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Department of Structural Engineering
School of Civil and Environmental Engineering
Cornell University

Report No. 82-14

- FINAL REPORT -

AN EXPLORATORY STUDY ON THE BEHAVIOR OF COLD-FORMED STEEL WALL STUDS

by

Yaochun Zhang

and

Teoman Peköz, Project Director

A Research Project Sponsored by
The American Iron and Steel Institute

Ithaca, N.Y.

September 1982

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1. GENERAL

Cold-formed steel wall studs are widely used in the U.S. and Canada. The 1980 A.I.S.I. Specification (Ref. 1) contains provisions for the design of such wall studs based primarily on the research conducted at Cornell University (Refs. 2 and 3). This research involved theoretical and experimental studies on wall studs subjected to axial loads only. The Specification provisions on the case of combined axial and lateral loading were derived intuitively and were made intentionally conservative.

The possible excessive conservatism in the provisions for the combined loading case prevents using wall studs as economically as might be possible. The primary objective of the tests reported herein was to provide experimental evidence to assess the degree of conservatism in the present approach and to formulate a program for future studies. This study was not intended to result in conclusive design recommendations. The secondary objective of the study was to explore the behavior of 16 foot long wall studs that are 6 inches deep. Such applications are more common now than when the original research was conducted. The previous work was on 4 inch deep and 12 foot long wall studs.

2. TEST PROGRAM

All the tests involved lipped channel wall studs 6.07 inches deep with 1.7 inch wide flanges and .077 inch in thickness. The measured average dimensions are given in Fig. 1. Nine tensile coupons were tested and the average .2 percent offset yield stress was found to be 50.16 ksi. The average ultimate stress was 70.28 ksi. The wallboard used was 1/2 inch thick Sheetrock Brand-USC gypsum panel (tapered), manufactured to meet ASTM Standard C36. Cantilever shear tests were conducted and the results are discussed below.

2.1 WALL ASSEMBLY TESTS

2.1.1 Specimens

Altogether 12 tests were conducted on three types of wall assemblies. The wall assembly types are shown in Fig. 2. Assembly types shown in Figs. 2a and 2b were tried first. However due to the uncertainties in the influence of the configuration on the behavior in these types of assemblies, the remaining tests were conducted on assemblies as shown in Fig. 2c. To explore the effect of the loading on the behavior, different arrangements as shown in Fig. 3 were tried.

In the first four tests 6x1" Drywall Screws with Sharp S Type Point were used. In the remaining tests No. 8x1.25" FS Tightlock screws provided by the manufacturer of the studs were used. In the first eight tests holes of smaller diameter than that of the screws were predrilled. In the last four tests no holes were predrilled. In the first eight tests the screws were drilled through the wallboard into the end channel and into the wall stud. In the last four tests the end channels were first connected to the studs by one screw at each flange of each stud. The wallboard was then screwed to the end channels and the studs as applicable.

In the first four tests the end channel used was such that the flanges of the studs rested on the round corner between the web and the flange of the end channels as shown in Fig. 4. In the first three tests when the axial load was applied to the studs the flanges of the end channels were wedged open. This caused a tensile force combined with a shear force in the screw on connecting the end channels and the wall studs. In general at failure these screws broke off. This might have resulted in premature failure of the entire assembly. In the subsequent tests, other channels that permitted the resting of the studs entirely on the web were used.

In the first four tests the wallboard was cut at the end studs. Thus the screws were near the cut edge of the wallboard. The cutting operation in general introduces cracks in the wallboard, and hence, lowers the strength of the overall assembly. In the assemblies for the last eight tests, the wallboard was cantilevered 4 inches over the studs (see Fig. 2c). Also in the first four tests, the wallboard was used in 8 foot long sections along the length of the studs. In the last eight tests the wallboards were cut into 4 foot long segments along the length of the studs. This was done to simulate the case when the wallboards are placed horizontally with the 8 foot wide side parallel to the floor.

2.1.2 Test Setup and Loading

The setup for axial loads is illustrated in Fig. 3. The axial loads were applied by hydraulic jacks. In Test 4, the lateral load was first applied by vacuum. However the wallboard could not sustain the vacuum pressures that the wall studs could carry (see the footnote in Table 1). Therefore the arrangement described in Table 1 was tried. In Tests 6 and 8 first an axial load equal to the ultimate load in tests 5 and 7, respectively, divided by 1.92 was applied. Then the lateral load was applied by means of iron bricks each weighing about 26 lbs. The bricks were 12"x4" in size. Pads of homosote 1"x1" were placed at each corner of the bricks between the bricks and the wallboard. This was done to reduce the effect of friction between the bricks and the wallboard. In Test 10, the lateral was applied as described in the footnote in Table 1.

Since the assemblies were tested in a horizontal position, the dead load in all cases was present as a lateral load. The dead loads were 7.55, 6.47, 6.51, and 6.84 psf for the assemblies shown in Figs. 2a, 2b, and 2c for 16 ft span and 2c for 8 ft span, respectively.

The ends of the stud assemblies were free to rotate about the symmetry axes of the studs due to the knife edges provided. However, the rotation was partially restrained about the principal axes perpendicular to the symmetry axes due to the end channels and the wallboard. The axial loads were aligned with the centroidal axes geometrically at the ends.

In general, the studs had about .5 inch sweep in 16 feet before they were connected to the wallboards. In the assemblies of Tests 1, 5, and 6, the sweep after the wallboards were attached was 0.50, 0.75, and .63 inches, respectively.

2.1.3 Test Results

The test results are summarized in Table 1. the deflections and rotations observed during the tests are plotted in Figs. 5 through 15. In these plots u is the deflection in the plane of the wall, v is the deflection perpendicular to the wall and ϕ is the rotation all measured at midspan. The tested specimens are shown in the photographs at the end of this report.

In general, the initial failure mode was not clear. Almost all the specimens had a significant amount of bending, twisting, and local buckling. However, this does not give a clear indication as to how the failure was initiated. In the first three tests it is likely that the failure of the screws connecting the end channels, wallboard and the studs might have initiated the failure as discussed above. Then a significant amount of bending, twisting, and local buckling followed. In each case the failure was quite sudden and caused in some cases the specimen to jump out of the test fixture. Frequently, the wallboard got detached from the studs over several screws. In almost all the tests snapping sounds were heard several steps before the failure. This could have been due to the biting of the screws into the wallboard and thus causing cracking.

In Test 1, the specimen jumped the farthest at failure (about 18 inches). The failure initiated in an end stud in Test 2 and the failure of the interior studs followed. On the other hand, in Test 3 the failure initiated in the interior studs and the failure of the other studs followed.

The failure in Tests 4 and 10 is described in part in Table 1. The failure in this case was rather gradual involving large deflections. In Test 5 the screws were seen to bite into the wallboard material several steps before failure. Considering the large initial sweep, the lower ultimate load in this test is not surprising.

Rather sudden failures were also observed in Tests 5 through 12 except Test 10. Again in each case local buckles were observed after the failure. In the 16 foot long studs the local buckling occurred near the midspan. In the 8 foot long studs all the local buckles were between the end and the sixth point near the supports.

2.2 CANTILEVER SHEAR TESTS

The cantilever shear tests were conducted on two types of specimens as illustrated in Figs. 16 and 17. The specimen in Fig. 16 is intended to simulate the conditions in the first four wall assembly tests. The specimen shown in Fig. 17 is intended to simulate conditions in the last eight tests. The results are plotted and evaluated in Figs. 18 through 20. In these figures it is seen that the results are sensitive to the type of screw used. The deflections for the ultimate loads were extrapolated in each case from the last two reading before failure. In general it is not possible to measure deflections at failure.

For No. 6 screws at 12 inches with gypsum board the A.I.S.I. Specification gives values of $\overline{g}$ and $\overline{\gamma}$ as 2.0 k/in and .008 in/in, respectively. The corresponding values observed in the tests were 2.642 k/in and .011 in/in, respectively.

It is desirable to carry out several duplicate tests and additional tests for panels with No. 8 screws. The values of the wallboard parameters as stipulated in the Specification and as determined in the tests will be used below in the correlation of the test results with the calculated results.

2.3 STUB COLUMN TESTS

Three stub column tests were conducted according to the A.I.S.I. Specification (Ref. 1) and Q values of .736, .720, and .693 were determined. The average of these values is .72. The value of Q calculated according to the A.I.S.I. Specification is .754.

3. CORRELATION OF THE TEST RESULTS WITH THOSE PREDICTED BY THE A.I.S.I. SPECIFICATION

The test results are compared with the results calculated using the A.I.S.I. Specification and a variation of it in Tables 2 through 7. In all cases in the calculations the factor of safety has been eliminated throughout in the A.I.S.I. Specification equation used. Therefore a ratio of 1.00 for the observed to calculated ultimate load indicates perfect correlation.

The A.I.S.I. interaction equations 5.1.2-1 and -2 were modified for the ultimate conditions as follows:*

$$\frac{f_{au}}{F_{a3u}} + \frac{f_{bxu}}{\left(1 - \frac{f_{au}}{F_{ex}}\right) F_{bxu}} = 1$$

---

*In an earlier progress report the ultimate loads were predicted by using the A.I.S.I. interaction equations to determine f_a, and f_{au} was taken as $1.92 f_a$. That approach gave results quite different than those obtained here. The present approach is considered to be more appropriate.

and

$$\frac{f_{au}}{F_{a3u}} + \frac{f_{bxu}}{F_{bxu}} = 1$$

where

f_{au} and f_{bxu} are the axial and flexural stresses at failure

$F_{a3u} = 1.92F_{a3}$

$F_{bxu} = 1.67F_{bx}$

$F_{ex} = 1.92F'_{ex}$

In Tables 2 through 6, the tests are considered where axial loads were applied. In Table 7 the tests with only lateral loads are considered.

In Tables 2 and 3 the calculations are based on the $\overline{q}$ and $\overline{\gamma}$ values given in the Specification. These values are given in the Specification for No. 6 screws. No. 6 screws were used only in Tests 1 through 4 and No. 8 screws were used in Tests 5 through 12. Therefore for the latter group the correlation is not strictly correct. In Table 2 the Specification is used as is (without the factors of safety in all cases); however in Table 3 the requirement that F_{bx} should not exceed $1.7F_{a3}$ has been eliminated. Tables 4 and 5 parallel Tables 2 and 3 with the exception that the experimentally determined values of $\overline{\gamma}$ and $\overline{q}$ used in reaching the calculated ultimate axial loads.

In all cases in applying the Specification Section 3.3, the length was taken as twice the screw spacing. The Specification Section 5.1.2 is not very clear in specifying the length to use in applying Section 3.3.

From the test results it is not possible to assess the accuracy of the Specification for the case of axial loading only since a lateral loading was present in all tests due to the weight of the assembly.

In general, the results of Tests 2 and 3 are questionable since the behavior of a four stud assembly is quite indeterminate. It is not clear how the bracing effect of the wallboard on the end and interior studs differ.

The cases of combined axial and lateral loading are self-explanatory in the tables. It is seen that if one uses the values of $\bar{\gamma}$ and $\bar{q}$ given in the Specification for No. 6 screws conservative results are obtained in all cases. The conservatism is largest for Tests 6 and 9 which were 16 ft long and subjected to an axial and 52 psf lateral loading. The calculated results are very conservative even when the $1.7F_{a3}$ requirement is ignored. In general, the conservatism gets less when the lateral load is reduced.

Similar observations can be made on the results when the experimentally obtained values of $\bar{q}$ and $\bar{\gamma}$ are used in the computations. These results tabulated in Tables 4 and 5 lead to a better evaluation of the procedure that is stipulated in the A.I.S.I. Specification. The observed ultimate axial load in Tests 6 and 9 are 1.42 and 1.47 times the ultimate (not the design) load predicted by the A.I.S.I. Specification. These two tests were on identical 16 ft long specimens with a total lateral load of 52 psf. The observed ultimate axial load is 1.39 times the ultimate load predicted by the Specification in Test 11. This test was on a 16 ft specimen with a 25 psf lateral load. Tests 5 and 12 were on identical 16 ft specimens which were subjected to axial and lateral dead loads. The observed ultimate loads are 16.00 and 20.74k, respectively. The ratios of the observed to calculated ultimate loads are 0.92 and 1.19. The scatter is rather alarming because it shows that the results are quite sensitive to minor details.

The results become less conservative when the requirement that F_{bx} should not exceed $1.7F_{a3}$ is ignored. However, still in Tests 6 and 9 the ratios of the observed ultimate axial load to that calculated are 1.16 and

1.20, respectively. The conservatism involved can be explained in part by considering the results of Tests 4 and 10 as is done in Table 7.

In Tests 4 and 10 only lateral loads were applied. The evaluation results are summarized in Table 7. In Test 4 the distribution of the loads between the four studs is not very clear. Thus the maximum calculated bending moment depends on the assumed distribution of the loading between the studs. It is likely that the concentrated loads which were the result of pig iron blocks placed on top of the assembly were equally shared among the studs. If the vacuum loading is assumed to be distributed according to the tributary area of each stud then the maximum moment at failure can be calculated to be 97.71 k-in. Assuming the vacuum load to be equally shared between the studs the calculated maximum bending moment becomes 83.34 k-in. The yield moment assuming full lateral restraint is 66.22 k-in. If 1.7 times F_{a3} were taken as the failure stress, the calculated ultimate moment would be 33.71 k-in. An ultimate moment for the section can be calculated according to Section 3.9 to be 83.60 k-in. The assumption of the yield moment as the failure moment is thus seen to be very conservative.

In Test 10, the experimentally observed ultimate load is more clear and correlates very well with the ultimate moment calculated according to Section 3.9 of the A.I.S.I. Specification but not according to Section 5.1.2.

The conservatism involved in treating the bending stresses also affects the calculations when the case of combined axial and lateral loading is considered. The composite behavior of the wallboard material with the studs may add to the conservatism. Another source of conservatism is the fact that in obtaining the formulas of the A.I.S.I. Specification the rotational restraint provided by the wallboard material was ignored.

The test evidence developed so far is indeed very inadequate to develop a design criterion. However it confirms the suspected very excessive conservatism in the Specification for the combined loading case.

4. CONCLUSIONS AND DESIRABLE FUTURE STUDIES

Based on a few tests the study herein indicates that the present A.I.S.I. Specification provisions on wall studs subjected to combined axial and lateral loads can depending on the application, be undesirably conservative. Since the study was exploratory in nature, design provisions cannot be reached at this time.

Further systematic theoretical and experimental studies are needed to formulate a design procedure for the case of combined loading. These studies should include repeat tests of the tests conducted in this exploratory study as well as theoretical studies and tests exploring several parameters not covered here. The following are some of the points to be considered:

— Stud sizes and wallboard types need to be varied.

— The effect of rotational restraint on the computed values of ultimate loads.

— The effect of perforations needs to be investigated.

— The effect of local instability ($Q < 1$) needs to be investigated.

— Screw types and spacing need to be varied.

— Loading should include eccentric axial load to simulate the effect of types of loads caused by the floor joists.

— The relative magnitudes of the axial load and the lateral load need to be varied systematically.

— Provisions need to be developed for the case of wallboard only on one side as well as the case of unmatched wall materials on each flange.

— The relevance of small scale cantilever shear tests to the predictions for full scale walls needs to be established.

— Composite action with the wallboard particularly for large lateral loads needs to be investigated.

REFERENCES

1. "Specification for the Design of Cold-Formed Steel Structural Members", American Iron and Steel Institute, Washington, D.C., 1980 Edition.
2. Simaan, A. and Peköz, T., "Buckling of Diaphragm-Braced Columns of Unsymmetrical Sections and Application to Wall Studs Design", Department of Structural Engineering, Cornell University, Report No. 353, August 1973.
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TABLE 1

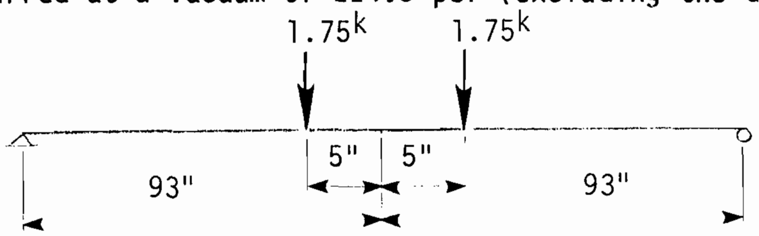
WALL ASSEMBLY TEST RESULTS

Test No.	No. of Studs	Assembly Figure	Axial Load Figure	Length (ft)	Pult (k)	Lat. Load (psf)(2)	Comment
1	2	2a	3a	16	15.80	7	
2	4	2b	3b	16	20.80	7	
3	4	2b	3c	16	11.00(1)	7	
4	4	2b	—	16	0.00	(3)	
5	2	2c	3a	16	16.00	7	
6	2	2c	3a	16	12.50	52	
7	2	2c	3a	8	23.14	7	
8	2	2c	3a	8	25.96	52	
9	2	2c	3a	16	12.94	52	Repeat of Test 6
10	2	2c	—	16	0.00	(4)	
11	2	2c	3a	16	18.30	25	
12	2	2c	3a	16	20.74	7	Repeat of Test 5

(1) Interior studs were loaded to twice the axial load of the end studs, value given is for the end studs.

(2) Includes a dead load of 7 psf.

(3) Wallboard failed at a vacuum of 82 psf. The wallboard was replaced and a 1/2 inch layer of plywood was placed on the assembly. The concentrated gravity loads shown in the figure below were applied. Then a vacuum was drawn. The failure occurred at a vacuum of 114.8 psf (excluding the dead load of 7 psf).



