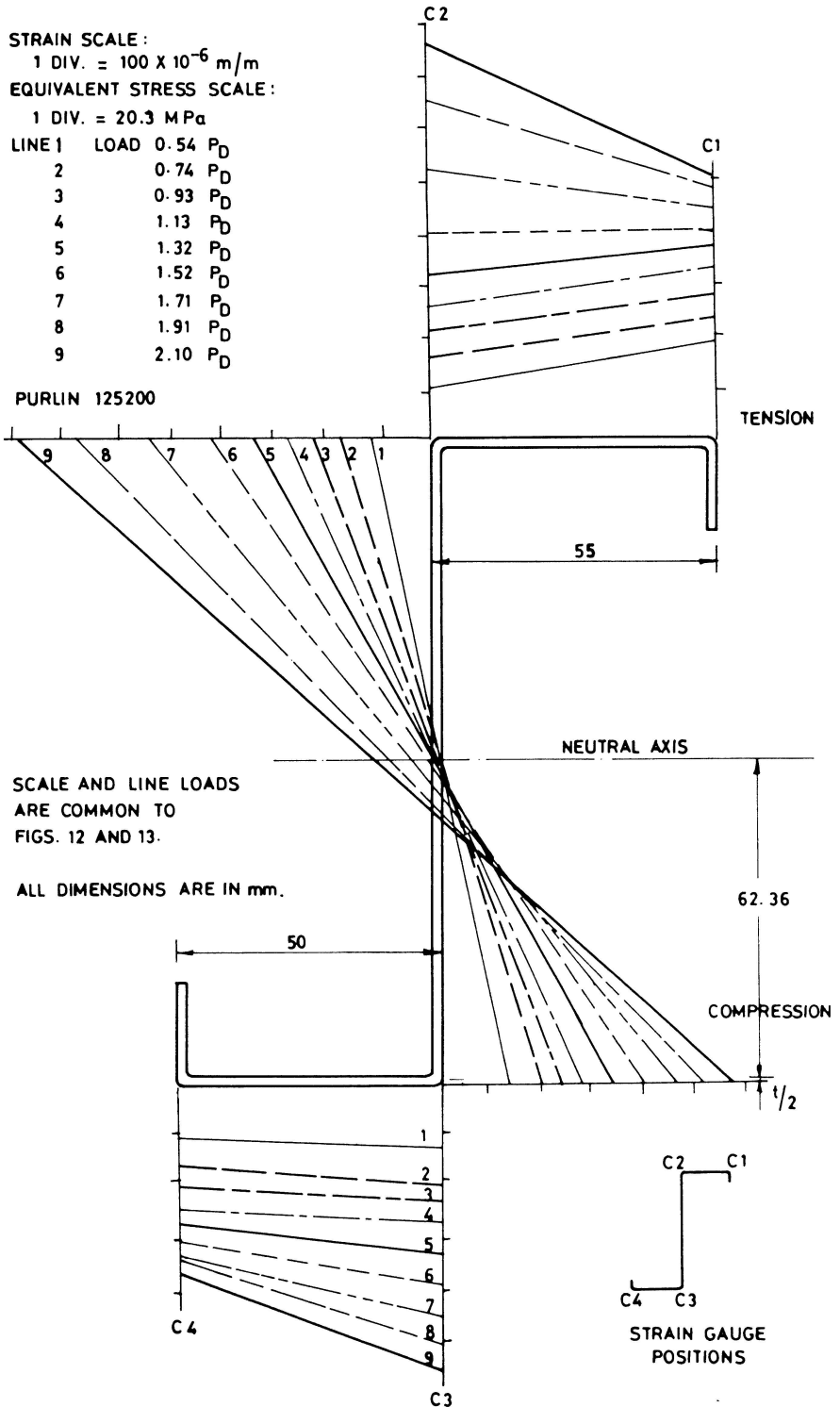
FIG.12. STRAIN RECORDED AT MAXIMUM MOMENT SECTION
(WIND UPWARD LOAD)

E3

COMPRESSION

E 4

TENSION

9 8 7 6 5 4 3 2   1

50

NEUTRAL AXIS

ALL DIMENSIONS ARE IN mm.

