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TEST OF JUMBO SHAPE
WITH SURFACE SEAMS

by

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1. INTRODUCTION

Seams or laminations may result from rolling thick plates or heavy shapes. These discontinuities are generally oriented in the direction of rolling.

Fatigue and fracture studies of structural details have shown that discontinuities are only detrimental when the discontinuity lies in a plane perpendicular to the applied stress.(1)(2)(3)(4) Fortunately, seams and lamination usually are in planes parallel to the line of stress and do not affect a member's behavior or performance.

To confirm this fact, a heavy rolled jumbo column section was tested which had extensive surface seams. The objective was to determine whether or not these seams changed shape or extended and influenced the capacity of the column. A stub column test was selected for this investigation since it can be used to measure the effectiveness of the member's resistance under fully plastic load. Also, it can furnish experimental data that can be used to make a column strength prediction. Based on a single stub column test, it is possible to establish column strength curves over the complete range of slenderness ratios used in practice.

2. TEST PROCEDURE AND RESULTS

Preparation of Test Specimen

A specimen with severe discontinuities in the form of surface seams was used to carry out the experimental investigation. The selected specimen was a W14x730 rolled shape ("jumbo" shape) of ASTM A572 grade 50 modified steel. The seams on the surface of the specimen are shown schematically in Fig. 1.

Several probe holes were drilled along the seams to accurately check the depth of the seams and to provide a means of detecting any crack growth or opening of the seams when the specimen was subjected to high axial compressive force. The locations of these probe holes and the seam depths at the respective locations are given in Table 1. The seam widths are about 0.001 in. near the flange surface and taper near their extremities. Figure 2 shows photographs of the flange surfaces after testing.

Tension Coupon Tests

A total of four 8-inch gage length tension coupon tests were made following ASTM specifications (E370): two from the flange and two from the web. Figure 3 is a schematic diagram of the locations of the coupons with respect to the cross section. The stress-strain curves for the flange and web are shown in Fig. 4. The "dynamic" stress rate used for the tension tests was about 3.5 ksi/min. This rate was established while the specimens were elastic and the same valve setting was maintained throughout the test. It is readily apparent from Fig. 4 that the material does not exhibit a yield plateau. An increase in load was observed after the proportional limit was exceeded with increasing strain. Table 2 summarizes the results of the coupon tests. The proportional limit was defined by a measured offset of 10 micro in./in. The static yield strength was defined by the stress at 0.005 in./in. strain. The proportional limit varied between 43.2 ksi to 46.0 ksi for the tension coupons. The recorded yield strength varied between 57.8 ksi and 59.6 ksi for the web, and between 60.7 ksi to 61.0 ksi for the flange. It is of interest to note that the specimens from the flange show a higher yield strength level than those taken from the web. This is contrary to the case observed in most lighter rolled shapes.

Stub Column

The purpose of a stub column test is to determine the average stress-strain curve for the entire cross section, including the effects of residual stress and yield strength variation over the cross section. The proportional limit, the elastic modulus, and the tangent modulus are the most important data furnished by a stub column test.

In this test the effects of the seams on the overall behavior of the column was of primary interest. The test was to provide data that could establish the applicability of crack propagation observations on the significance of discontinuities or seams on static strength.

The length of the column was selected such that it was sufficiently long to retain the original residual stress in the column but short enough to prevent premature failure by buckling before the yield load of the section was reached. For the W14x730 shape, a length of 100 inches was selected. The cross sectional measurements are compared with the nominal dimensions in Table 3. The procedure used in testing the column is described in detail in Ref. 5.

Figure 5 shows the stub column set-up and the instrumentation. The test was performed in the 12-million pound capacity testing machine at the National Bureau of Standards, Gaithersburg, Maryland. The average stress-strain curve obtained from this test is shown in Fig. 6. Using an offset of 10 micro in./in. the proportional limit was estimated to be 28.0 ksi for the stub column. The testing was terminated when the specimen was loaded up to the capacity of the testing machine (12 million pounds). At this load, the specimen was beyond the initiation of yield and had exhibited substantial evidence of yielding by the flaking of mill scale. The dashed line in Fig. 6 shows the stub column behavior that was predicted from the tension tests. The weighted yield strength level of the stub column is estimated as 60.4 ksi which is significantly greater than the minimum specified value of 50 ksi.