(4) The concentrated gravity loads shown in the figure in combination with an applied uniform load of 27.83 psf in addition to the dead load caused the failure.

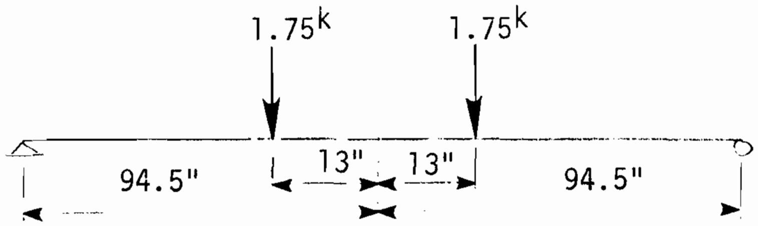


TABLE 2

EVALUATION OF TEST RESULTS*

$\bar{q}$ = 2000 lb/in and $\bar{\gamma}$ = 0.008 in/in

(Ultimate Loads Calculated According to the A.I.S.I. Specification)

Test Number	PT1	PT2	P1	P2	PT1/P1	PT2/P2
1	15.80		8.3		1.90	
2	20.80	20.80	8.3	10.7	2.51	1.94
3	11.00	22.00	8.3	10.7	1.33	2.06
5	16.00		11.4		1.40	
6	12.50		6.1		3.05	
7	23.14		17.4		1.33	
8	25.96		15.5		1.67	
9	12.94		4.1		3.16	
11	18.30		8.0		2.29	
12	20.74		11.4		1.82	

*The values of $\bar{q}$ and $\bar{\gamma}$ are as given in the A.I.S.I. Specification for No. 6 screws. No. 6 screws were used in Tests 1 through 4 and No. 8 screws were used in Tests 5 through 12.

Tests 4 and 10 did not have any axial loading; they were evaluated in Table 7.

All loads in kips and per stud.

The dead load is taken to be 7 psf.

PT1, PT2 test ultimate axial loads of end and interior studs, respectively.

P1 and P2 calculated ultimate axial loads for end and interior studs, respectively.

Q = .754 calculated according to the A.I.S.I. Specification and used in computing P1 and P2.

TABLE 3

EVALUATION OF TEST RESULTS*

$\bar{q}$ = 2000 lb/in and $\bar{\gamma}$ = 0.008 in/in

(Ultimate Loads Calculated According to the A.I.S.I. Specification Except for the $1.7F_{a3}$ Requirement)

Test Number	PT1	PT2	P1	P2	PT1/P1	PT2/P2
1	15.80		8.9		1.78	
2	20.80	20.80	8.9	11.7	2.34	1.78
3	11.00	22.00	8.9	11.7	1.24	1.88
5	16.00		12.2		1.31	
6	12.50		17.9		1.58	
7	23.14		17.5		1.32	
8	25.96		16.2		1.60	
9	12.94		7.9		1.64	
11	18.30		10.3		1.78	
12	20.74		12.2		1.70	

*The values of $\bar{q}$ and $\bar{\gamma}$ are as given in the A.I.S.I. Specification for No. 6 screws. No. 6 screws were used in Tests 1 through 4 and No. 8 screws were used in Tests 5 through 12.

Tests 4 and 10 did not have any axial loading; they were evaluated in Table 7.

All loads in kips and per stud.

The dead load is taken to be 7 psf.

PT1, PT2 test ultimate axial loads of end and interior studs, respectively.

P1 and P2 calculated ultimate axial loads for end and interior studs, respectively.

Q = .754 calculated according to the A.I.S.I. Specification and used in computing P1 and P2.

TABLE 4

EVALUATION OF TEST RESULTS

$\overline{q}$ and $\overline{\gamma}$ determined experimentally

(Ultimate Load Calculated According to the A.I.S.I. Specification)

Test Number	PT1	PT2	P1	P2	PT1/P1	PT2/P2
1	15.80		12.0		1.32	
2	20.80	20.80	12.0	15.7	1.73	1.32
3	11.00	22.00	12.0	15.7	0.92	1.40
5	16.00		17.4		0.92	
6	12.50		8.8		1.42	
7	23.14		26.9		0.93	
8	25.96		22.8		1.14	
9	12.94		8.8		1.47	
11	18.30		13.2		1.39	
12	20.74		17.4		1.19	

Notes:

Tests 4 and 10 did not have any axial load; they are evaluated in Table 7.

All loads in kips and per stud.

The dead load is taken to be 7 psf.

For Test 1 and end studs of Tests 2, 3, $\overline{q}$ = 3800 lb/in, $\overline{\gamma}$ = 0.009 in/in (see Fig. 18)

For interior studs of Test 2, 3, $\overline{q}$ = 2600 lb/in, $\overline{\gamma}$ = 0.011 in/in (see Fig. 19).

For test 5, 6, 7, and 8, $\overline{q}$ = 5600 lb/in, $\overline{\gamma}$ = 0.007 in/in, b = 11.94 in (see Fig. 20).

PT1 and PT2 test ultimate axial loads of end and interior studs, respectively.

P1, P2 calculated ultimate axial loads for end and interior studs, respectively.

Q = .72 determined by test and used in computing P1 and P2.

TABLE 5

EVALUATION OF TEST RESULTS

$\overline{q}$ and $\overline{\gamma}$ determined experimentally

(Ultimate Loads Calculated According to the A.I.S.I. Specification Except for the $1.7F_{a3}$ Requirement)

Test Number	PT1	PT2	P1	P2	PT1/P1	PT2/P2
1	15.80		12.5		1.26	
2	20.80	20.80	12.5	16.4	1.66	1.27
3	11.00	22.00	12.5	16.4	0.88	1.34
5	16.00		17.9		0.89	
6	12.50		10.8		1.16	
7	23.14		26.9		0.93	
8	25.96		22.9		1.13	
9	12.94		10.8		1.20	
11	18.30		14.5		1.26	
12	20.74		17.9		1.16	

Notes:

Tests 4 and 10 did not have any axial load; they are evaluated in Table 7.

All loads in kips and per stud.

The dead load is taken to be 7 psf.

For Test 1 and end studs of Tests 2, 3, $\overline{q}$ = 3800 lb/in, $\overline{\gamma}$ = 0.009 in/in (see Fig. 18)

For interior studs of Test 2, 3, $\overline{q}$ = 2600 lb/in, $\overline{\gamma}$ = 0.011 in/in (see Fig. 19).

For test 5, 6, 7, and 8, $\overline{q}$ = 5600 lb/in, $\overline{\gamma}$ = 0.007 in/in, b = 11.94 in (see Fig. 20).

PT1 and PT2 test ultimate axial loads of end and interior studs, respectively.

P1, P2 calculated ultimate axial loads for end and interior studs, respectively.

Q = .72 determined by test and used in computing P1 and P2.

TABLE 6

SUMMARY OF EVALUATIONS

$\overline{\gamma}_0$ and $\overline{q}_0$ from			AISI	AISI	Test	Test
$1.7F_{a3}$ Requirement			Yes	No	Yes	No
Values from Table			2	3	4	5
Test No.	Lateral Load (psf)	Length (ft)	PT1/PI(*)			
1	7	16	1.90	1.78	1.32	1.26
2	7	16	2.51	2.34	1.73	1.66
3	7	16	2.06	1.88	1.40	1.34
5	7	16	1.40	1.31	0.92	0.89
6	52	16	3.05	1.58	1.42	1.16
7	7	8	1.33	1.32	0.93	0.93
8	52	8	1.67	1.60	1.14	1.13
9	52	16	3.16	1.64	1.47	1.20
11	25	16	2.29	1.78	1.39	1.26
12	7	16	1.82	1.70	1.19	1.16

*observed/calculated ultimate axial loads from the tables indicated. For Tests 4 and 10, see Table 7.

TABLE 7

EVALUATION OF TEST RESULTS
LATERAL LOADING ONLY

CALCULATED RESULTS - (Per Stud)

$M_{ult\ AISI} = 33.71$ k-in	—	Based on section modulus times $1.7F_{a3}$ (Factor of safety was eliminated in computing F_{a3}.)
$M_{yd} = 66.22$ k-in	—	Based on section modulus times F_y (Full torsional and lateral restraint is assumed.)
$M_{ult} = 83.60$ k-in	—	Based on A.I.S.I. Specification Section 3.9 (Inelastic reserve capacity is used.)

OBSERVED RESULTS - (Per Stud)

TEST 4

$M_{ult} = 97.71$ k-in	—	For the end studs, assuming the concentrated loads to be equally supported by each of the 4 studs, but the vacuum load to be distributed according to the tributary area.
$M_{ult} = 83.34$ k-in	—	Assuming both the concentrated and the vacuum loads to be equally supported by each of the 4 studs.

TEST 10

$M_{ult} = 84.20$ k-in

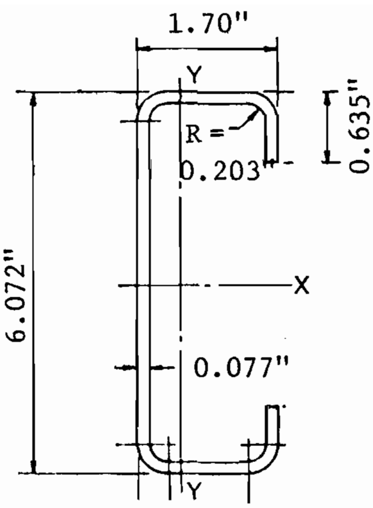


Fig. 1 Stud Section

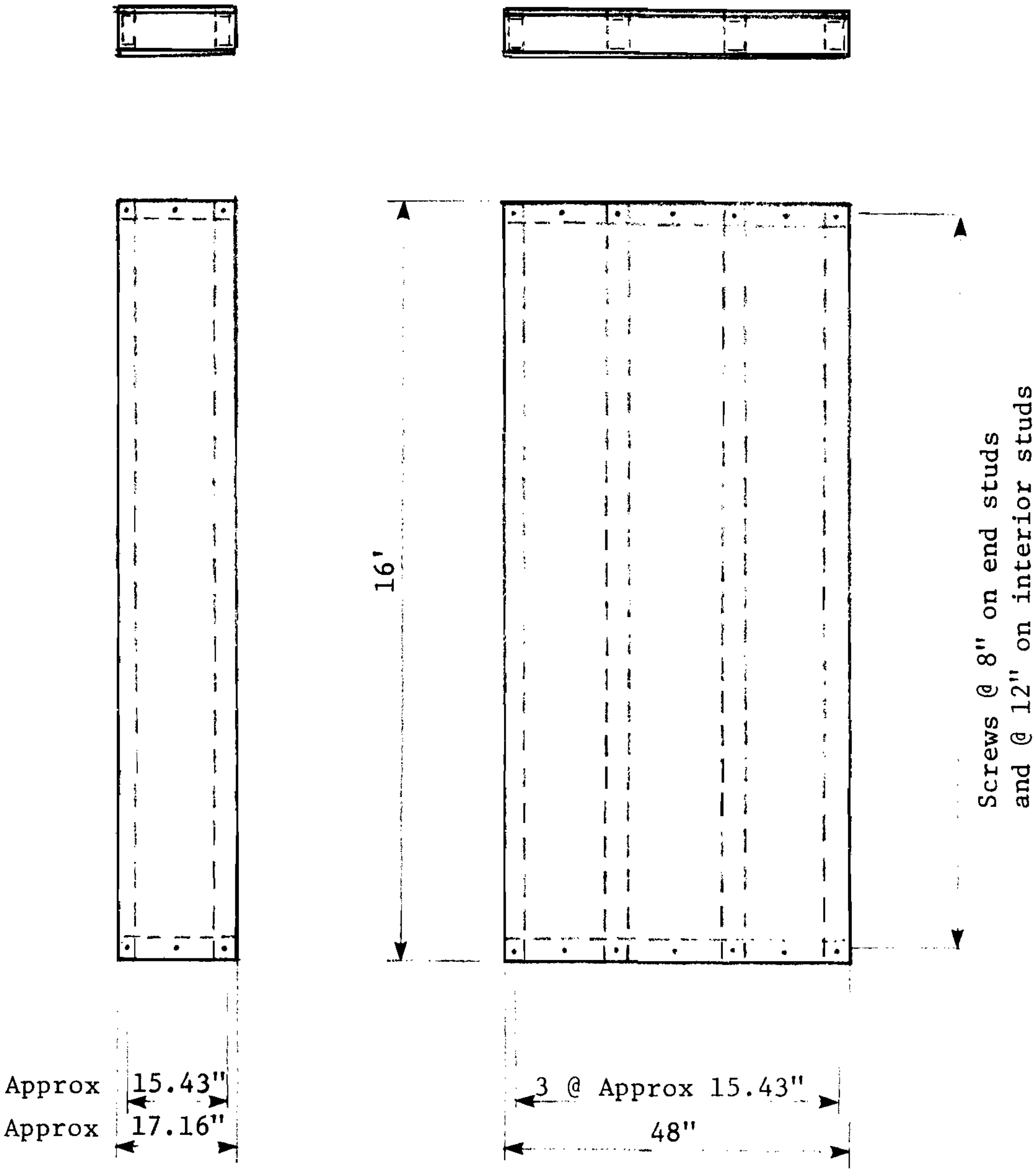


Fig. 2a

Fig. 2b

Fig. 2 Test Assemblies

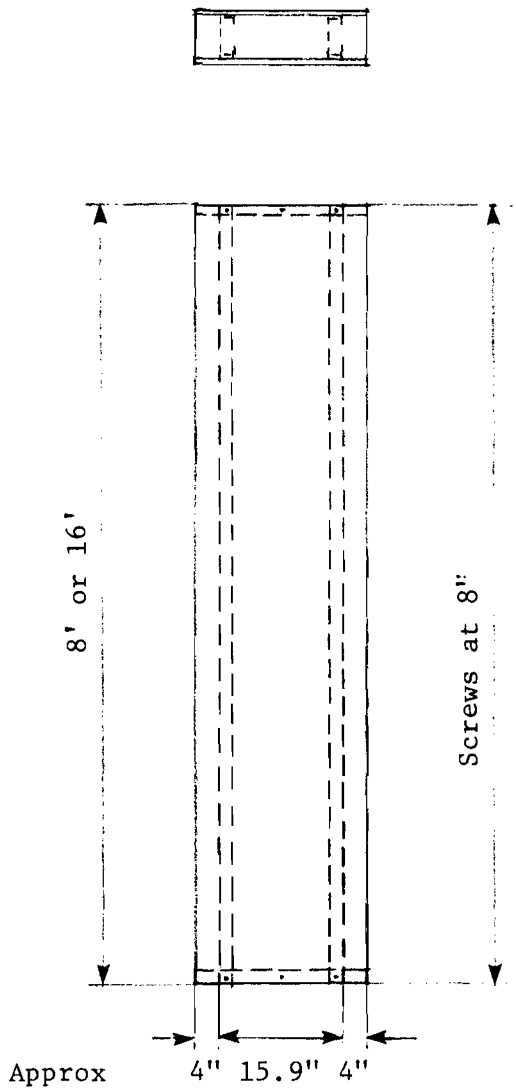


Fig. 2c

Fig. 2 Test Assemblies (cont.)