55

1
2
3
4
5
6
7
8
9

E 1

E 2

TENSION

E3   E4

E1   E2
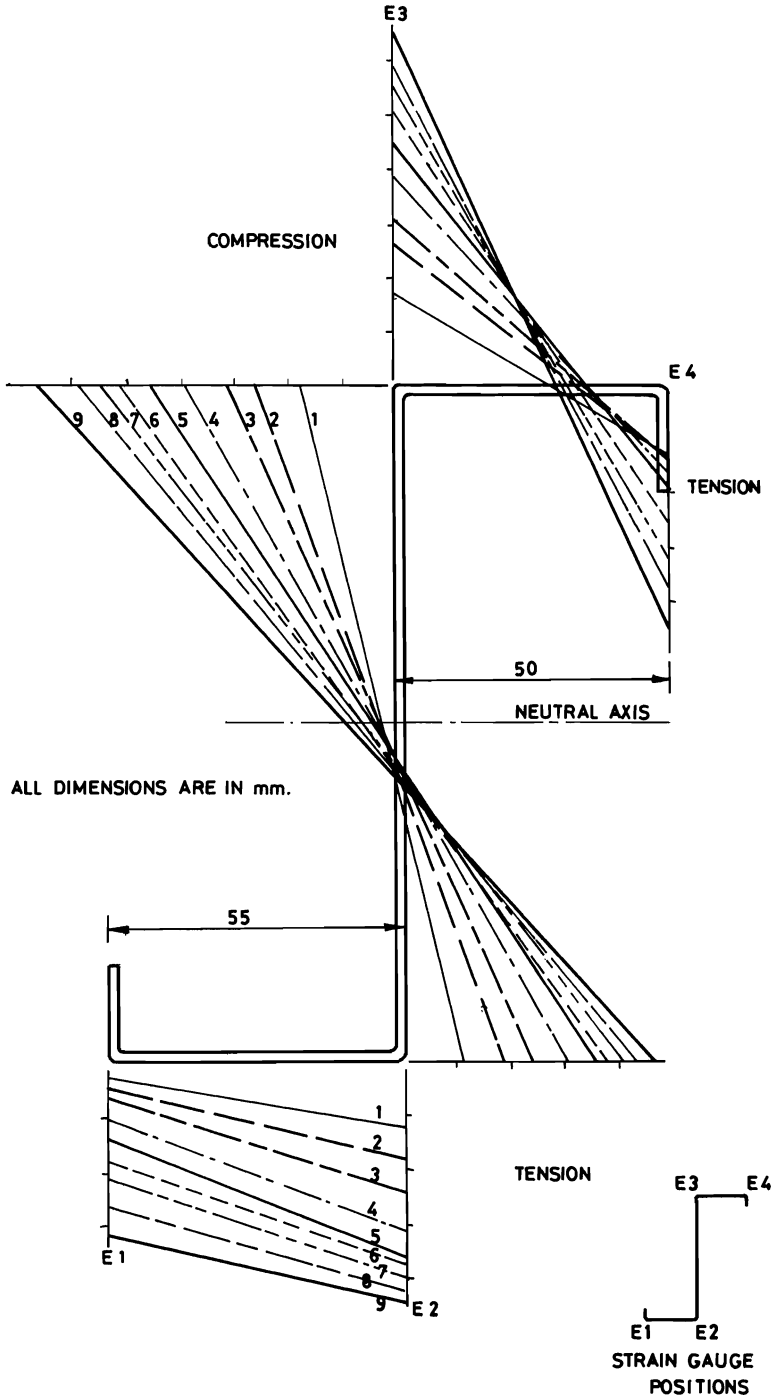STRAIN GAUGE
POSITIONS

FIG. 13. STRAIN RECORD AT MID SUPPORT-ON SLEEVE
(WIND UPWARD LOAD)