It is readily apparent in Fig. 6 that the stub column test is in good agreement with the prediction based on coupon tests. The results are directly comparable to other stub column tests where no seams were present.(5) The deviation from the predicted curve reflects the influence of residual stresses. The maximum compressive residual stress level was estimated from the difference between the proportional limits of the tension coupons and the stub column. This yielded an estimated maximum compressive residual stress for this specimen of 16.5 ksi.

During the test each proble hole was examined for growth or change in seam size or its shape as the applied load was increased. There was no indication of any change in the size or shape of the seams due to the applied load when observed with a 50x hand microscope. This was true even though loads between 8 million and 12 million pounds were applied to the column for 30 to 45 minutes. A comparison of the conditions of the seam at probe holes A and B is shown in Figs. 7 and 8. The photographs show the specimen at the zero load level and at 12 million pounds. The seams were not changed by the high axial force.

3. SUMMARY AND CONCLUSIONS

A specimen with severe discontinuities in the form of surface seams was experimentally investigated to determine the influence of seams on the capacity of columns. The selected specimen was a W14x730 rolled shape of ASTM A570 grade 50 modified steel. Standard tension coupons were tested to determine the basic properties of the specimen and a stub column test was performed to check the effects of the seams on the overall behavior of the column.

This test on a stub column with large seams in the flange surface from the rolling process has confirmed that discontinuities that are in the direction of applied stress have no effect on the strength and behavior of a structural member. This is in agreement with other studies on structural members. For example, the lack of penetration at partial penetration web-to-flange welds have also been observed to have a negligible effect on both beam and column behavior. These discontinuities are also parallel to the applied stress. Comparable conditions have existed in riveted and bolted built-up shapes.

TABLE 1

PROBE HOLE DIMENSIONS AND SEAM DEPTHS(*)

Probe Hole	Hole Diam.(In)	Seam Depth(In)	Hole Depth(In)	Seam Width (In)
A	3/4	3/16	7/16	0.0009
B	3/4	7/32	15/32	0.0009
C	3/4	5/16	9/16	0.0006

(*) Refer to Fig. 1 for locations of probe holes.

TABLE 2

SUMMARY OF TENSION COUPON TESTS (ASTM)

	FLANGE		WEB	
	F1	F2	W1	W2
Area at Net Section (in^2)	2.315	2.303	2.293	2.290
Dynamic σ_{yd}	62.7	62.5	59.5	61.4
Proportional Limit	43.2	45.0	46.0	43.6
Static σ_{ys}	60.7	61.0	57.8	59.6
Ultimate Stress	89.4	90.3	92.9	87.8
Fracture Stress	82.5	83.0	70.9	69.9
Percent Elongation	18.0	18.8	22.8	20.6
Percent Reduction	26.4	27.9	49.1	49.4

All stresses in ksi.
Refer to Fig. 3 for locations of specimens.

TABLE 3

CROSS-SECTIONAL MEASUREMENTS

	Measured(in)	Nominal(in)
Depth	22.513	22.440
Flange Width	17.777	17.889
Flange Thickness	4.881	4.910
Web Thickness	3.175	3.069
AREA(in^2)	214.02	214.65