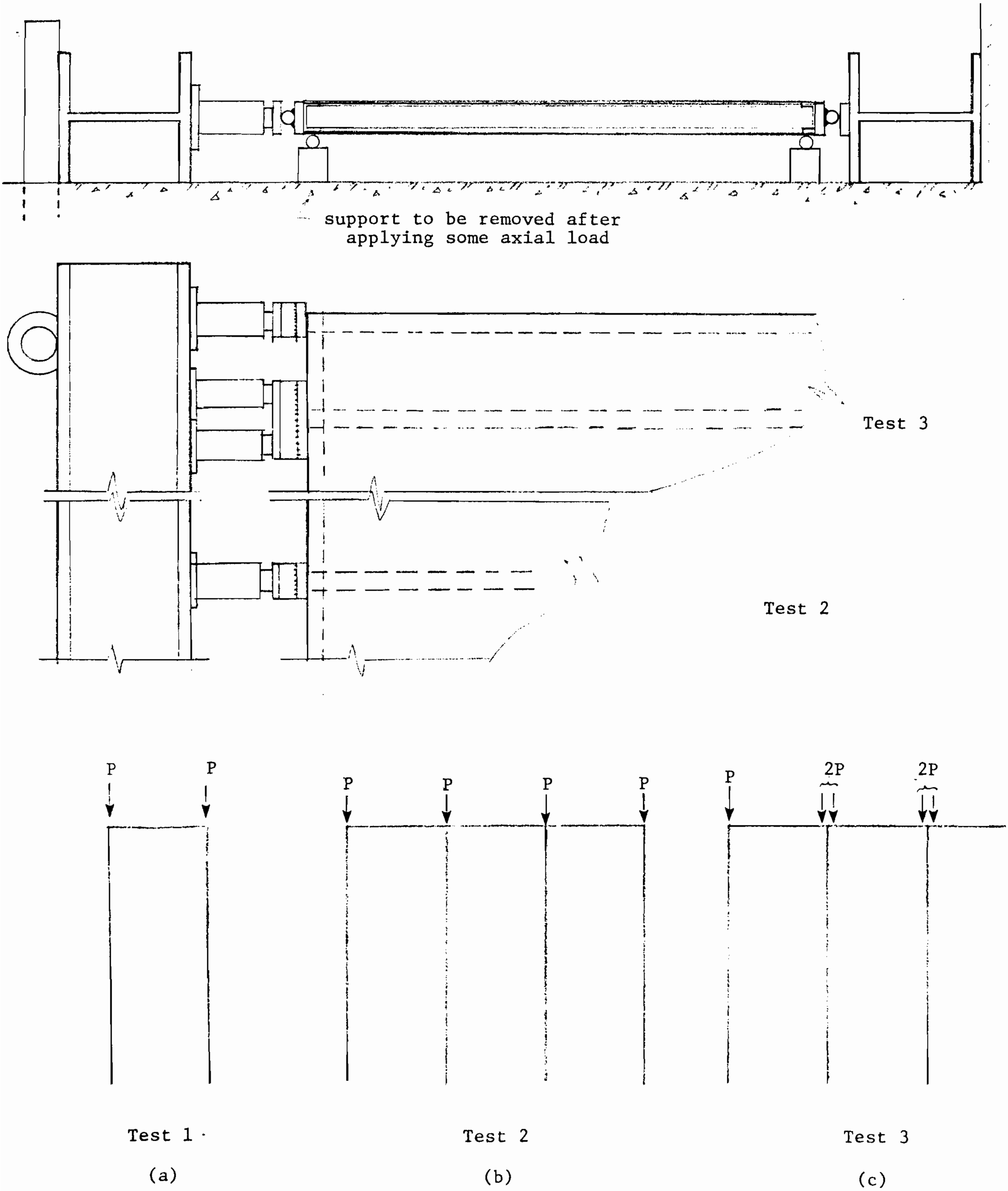


Fig. 3 Loading Schemes

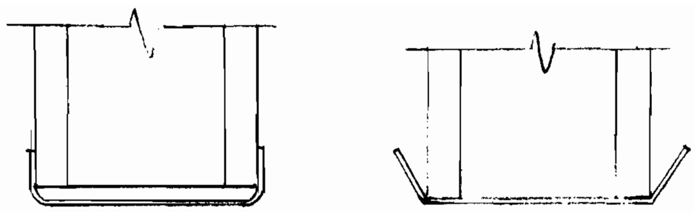


Fig. 4 End Channel

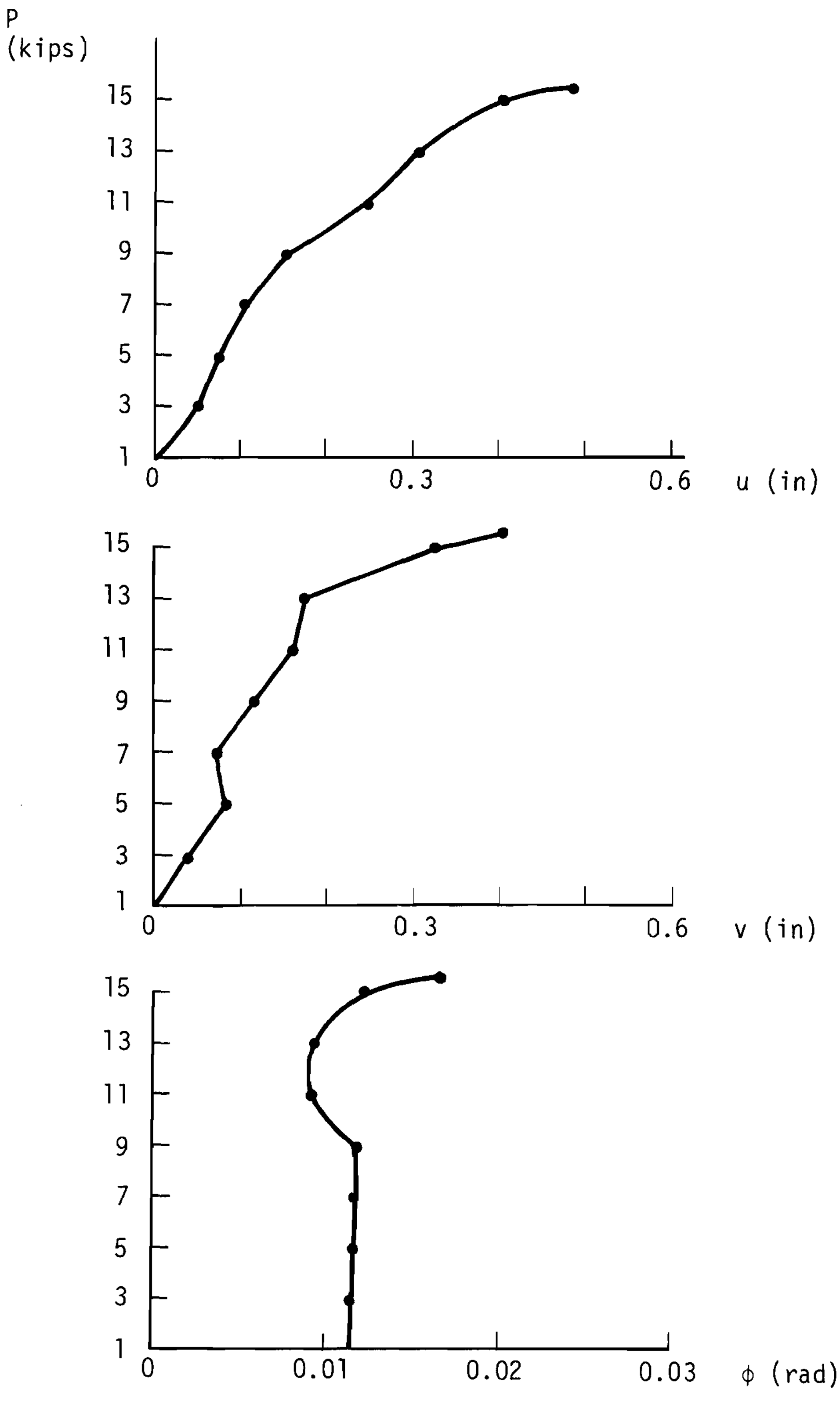


Fig. 5a Load-Deformation Curves for Test 1, Stud 1

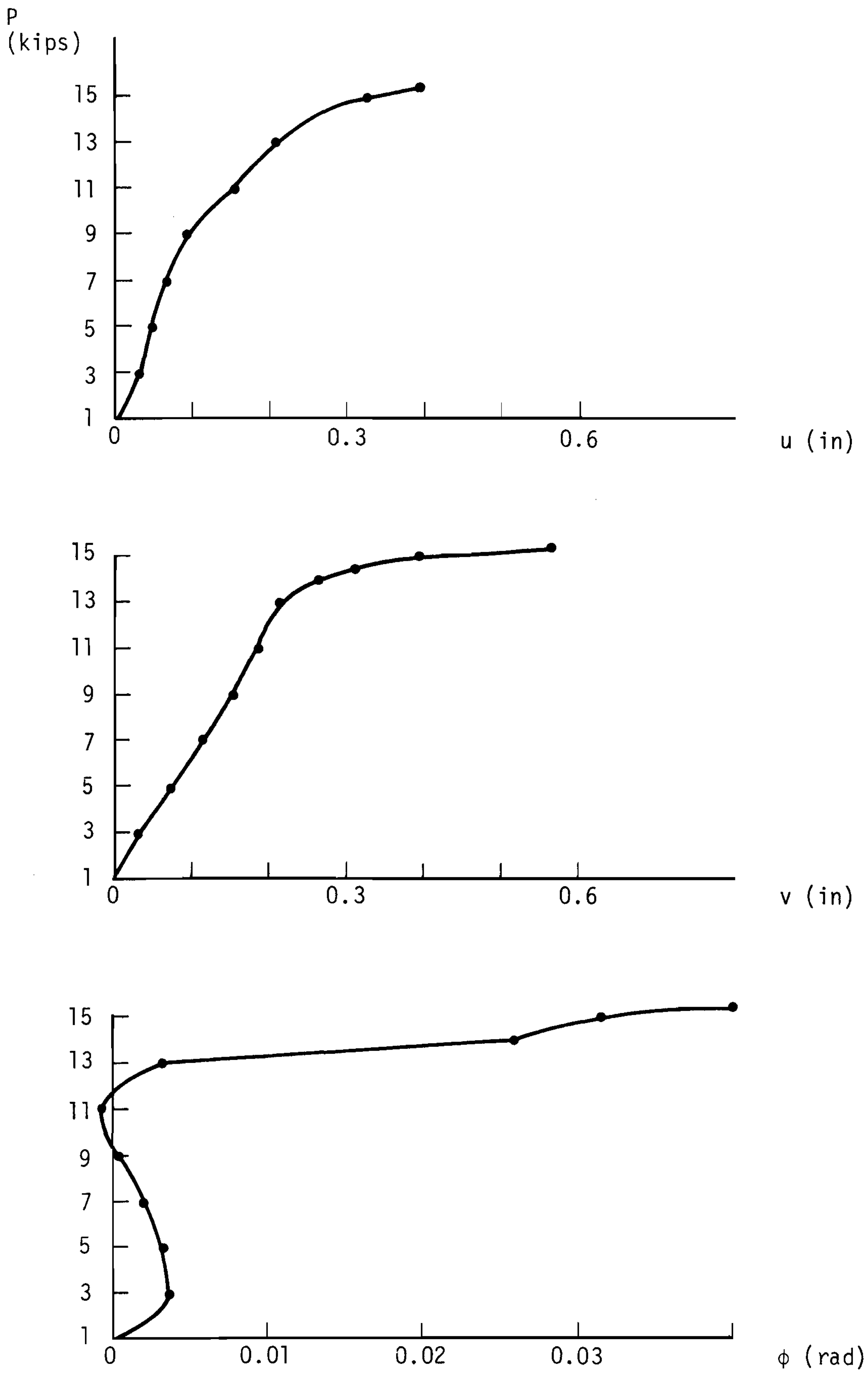


Fig. 5b Load-Deformation Curves for Test 1, Stud 2

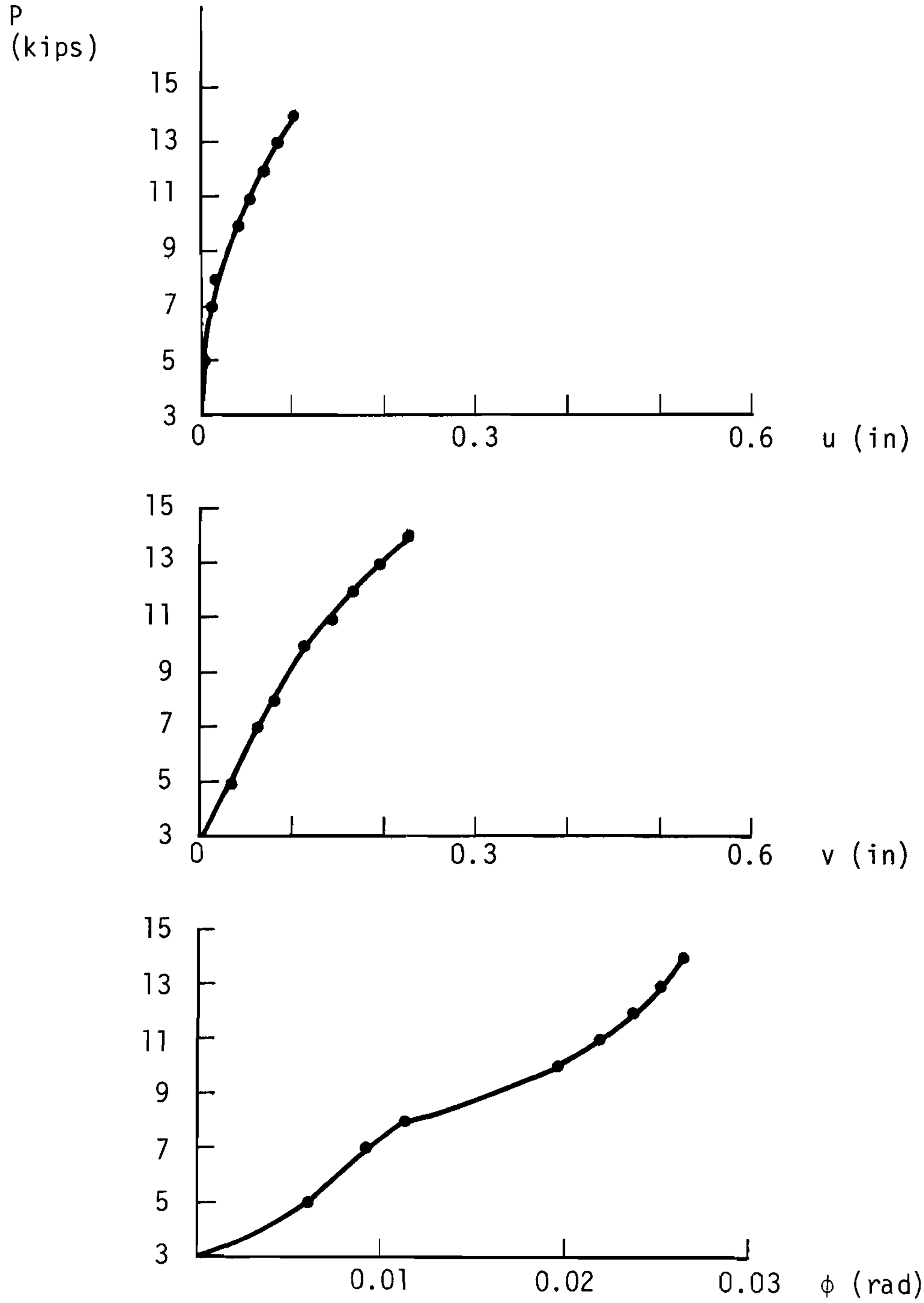


Fig. 6 Load-Deformation Curves for Test 2

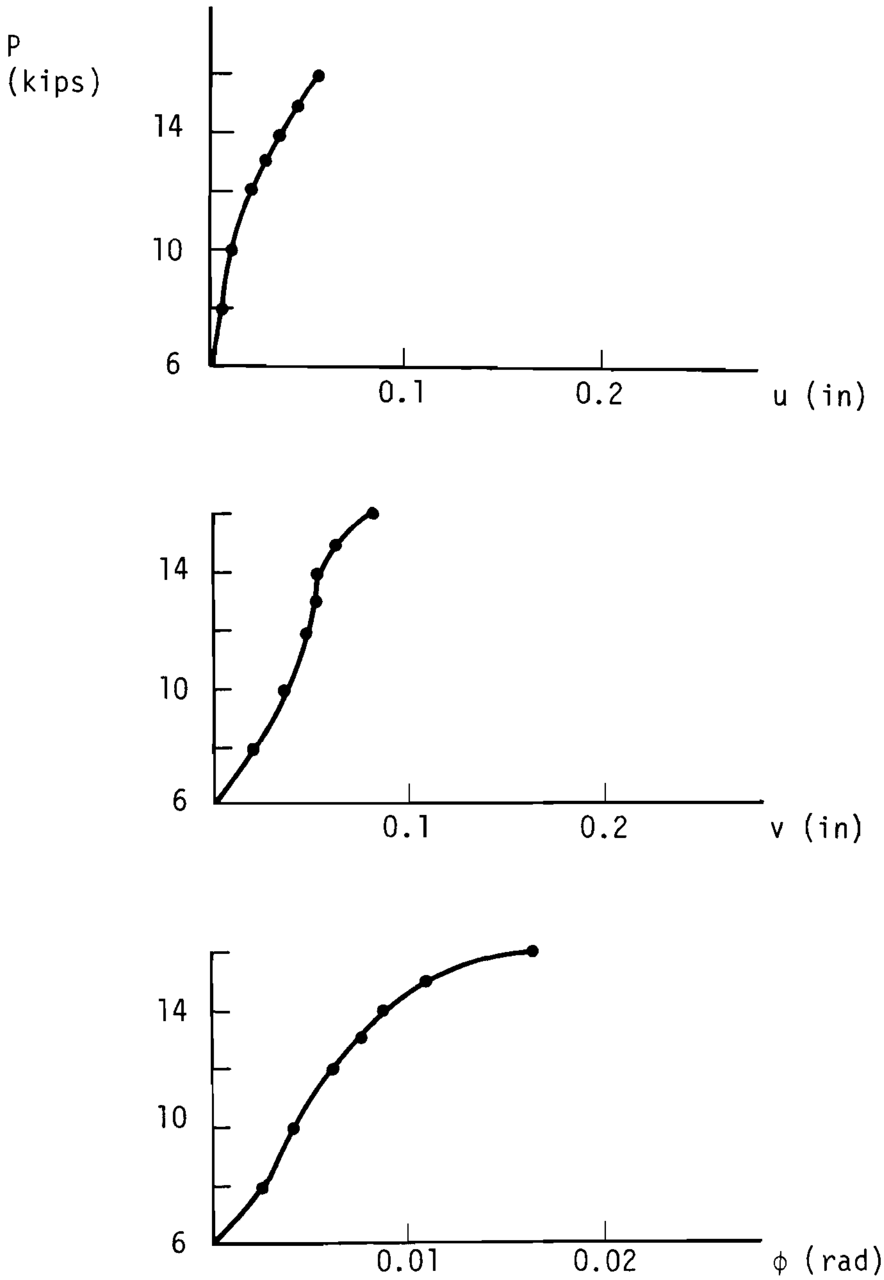


Fig. 7 Load-Deformation Curves for Test 3

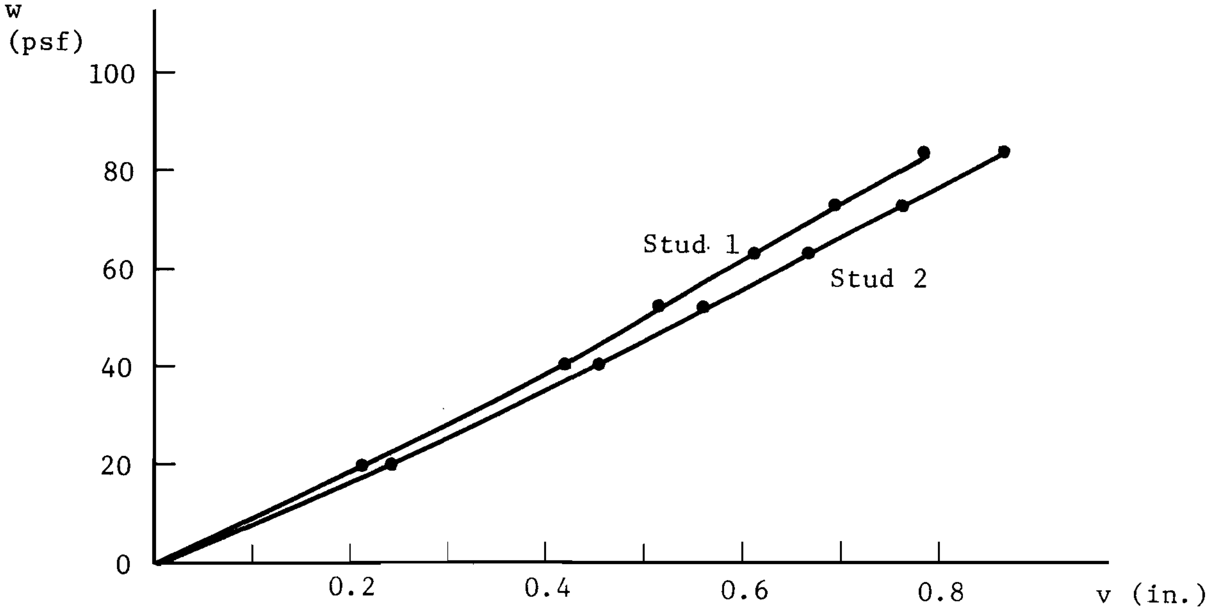


Fig. 8 Load-Deflection Curves for Test 4

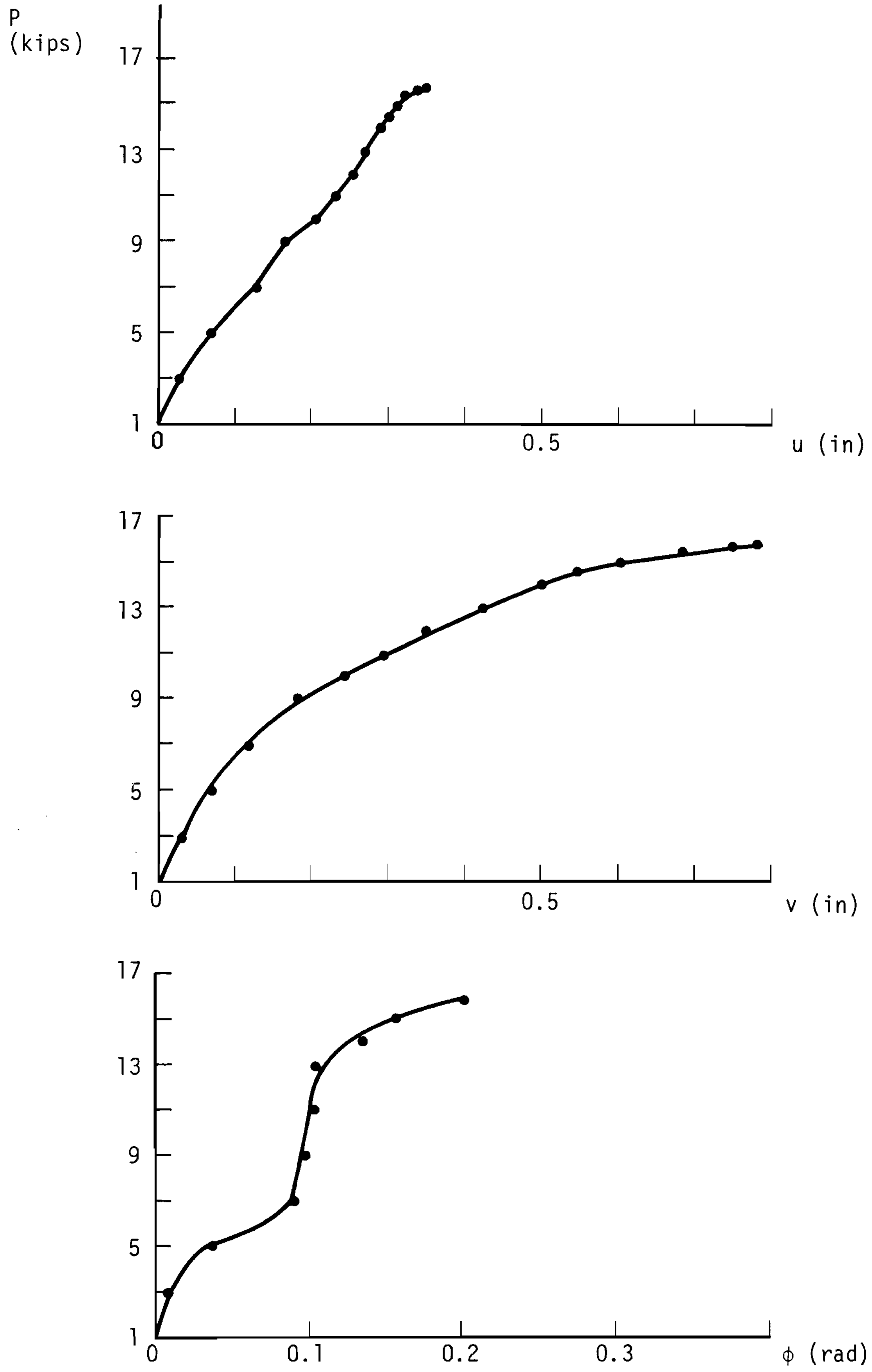


Fig. 9 Load-Deformation Curves for Test 5

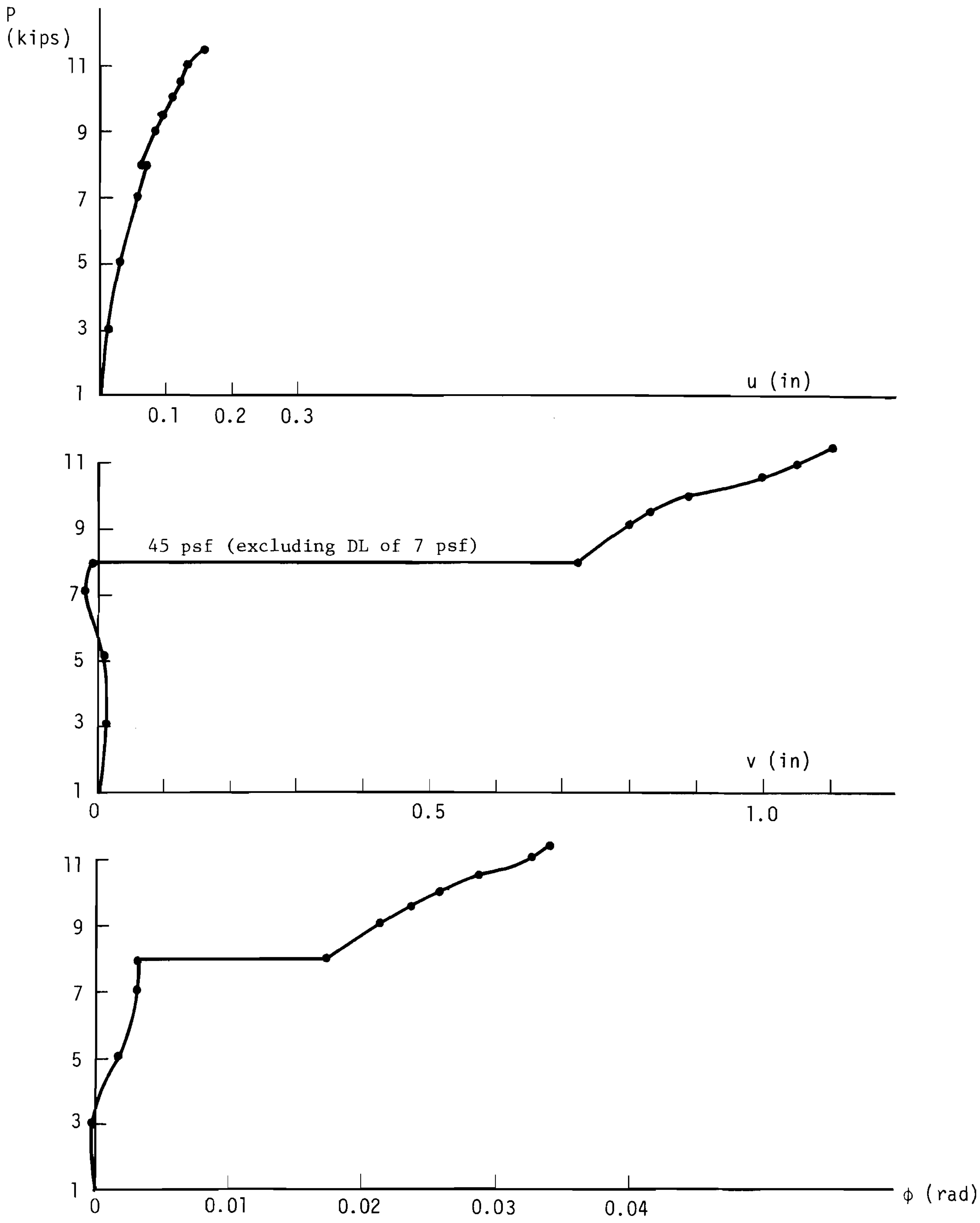