Z-PURLINS WITH SHEET CLADDING

STRAIN SCALE:
  1 DIV. = 200 X 10^{-6} m/m
EQUIVALENT STRESS SCALE:
  1 DIV. = 40.6 MPa
PURLIN 125230

LINE 1   LOAD 0.26 P_D
     2   0.51 P_D
     3   0.74 P_D
     4   0.97 P_D
     5   1.19 P_D
     6   1.43 P_D
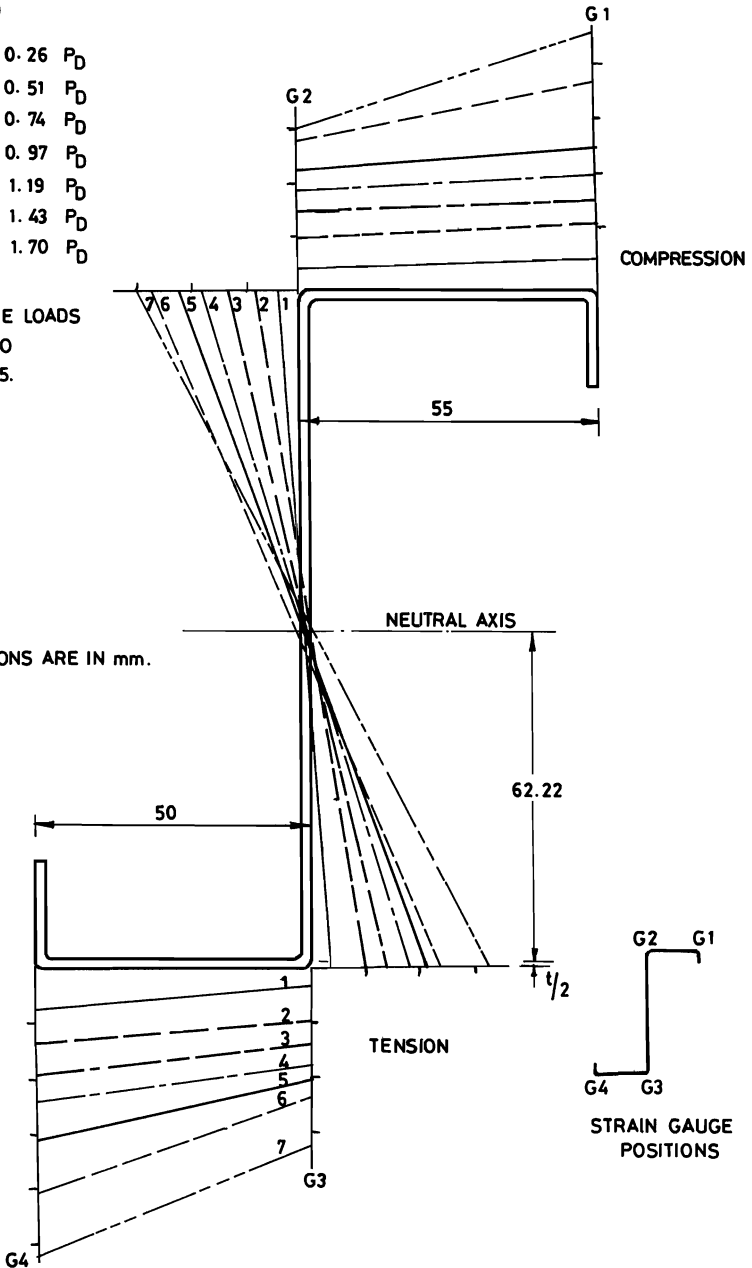   7   1.70 P_D

SCALE AND LINE LOADS
ARE COMMON TO
FIGS. 14 AND 15.

ALL DIMENSIONS ARE IN mm.