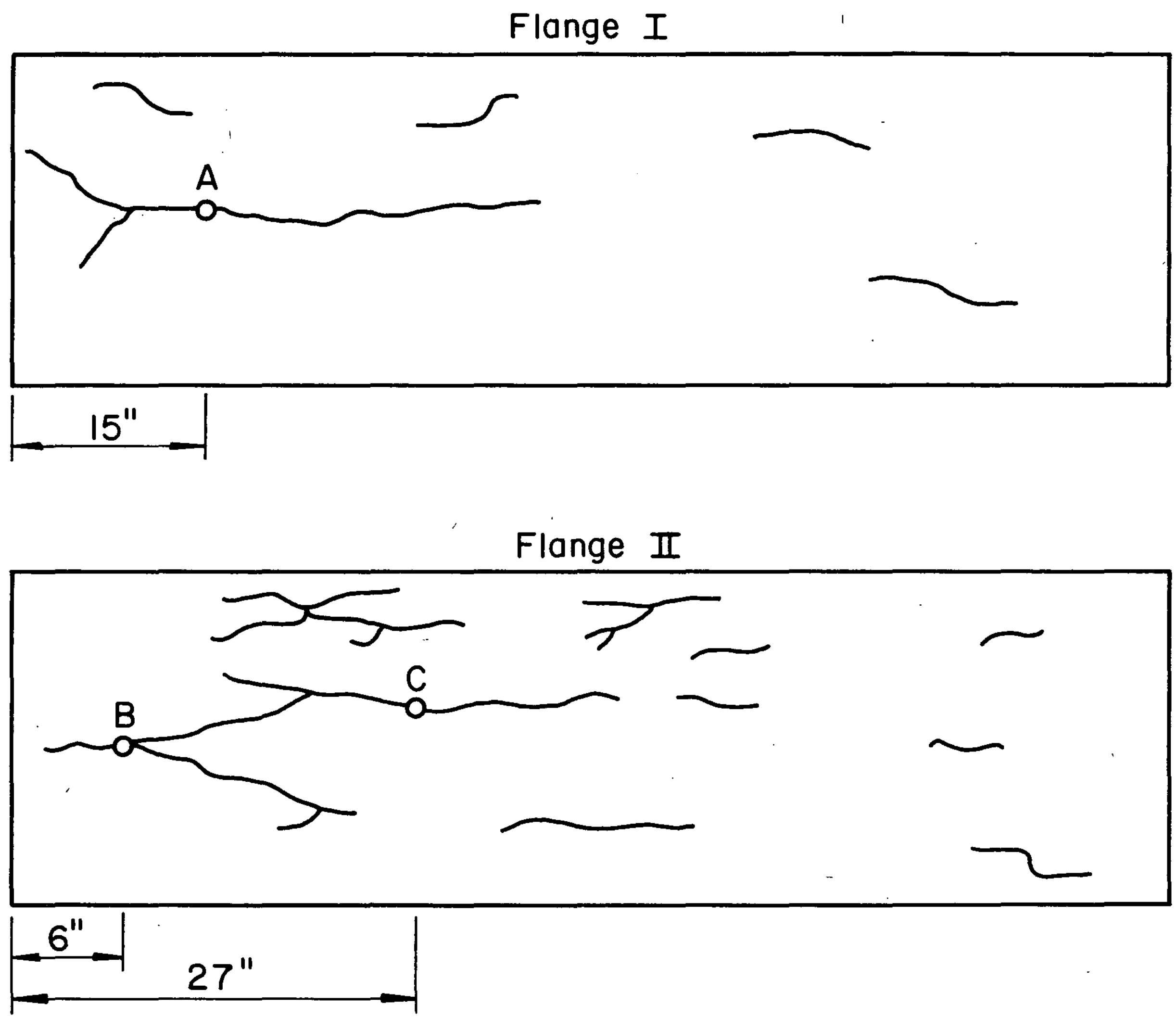


Fig. 1 Schematic Layout of Seams and Probe Holes

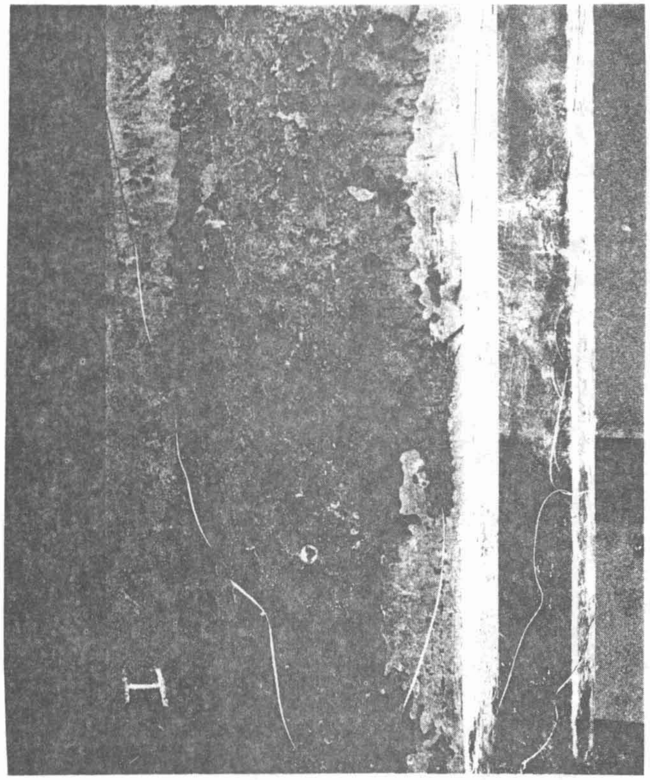


Fig. 2a Flange I Surface after Test