Fig. 10 Load-Deformation Curves for Test 6

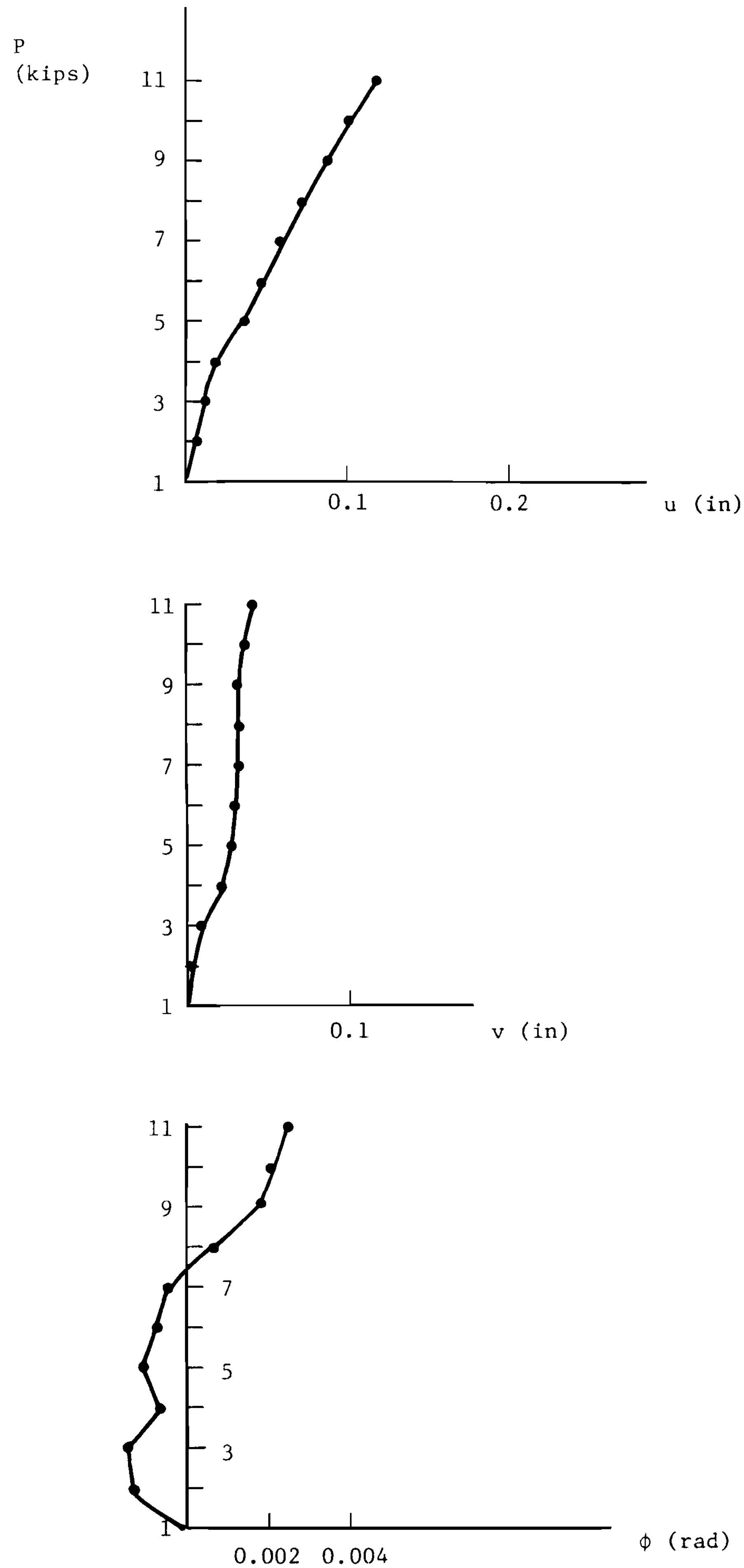


Fig. 11 Load-Deformation Curves for Test 7

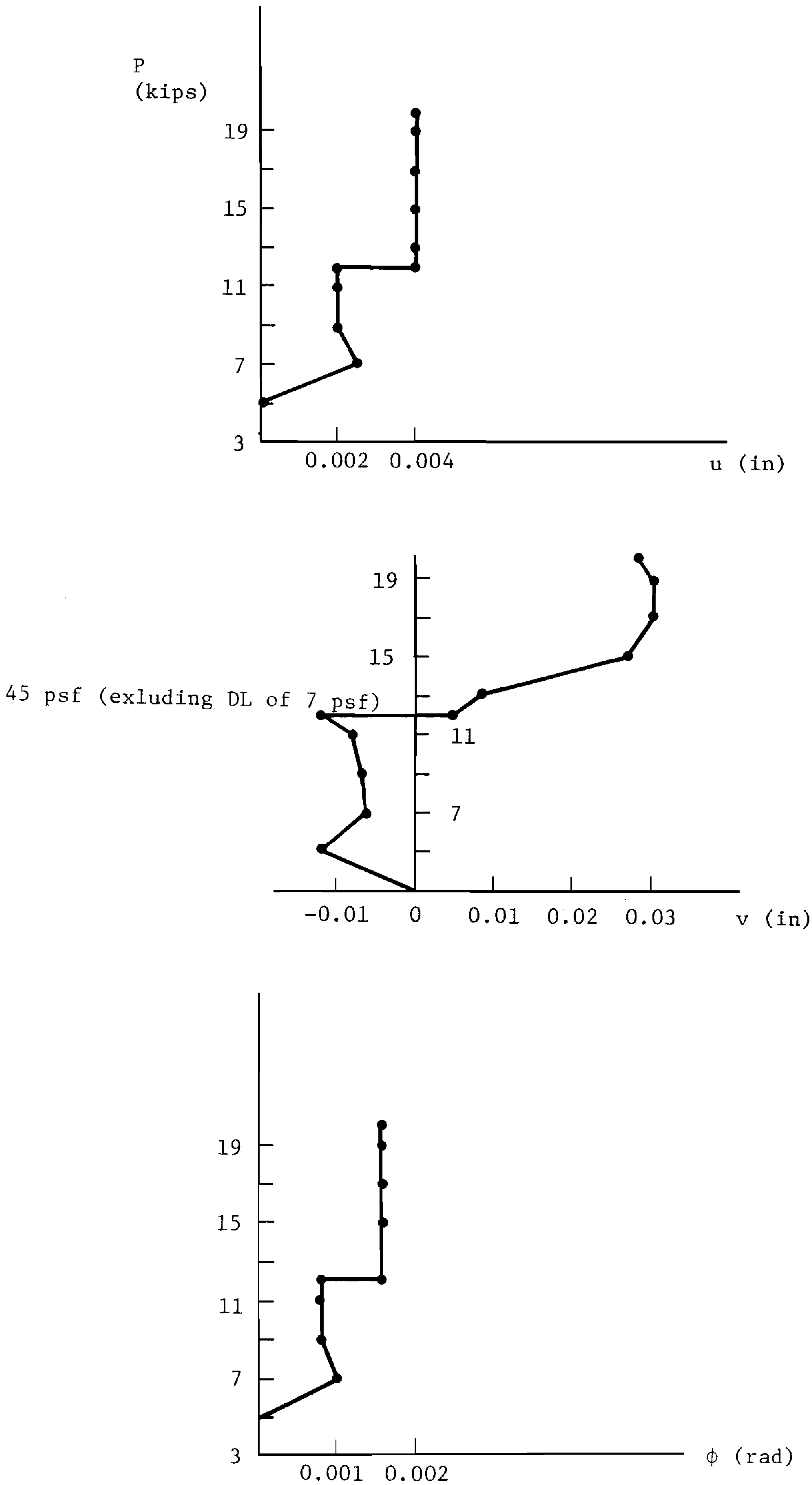


Fig. 12 Load-Deformation Curves for Test 8

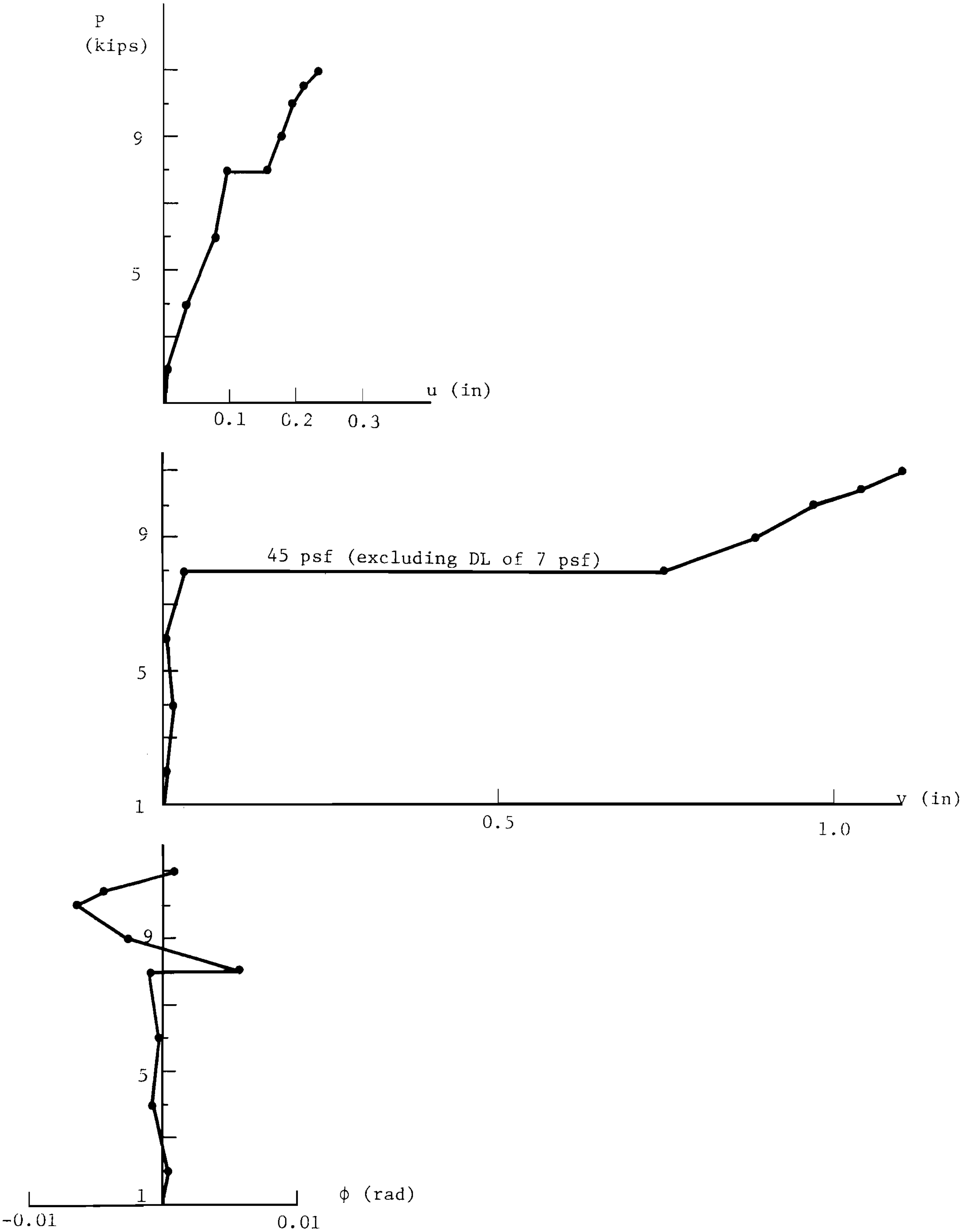


Fig. 13 Load-Deformation Curves for Test 9

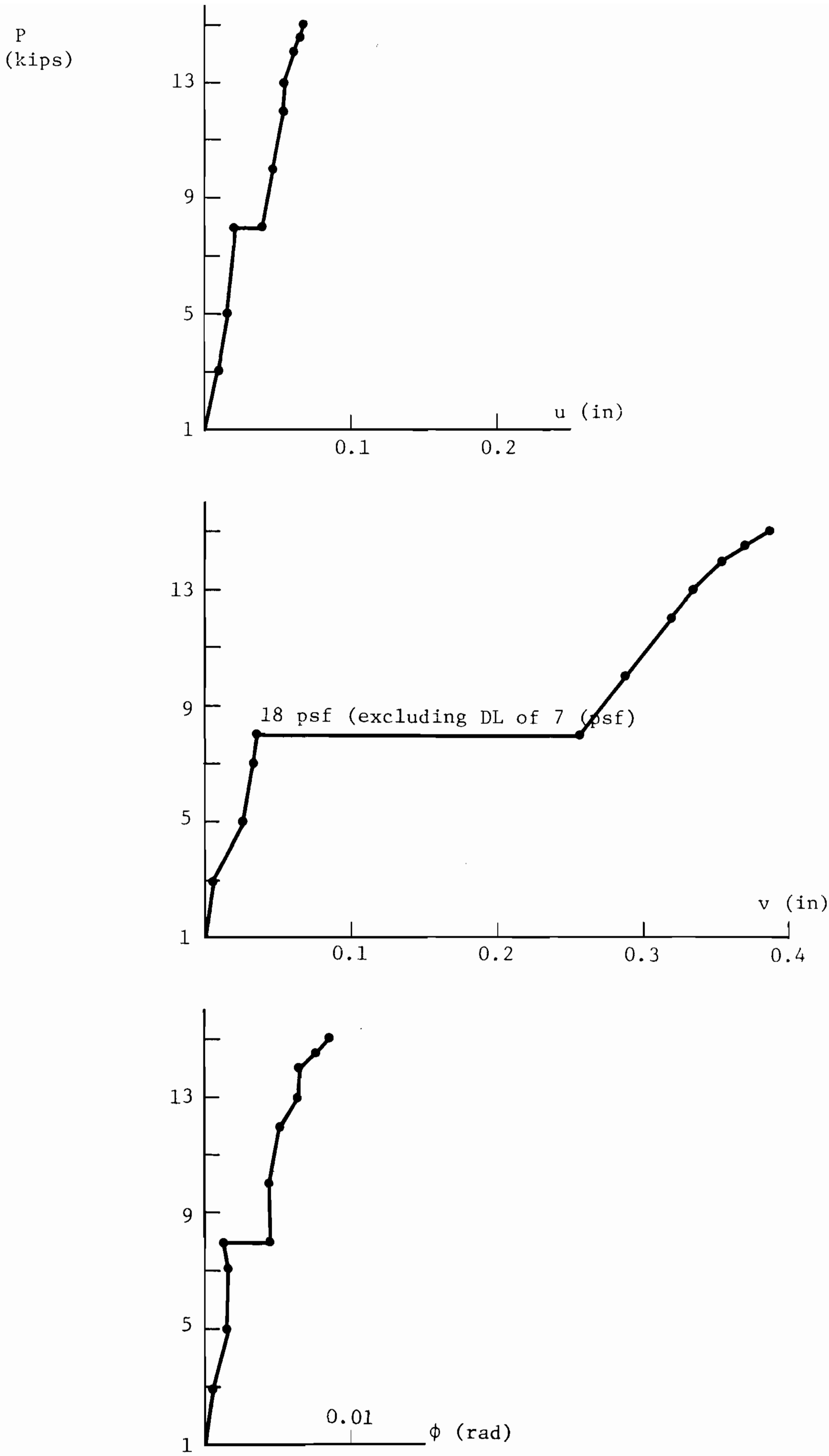


Fig. 14 Load-Deformation Curves for Test 11

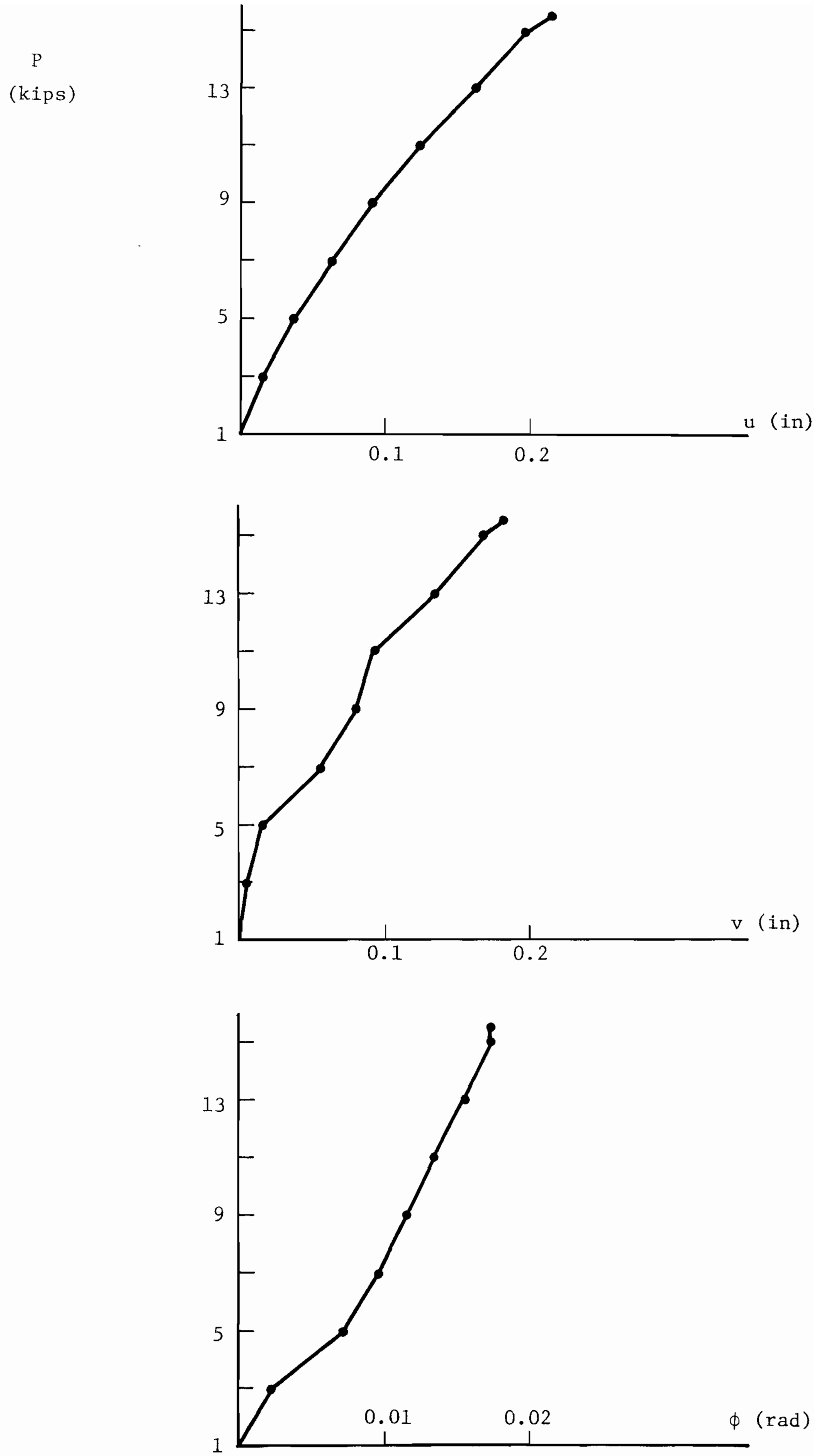


Fig. 15 Load-Deformation Curves for Test 12

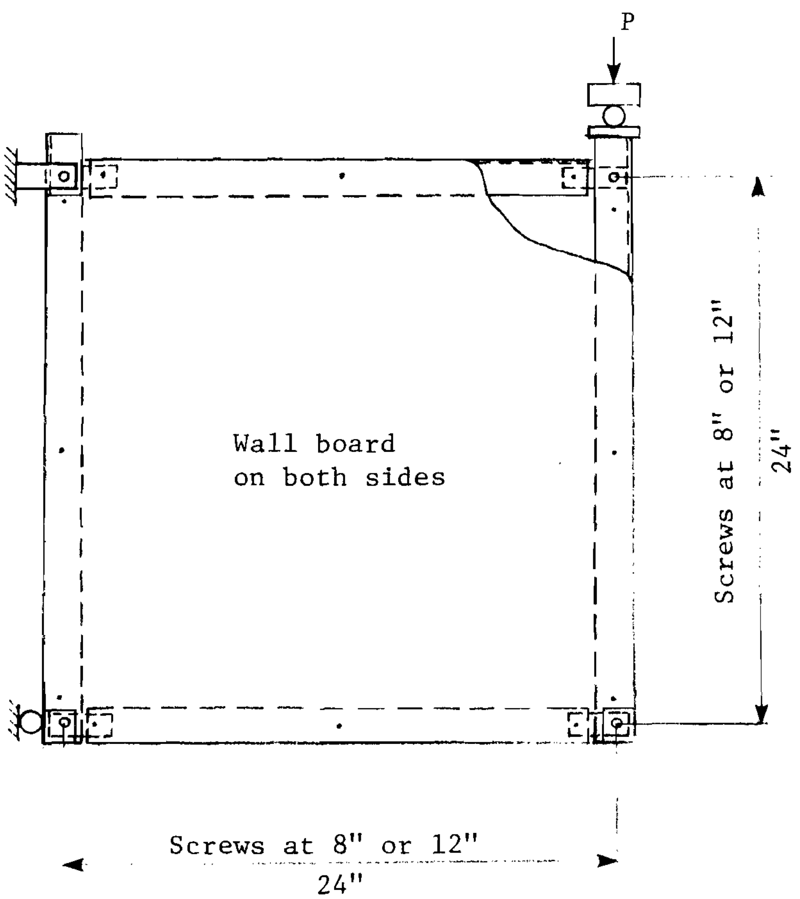


Fig. 16 Cantilever Shear Test Set-up

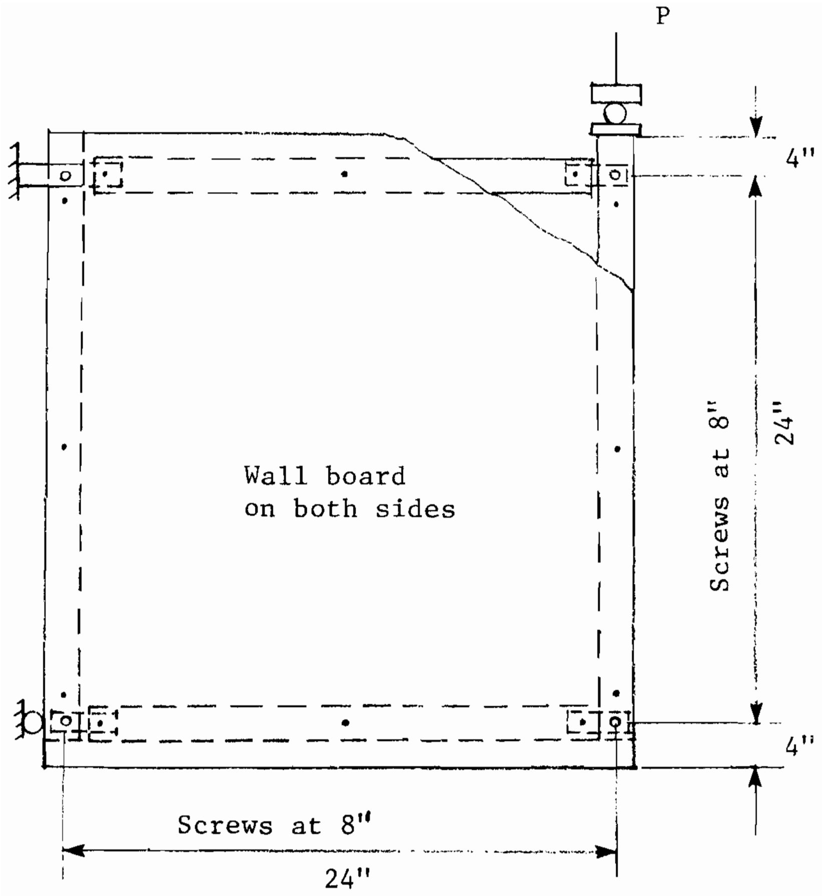


Fig. 17 Cantilever Shear Test Set-up

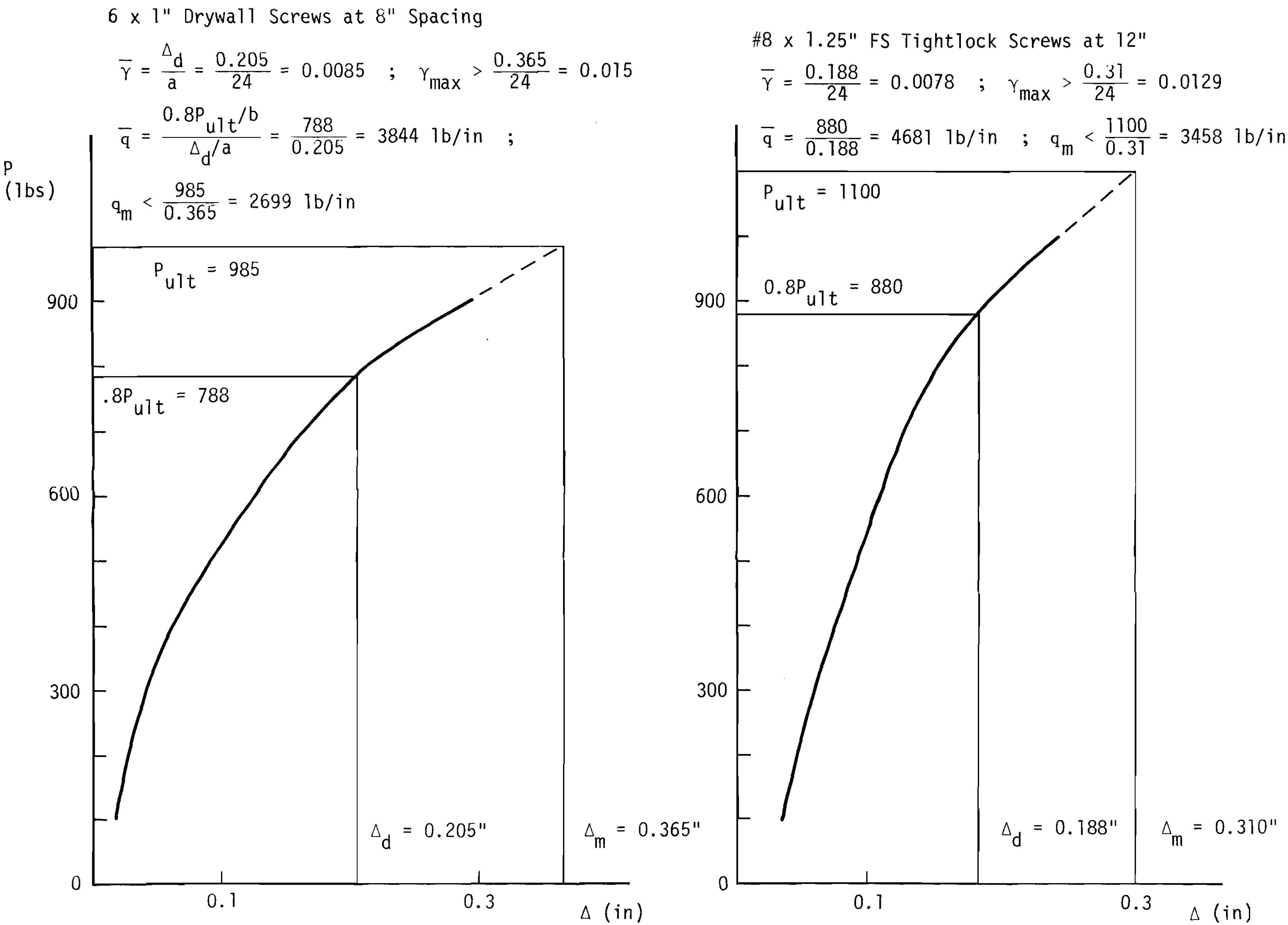