G1
G2
COMPRESSION
55
NEUTRAL AXIS
62.22
t/2
50
TENSION
1
2
3
4
5
6
7
G3
G4
7 6 5 4 3 2 1

G2   G1
G4   G3
STRAIN GAUGE
POSITIONS

FIG. 14. STRAIN MEASUREMENT AT MAXIMUM MOMENT SECTION
(GRAVITY LOAD)
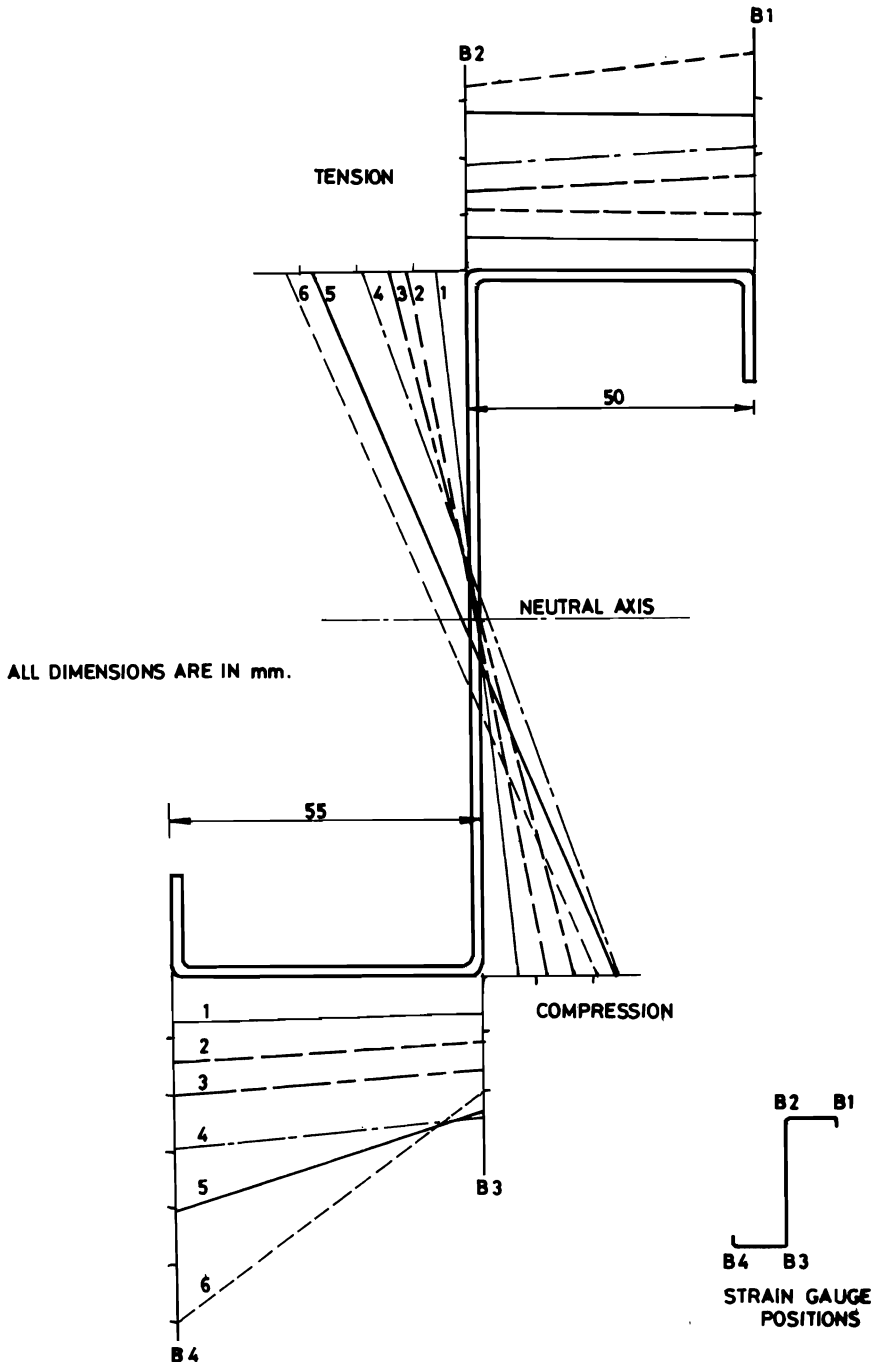
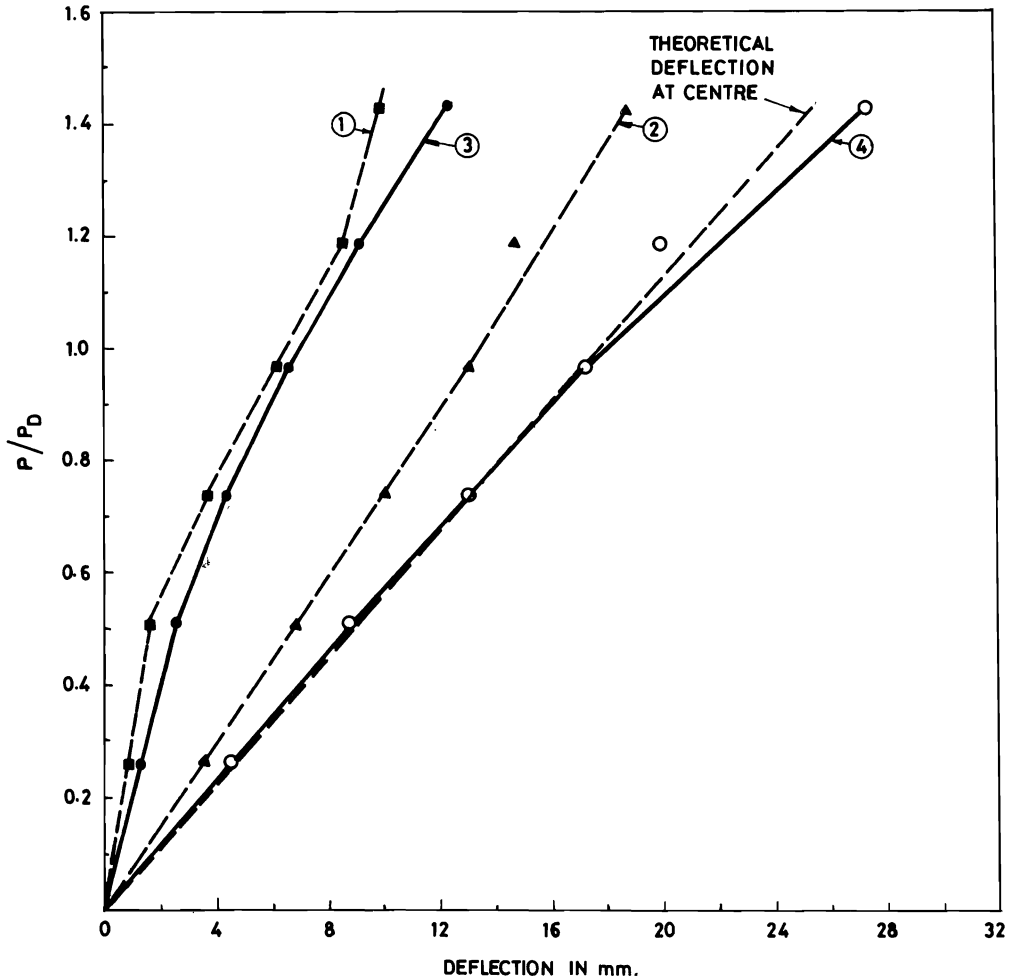FIG.15. STRAIN GAUGE MEASUREMENT AT MID-SUPPORT: ON SLEEVE
(GRAVITY LOAD)
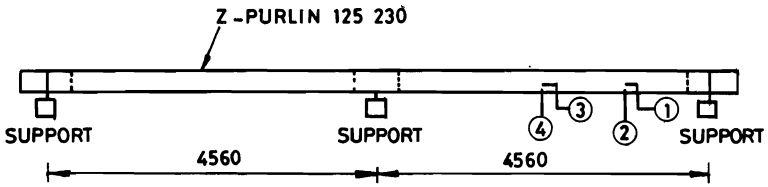
FIG. 16. PURLIN DEFLECTION FOR GRAVITY LOAD