Showing Probe Hole A and Flaking Mill Scale

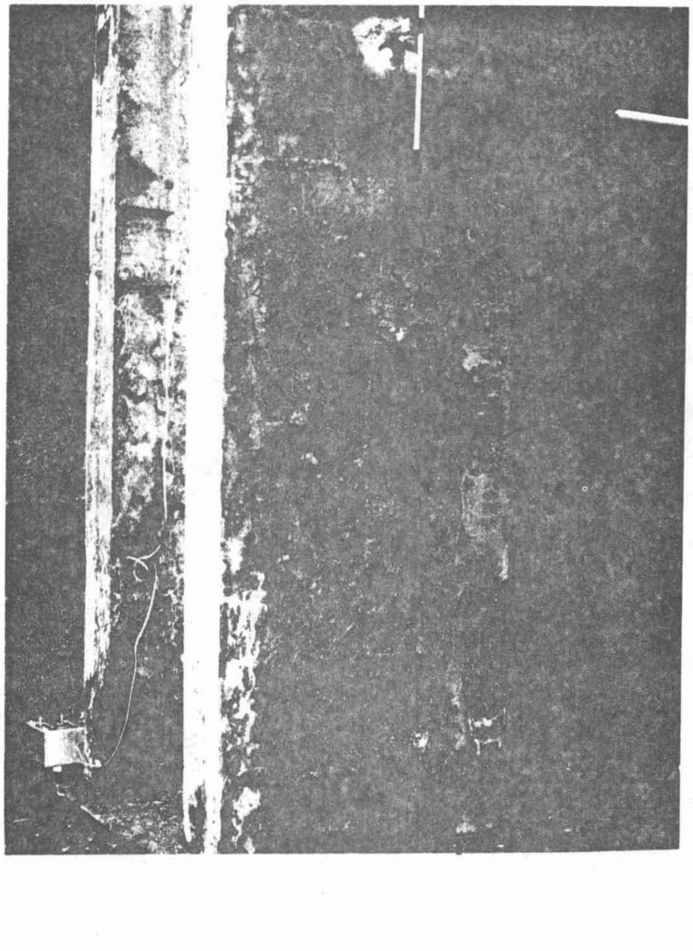


Fig. 2b Flange II Surface after Test Showing Probe Holes B and C and Flaking Mill Scale