Fig. 18 Cantilever Shear Test Results (Specimen as shown in Fig. 16)

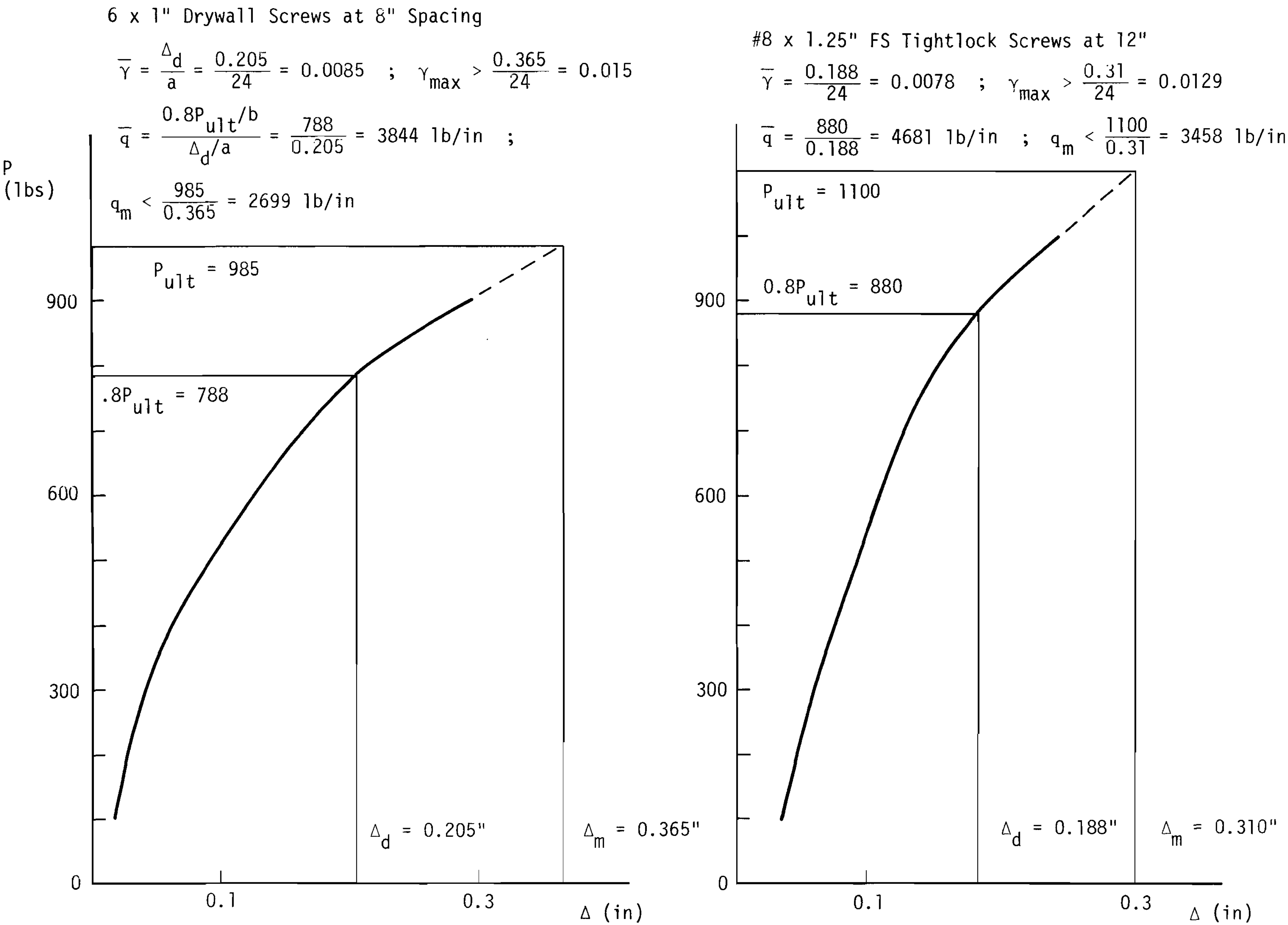


Fig. 18 Cantilever Shear Test Results (Specimen as shown in Fig. 16)

6 x 1" Drywall Screws at 12" Spacing

$$\bar{\gamma} = \frac{\Delta_d}{a} = \frac{0.265}{24} = 0.011 \quad ; \quad \gamma_{max} > \frac{0.44}{24} = 0.018$$

$$\bar{q} = \frac{0.8P_{ult}/b}{\Delta_d/a} = \frac{700}{0.265} = 2642 \text{ lb/in}$$

$$q_m < \frac{875}{0.44} = 1989 \text{ lb/in}$$

#8 x 1.25" FS Tightlock Screws at 8"

$$\bar{\gamma} = \frac{0.17}{24} = 0.007 \quad ; \quad \gamma_{max} > \frac{0.26}{24} = 0.011$$

$$\bar{q} = \frac{716}{0.17} = 4212 \text{ lb/in}$$

$$q_m < \frac{895}{0.26} = 3442 \text{ lb/in}$$

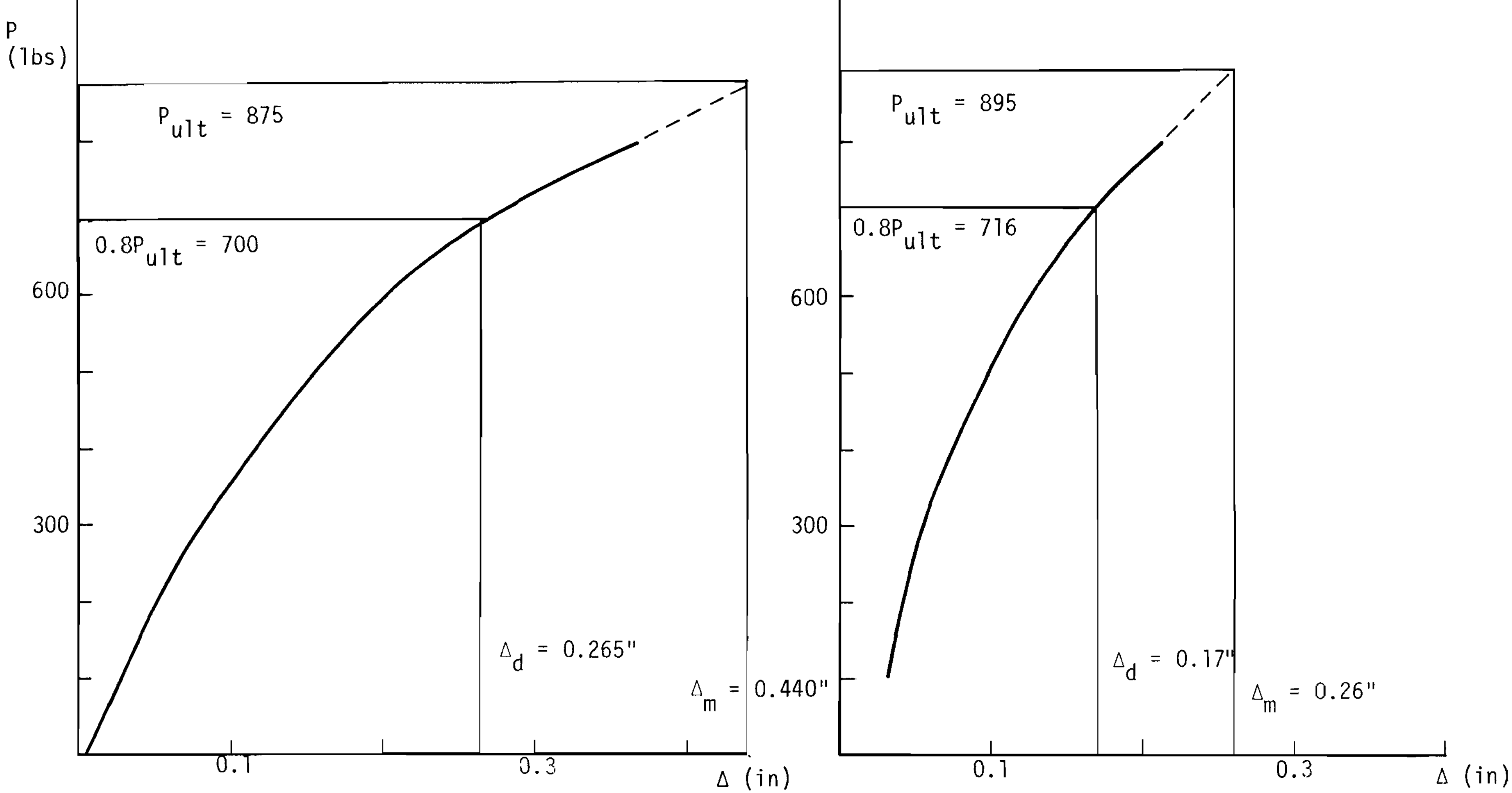