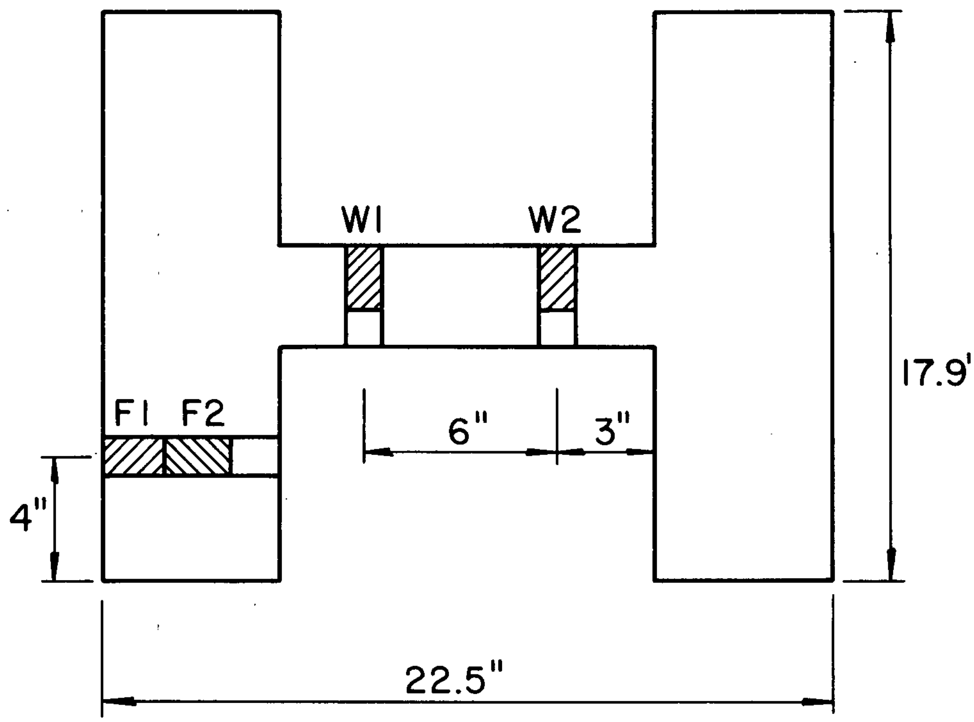


Fig. 3 Locations of Test Specimens in the Cross Section of the W14x730 Shape

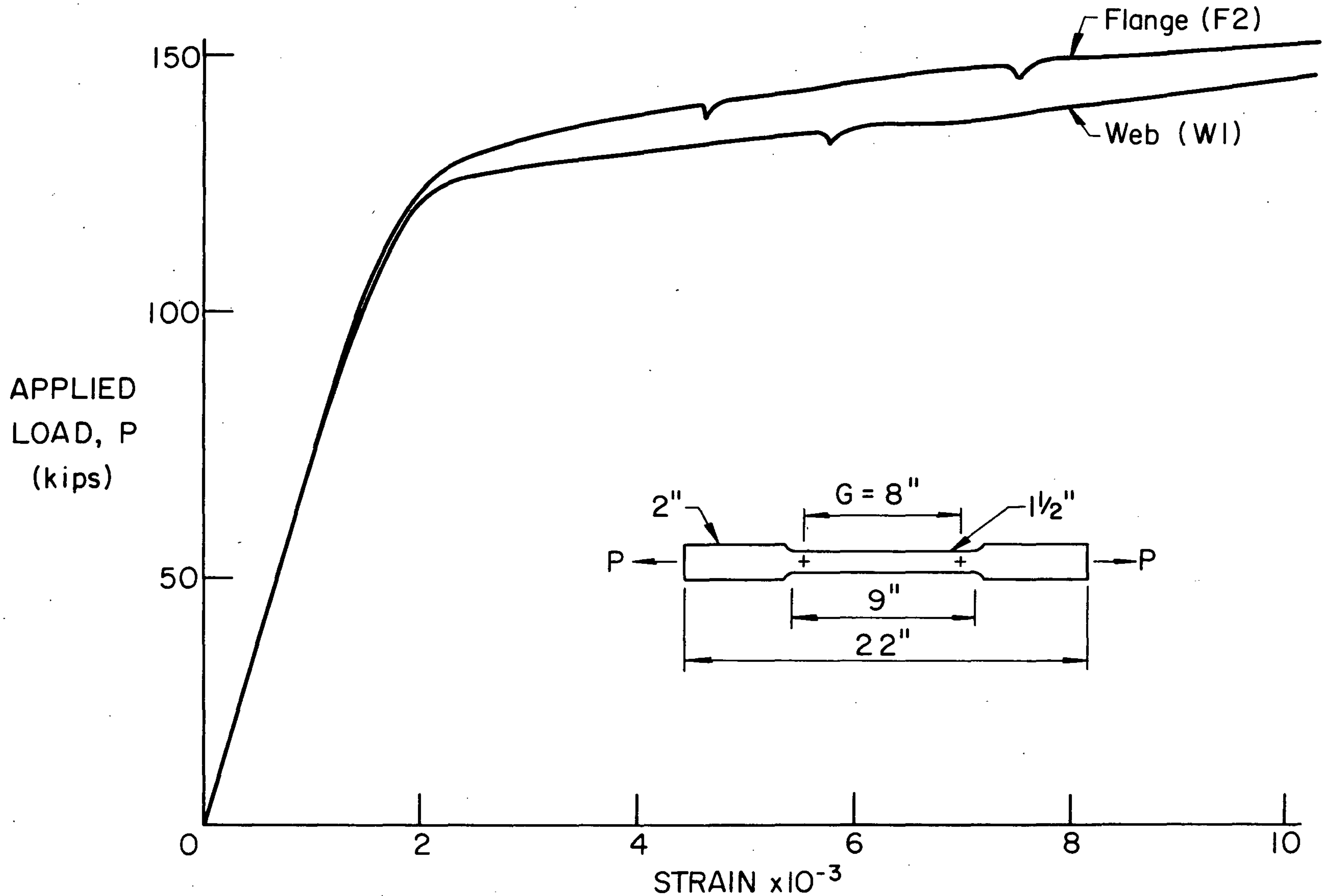


Fig. 4 Tension Coupon Test Results

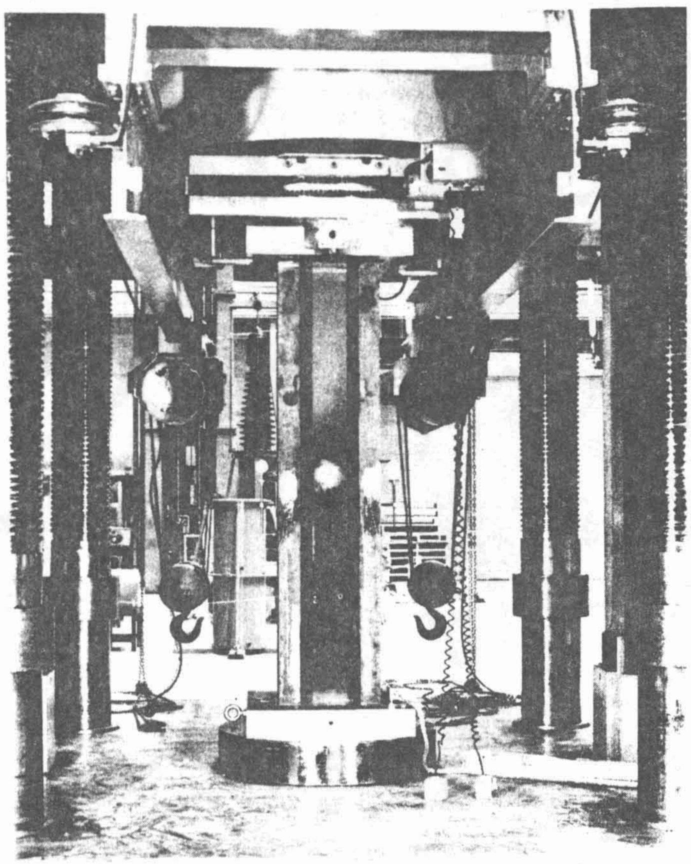


Fig. 5 Test Set-up and Instrumentation

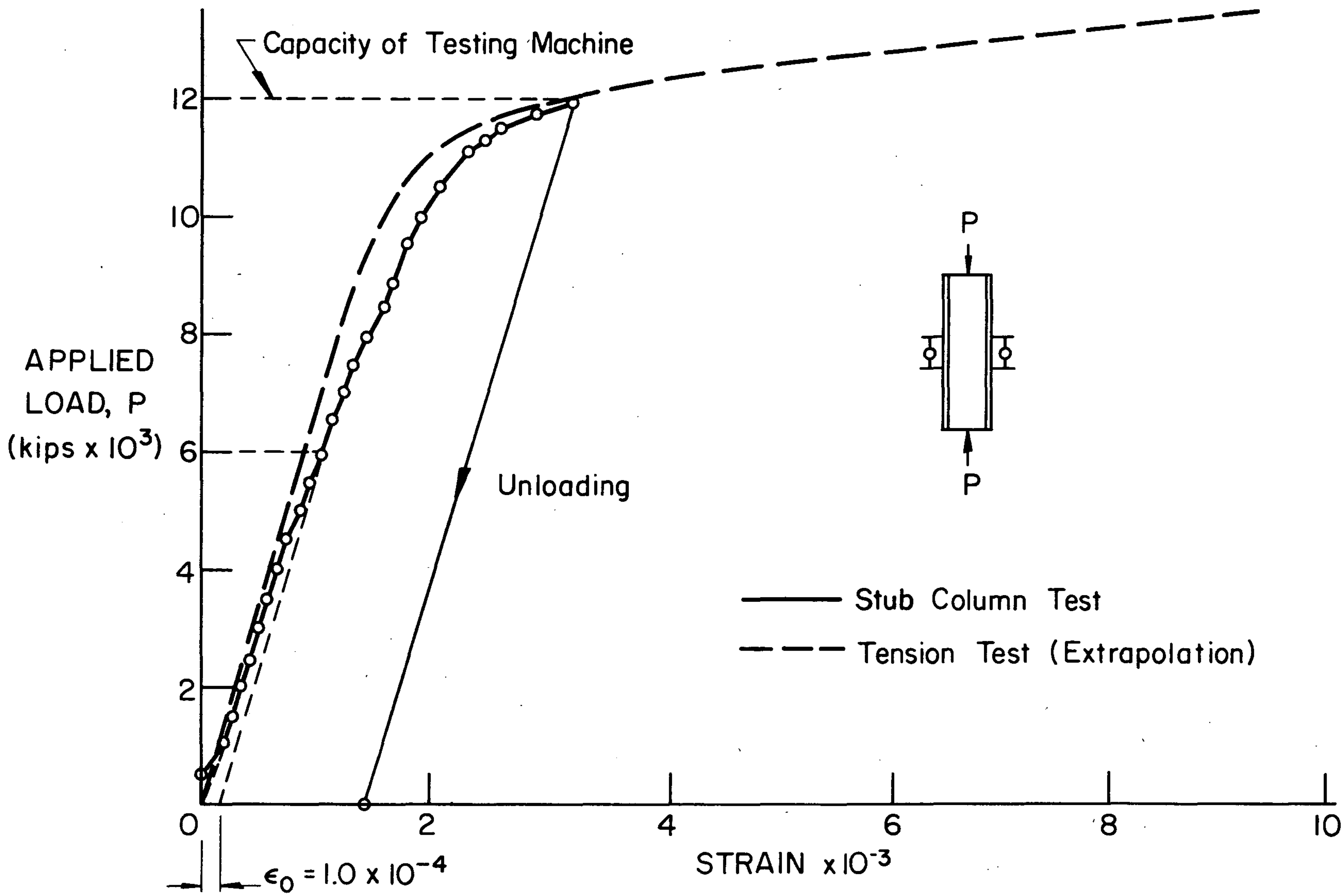