Fig. 19 Cantilever Shear Test Results (Specimen as shown in Fig. 13)

#8 x 1.25 FS Tightlock Screws at 8"

$$\bar{\gamma} = \frac{0.165}{24} = 0.0068 \quad ; \quad \gamma_{max} > 0.0133$$

$$\bar{q} = \frac{916}{0.165} = 5552 \text{ lb/in} \quad ; \quad q_m < \frac{1145}{0.318} = 3601 \text{ lb/in}$$

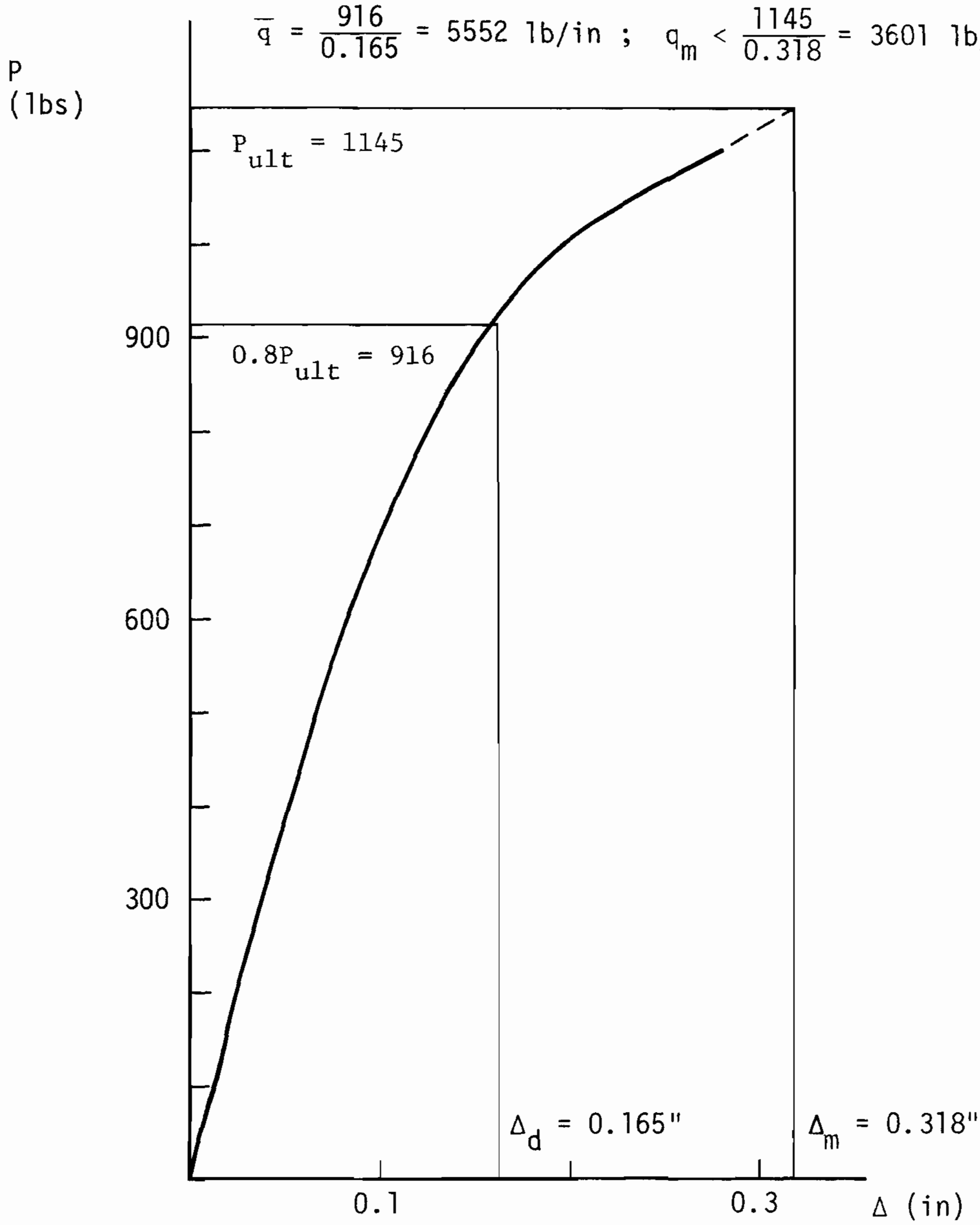


Fig. 20 Cantilever Shear Test Results
(Specimen as shown in Fig. 14)

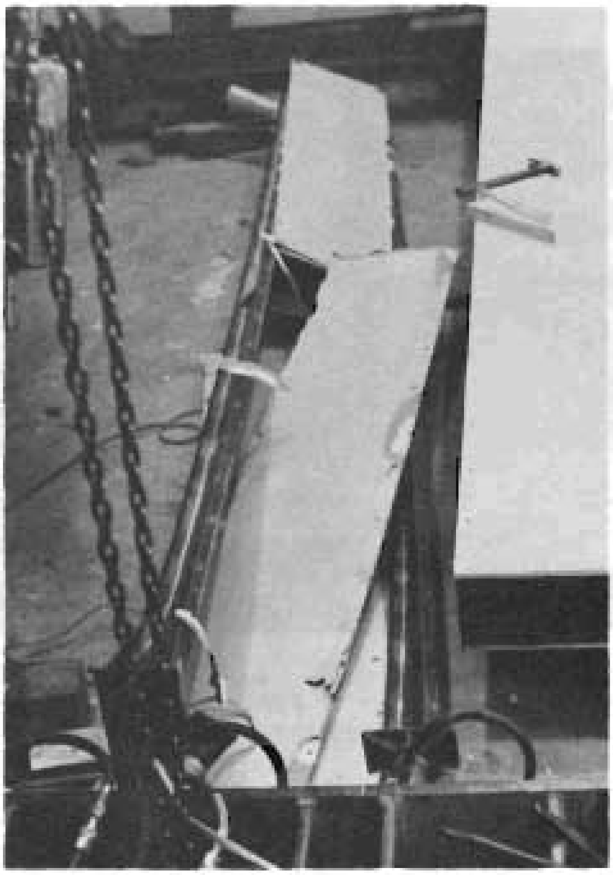


Photo 1 View of Test 1 - The specimen jumped out of the test fixture

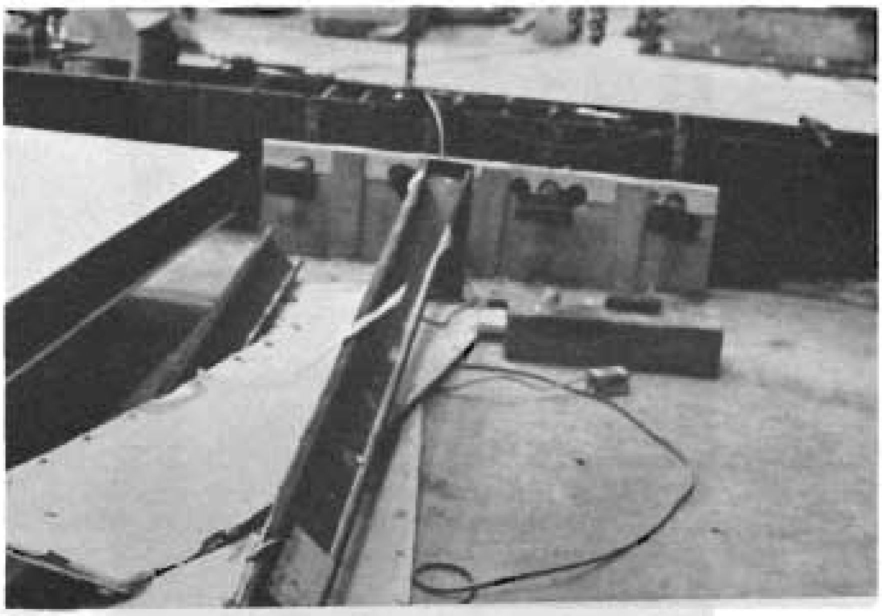


Photo 2 View of Test 1

Photo 3 End Channels in Test 1 - The flanges opened up when the studs press against the round corners

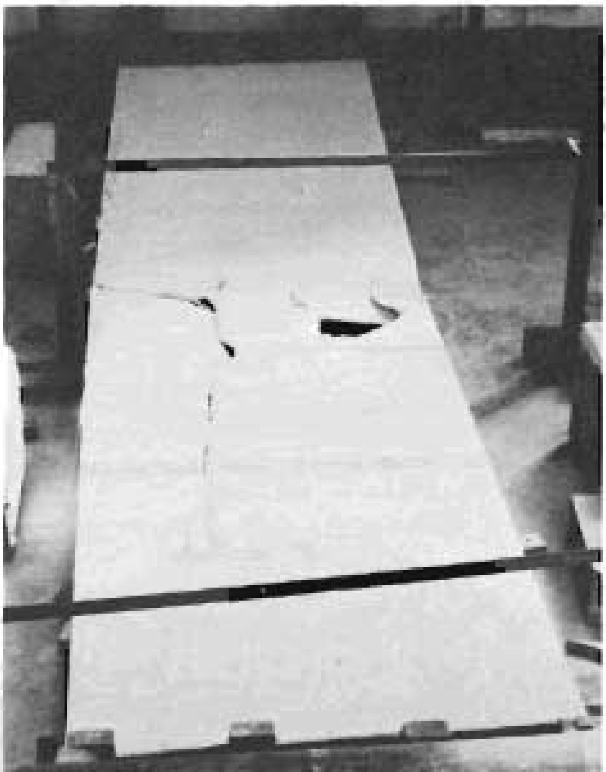


Photo 4 View of Test 2

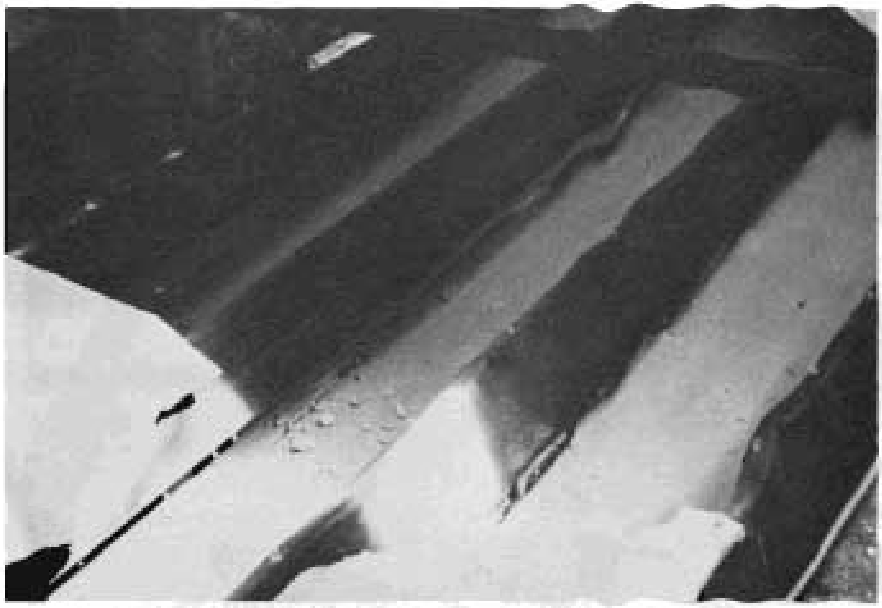


Photo 5 View of Test 2 - All four studs deformed

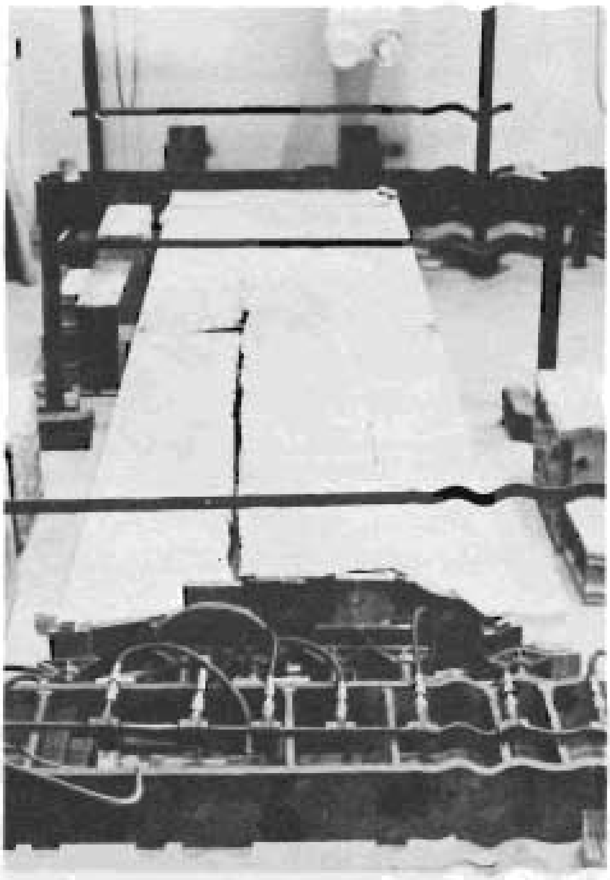


Photo 6 View of Test 3

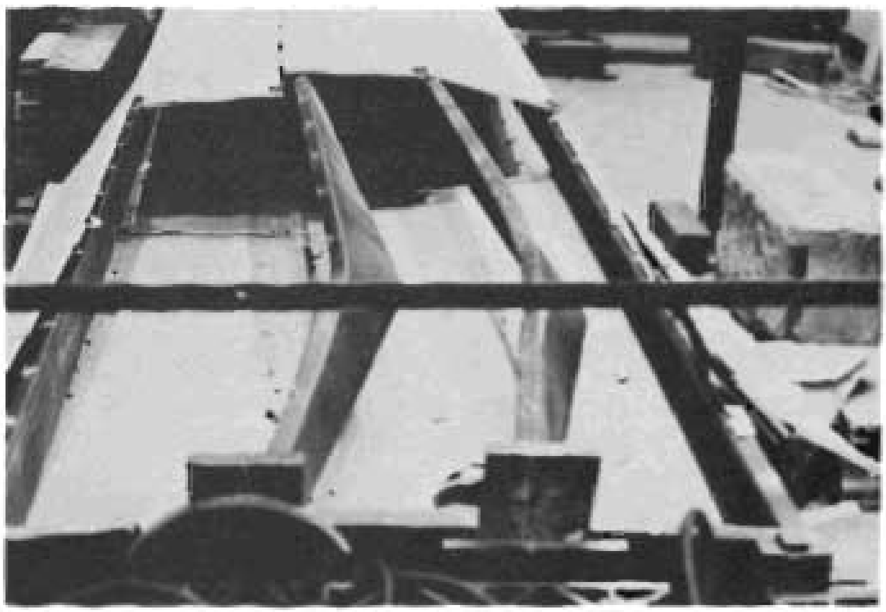


Photo 7 View of Test 3 - The intermediate studs deformed while the end studs remained straight

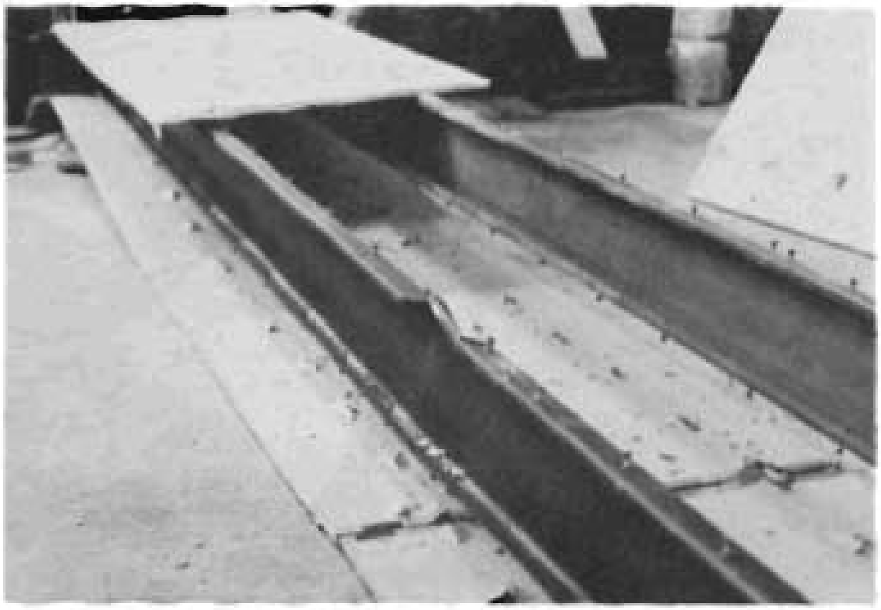


Photo 8 View of Test 5

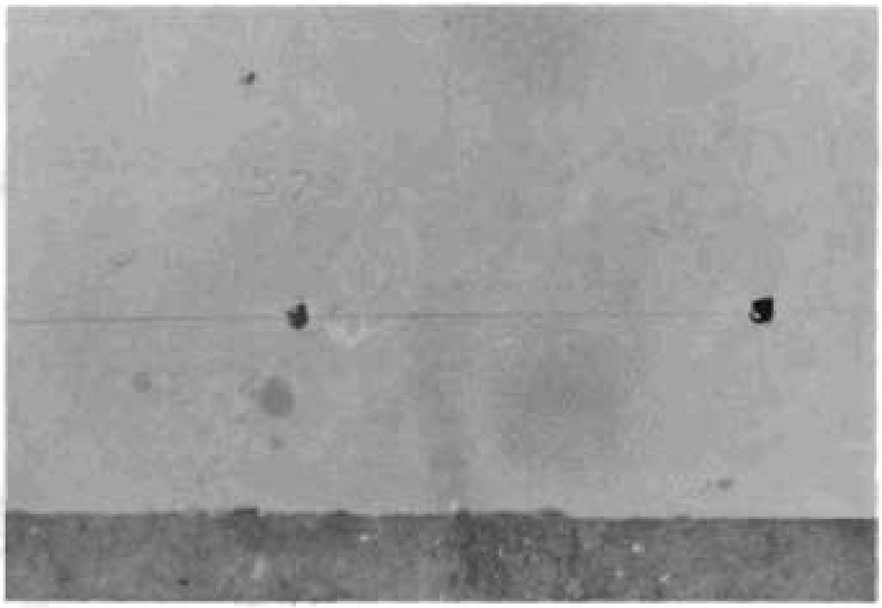


Photo 9 View of Test 5 - Typical pressing of the screws into the wallboard material