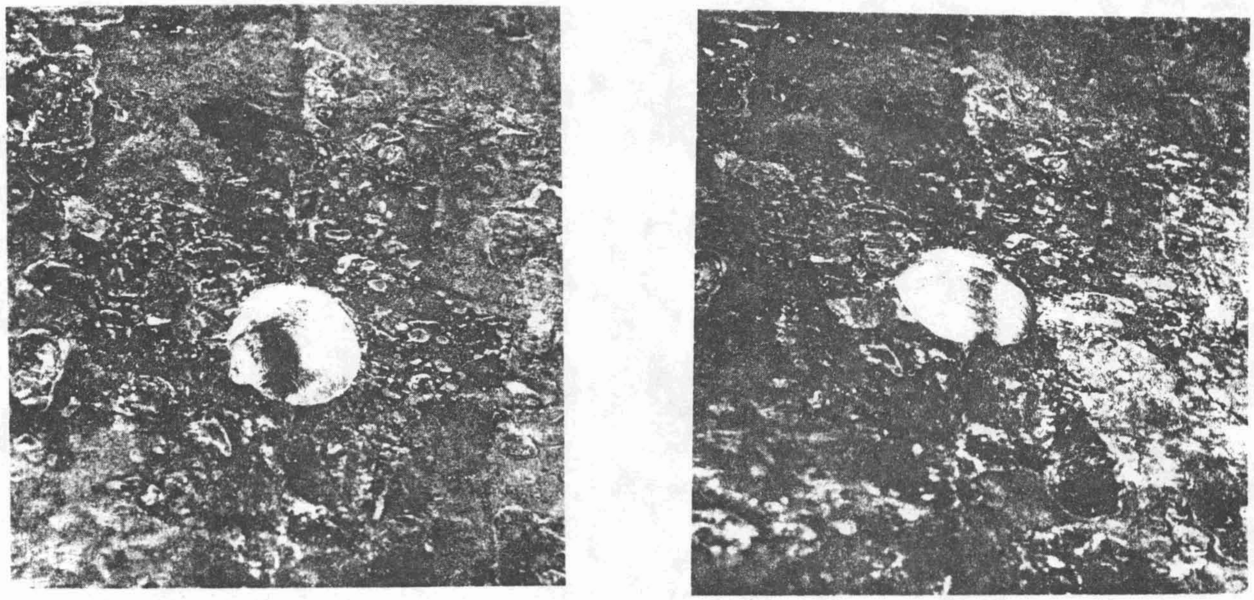
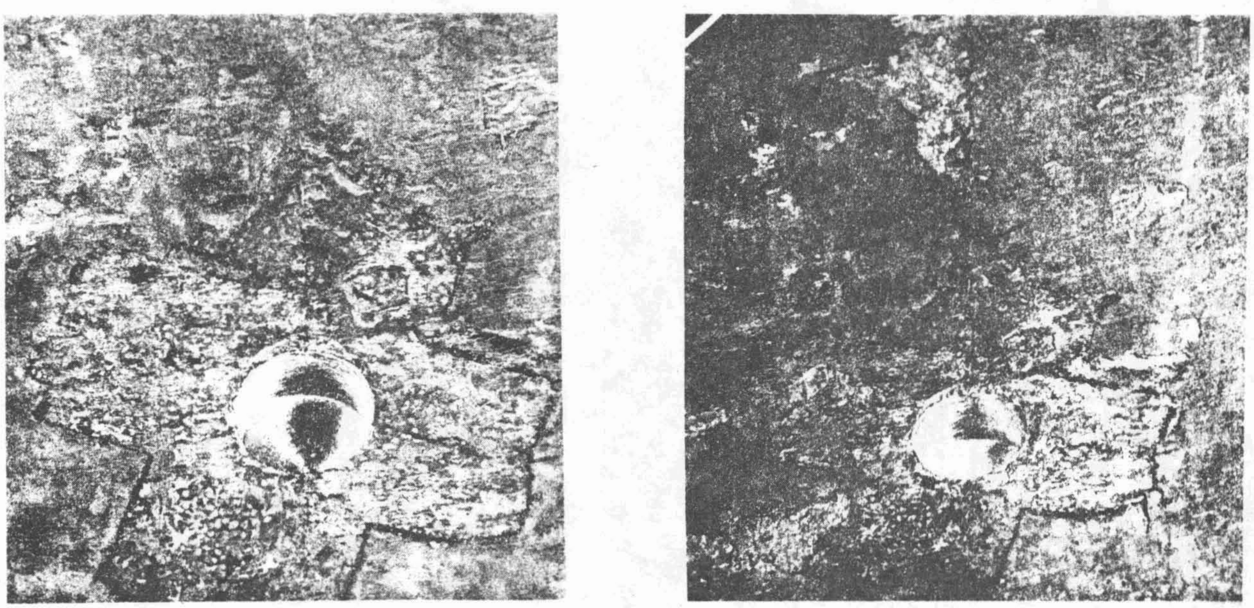


Fig. 6 Stub Column Test Result



Prior to Loading | At 12,000,000 lb.

Fig. 7 Close-up of Probe Hole A



Prior to Loading | At 12,000,000 lb.

Fig. 8 Close-up of Probe Hole C

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