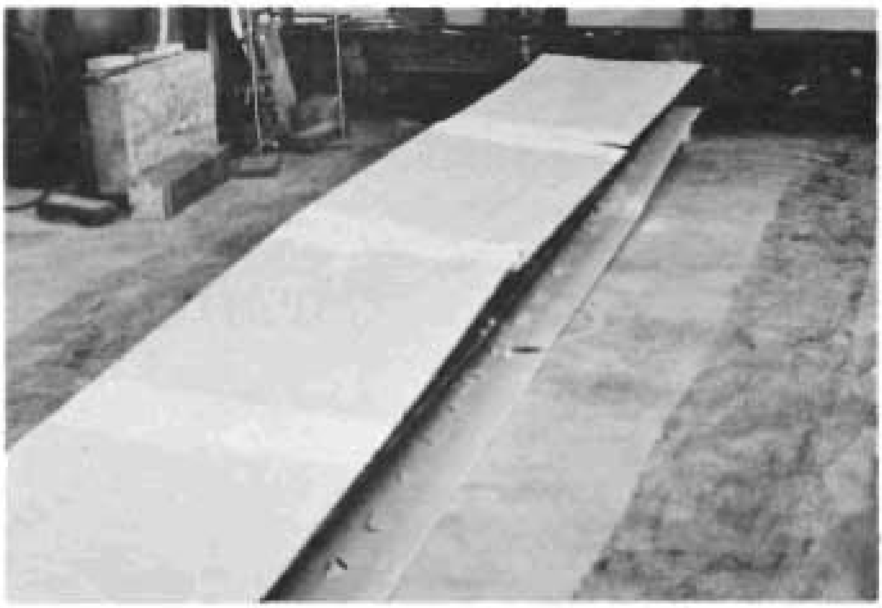


Photo 10 View of Test 5 - This test specimen had the largest initial sweep

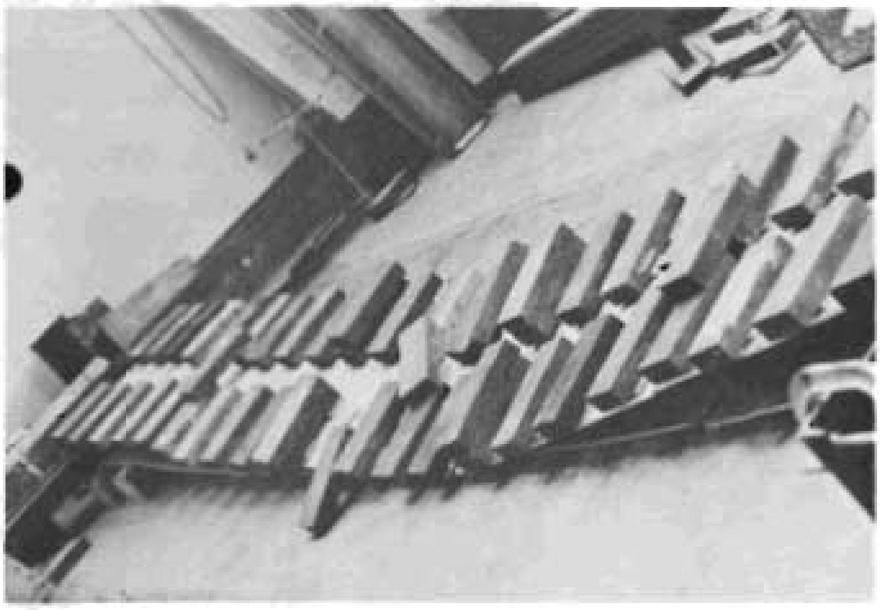


Photo 11 View of Test 6

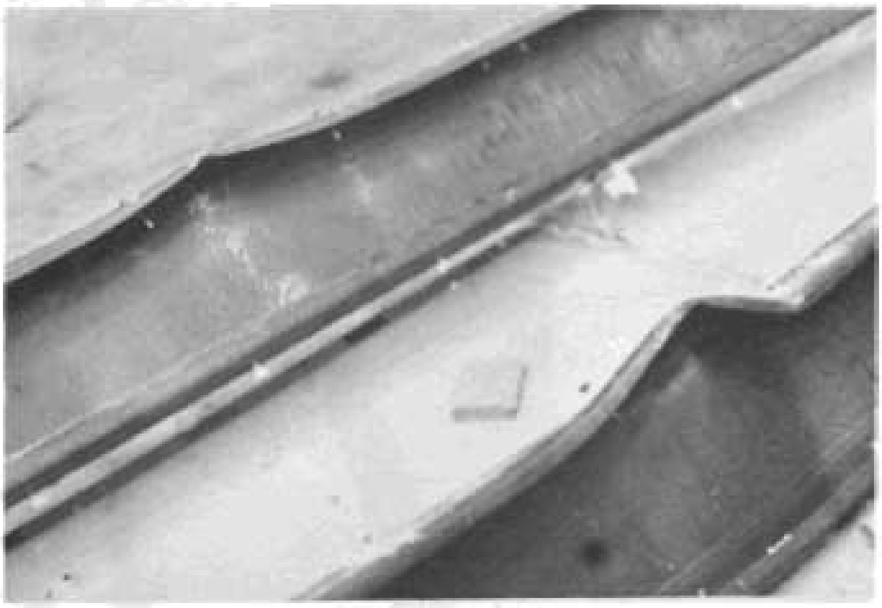


Photo 12 View of Test 6

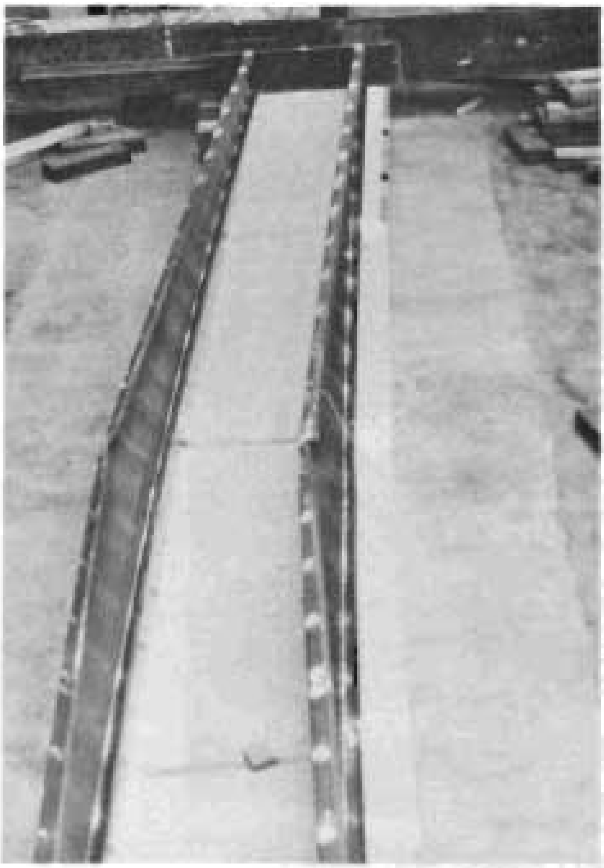


Photo 13 View of Test 6

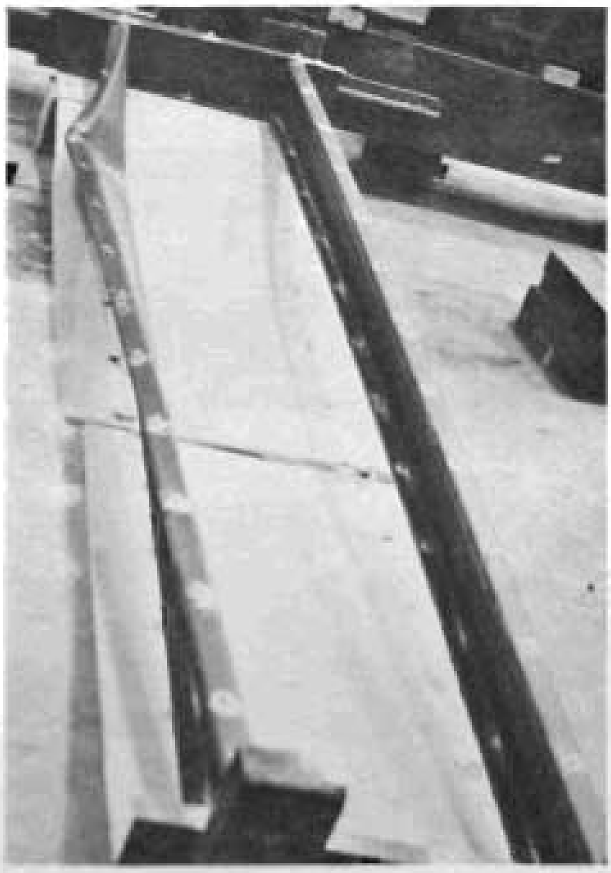


Photo 14 View of Test 7

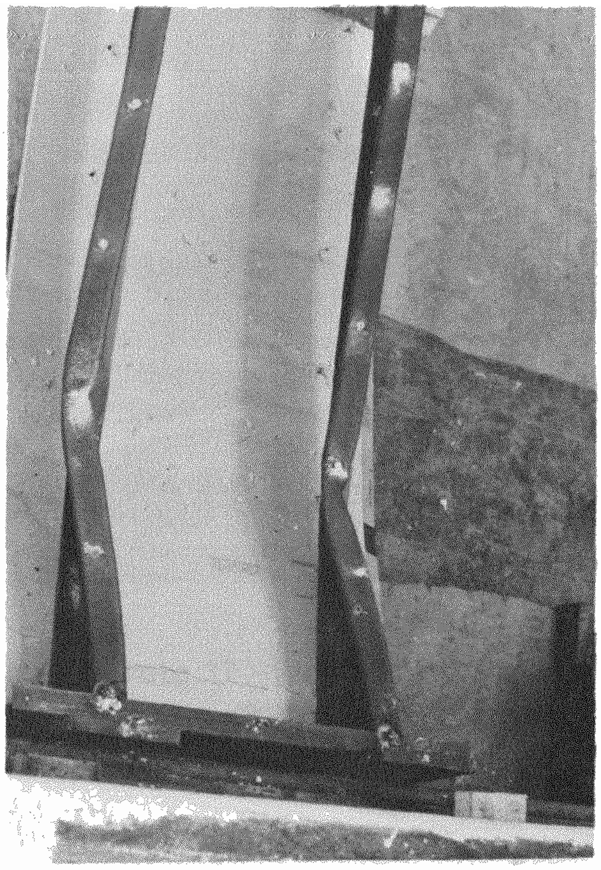


Photo 15 View of Test 8

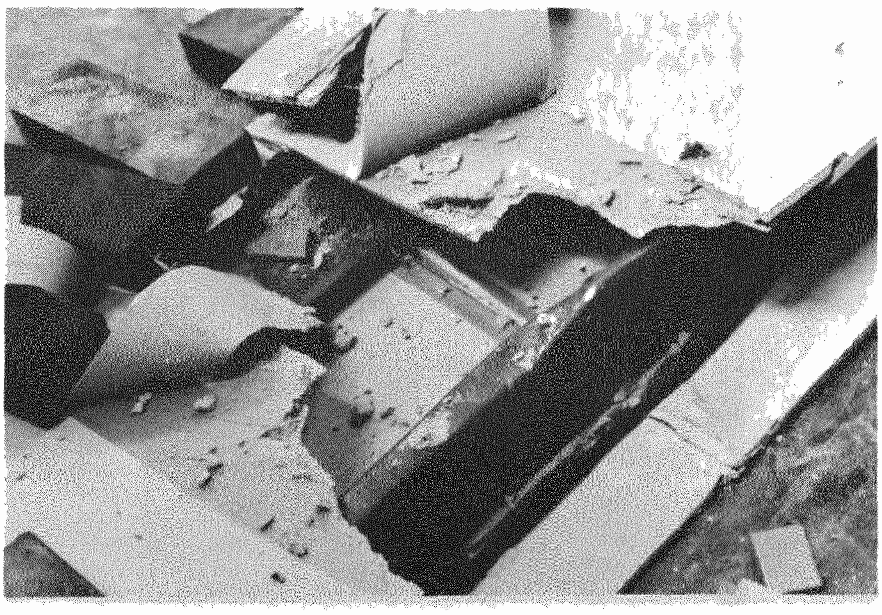


Photo 16 View of Test 9

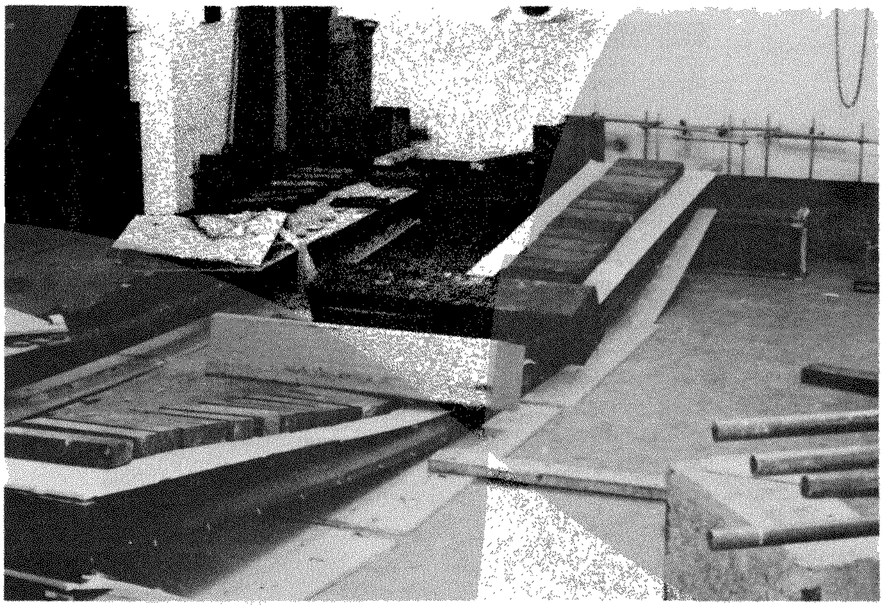


Photo 17 View of Test 10

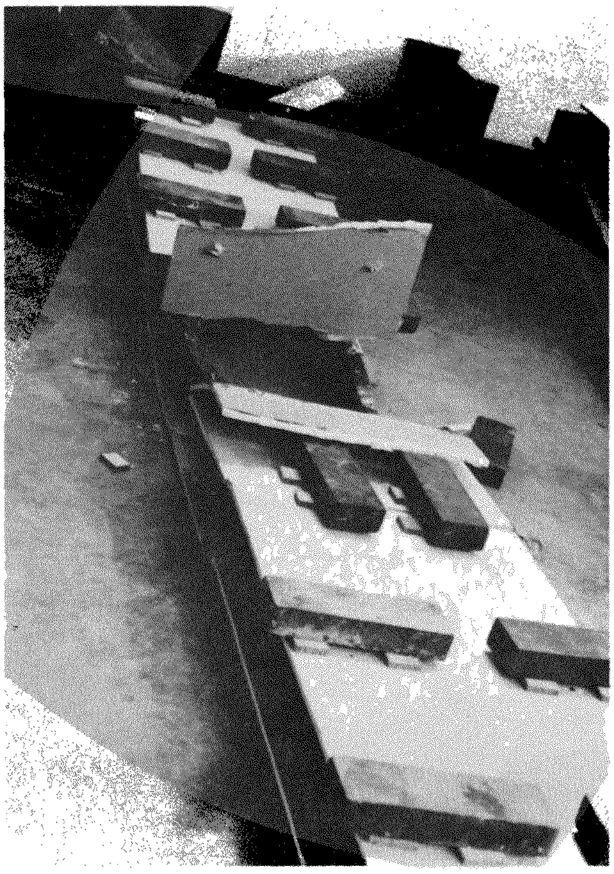


Photo 18 View of Test 11

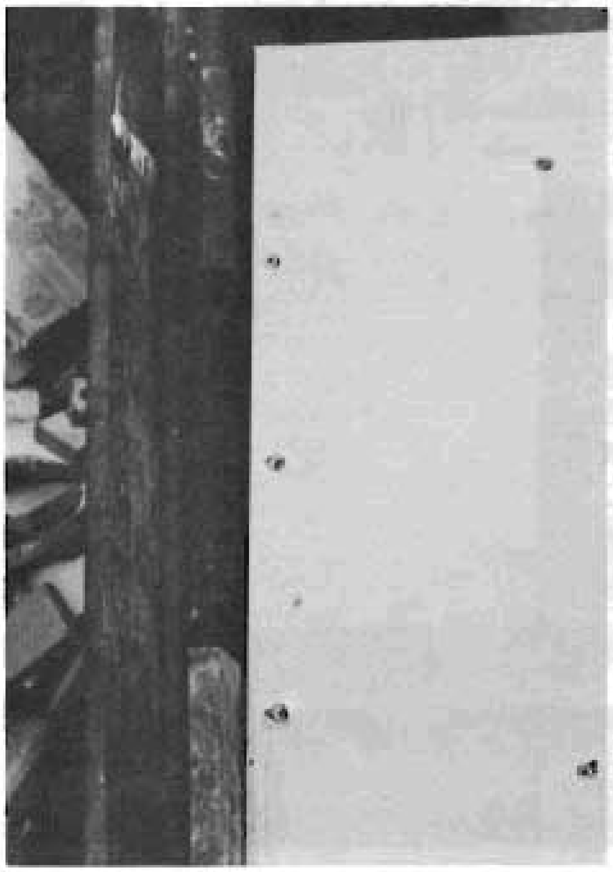


Photo 19 View of Test 11 - Typical pressing of the screws into the wallboard material

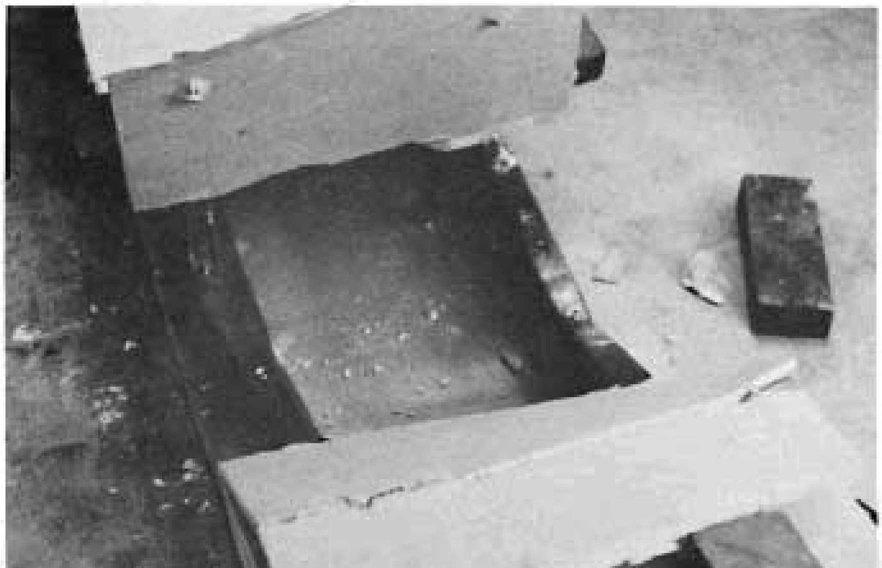


Photo 20 View of Test 11

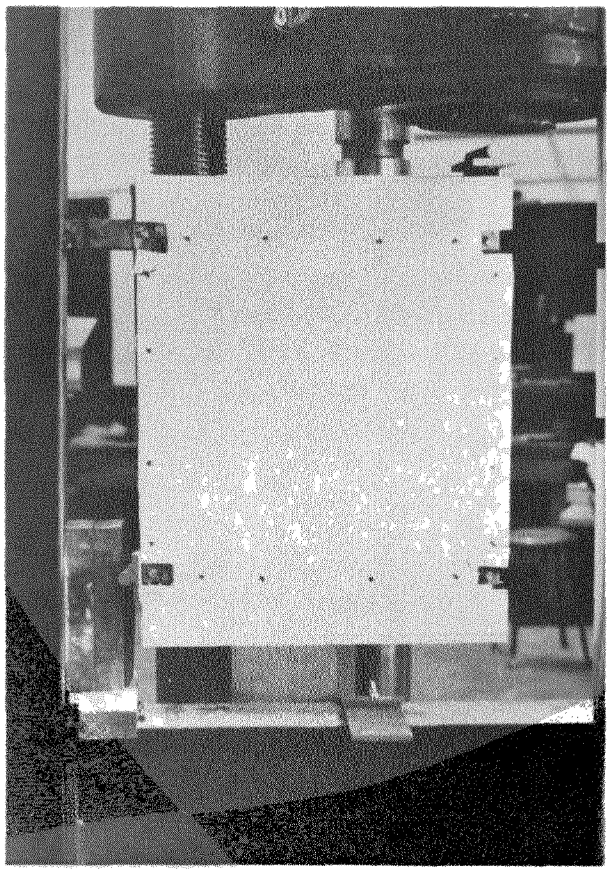


Photo 21 View of Cantilever Shear Test

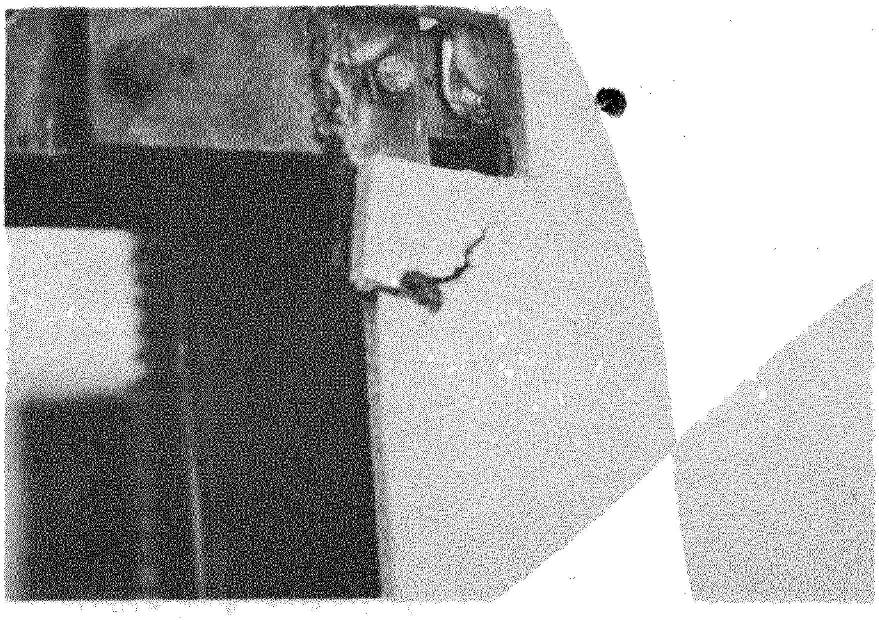


Photo 22 View of Cantilever Shear Test