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NATIONAL BUREAU OF STANDARDS REPORT

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Tests of "In-Block" Masonry

by

Louis E. Cattaneo and Robert G. Mathey

Report to
Federal Housing Administration
Department of Housing and Urban Development

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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U.S. DEPARTMENT OF COMMERCE

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Compression tests were conducted on "In-Block" masonry and conventional masonry walls in accordance with ASTM E-72 procedure. The tests were made with 4-x 8-ft. masonry wall panel specimens of five different thicknesses to demonstrate performance of "In-Block" masonry. The test specimens included two thicknesses of "In-Block" masonry and three thicknesses of conventional concrete masonry.

The masonry wall specimens were tested in compression in triplicate. In addition to the maximum compressive loads, data are reported on the vertical deformation, vertical set, lateral deflection, and lateral set developed in the load tests of the different types of masonry walls.

1. Introduction

The Federal Housing Administration, in a letter dated January 4, 1967, requested the National Bureau of Standards to perform compression tests on a proposed masonry system designated as "In-Block" masonry that may possibly be used in urban renewal construction. This masonry system was proposed to the Federal Housing Administration by Mr. Earl M. Smith, Jr., of New Canaan, Connecticut. A sketch of the "In-Block" masonry system is shown in Figure 1 and a photograph of the "In-Block" concrete masonry units is shown in Figure 3a.

2. Test Specimens

Test specimens were constructed and stored in a laboratory in which the temperature is maintained at 73°F and the relative humidity at 50%. The five wall types of 4- x 8-ft. concrete masonry test panel specimens were as follows:

a. Conventional 8-inch wall

b. Conventional 10-inch wall

c. Conventional 12-inch wall

d. "In-Block" with 8-inch block

e. "In-Block" with 10-inch block

Three walls of each type were constructed by a masonry contractor using ASTM C270 type N mortar (by proportion). The mortar was proportioned by volume (1 part of Blue Bond masonry cement to 2 1/4 parts of damp, loose, washed, river masonry sand conforming to ASTM C-144 grading) and its moist-cured strength (1660 psi at 28 days, average of 6 cubes from wall specimen 12-3) was determined according to ASTM Specification C-270. The amount of sand needed for each 1-bag batch of mortar (70 lbs or 1 cu. ft. of masonry cement) was determined by weighing, using a specific weight of 80 lb. per cu. ft. The amount of water used for each batch of mortar was nominally 31 lbs; this amount was adjusted by judgement of the mason to maintain a suitable mortar consistency in the numerous batches. The strengths of mortar of representative batches from the wall specimens are given in Table 1 and were determined from tests of 2-in. cubes that were air-cured and tested under the same conditions as the wall panels. The average strength of the 6 batches of mortar sampled and air-cured with the walls was 790 psi.

Thickness of mortar joints between conventional masonry units was

nominally 3/8 inch for horizontal joints and from 3/8 in. to 1/2 in. for vertical joints. Elevation view dimensions of "In-Block" units in the 'as used' position were nominally 7 5/8 in. in width at back, 7 3/8 in. in width at the front and 17 inches in overall vertical length. Thickness of vertical mortar joints between "In-Block" units was nominally 3/8 inch at the back and 5/8 inch at the front. Mortar joints on the front face of all specimens were tooled; joints on the back face of all specimens were cut flush and left untooled.

Durowall transverse joint reinforcement of the truss type made from No. 9 gage wire was placed over every second course in all wall panels, including the top of "In-Block" wall panels. A photograph of typical joint reinforcement is shown in Figure 3c. Width of reinforcement used (6", 7 5/8" or 9 3/4") in all wall panels was determined by respective nominal width (8", 10" or 12") of conventional units in each wall.

Mr. Earl M. Smith, Jr., supplied the "In-Block" units. The 8-, and 10-inch header units along with the conventional 8-, 10-, and 12-inch blocks were purchased from Paturzo Concrete Block Company, Baltimore, Maryland. After receiving the conventional blocks it was noted that the 10-inch units had three cells and the 8- and 12-inch blocks had two cells. Therefore, in the interest of better test comparisons two-cell 10-inch blocks (which could not be obtained from the original supplier) were obtained from Ernest Maier, Inc., Bladensburg, Maryland. For each specimen, conventional stretcher units were cut to half-length for use at the ends of alternate courses. "In-Block" units were cut in half and used at the ends of alternate shingle courses as shown in Figure 1. The three-cell, 10-inch,conventional blocks were cut for end blocks and used with the 10-inch,

whole, two-cell conventional units in wall specimens containing these units. The header units in all the wall panels had three cells. Photographs of typical masonry units are shown in Figure 3b. The compressive strengths and dimensions of the concrete masonry units are given in Table 1 along with other properties of the wall panel specimens. The net cross-sectional area and compressive strength of the stretcher and header masonry units were determined in accordance with ASTM Specification C-140. Modifications of this test method were necessary for carrying out tests of the header units.

3. Test Procedure

The 4- x 8-ft. wall panels were tested in accordance with ASTM Standard E 72-61, Standard Methods of Conducting Strength Tests of Panels for Building Construction. A 1-inch thick steel plate was set in high-strength plaster at the upper end of the wall specimen. In all wall specimens this gross bedment area extended over the width of the conventional units for the full width of the wall. A 1/8-in. thick piece of cardboard was used as a filler between the 1-in. steel plate and a 2-in. thick steel bearing plate. The load was applied uniformly through a 1- x 1-inch steel bar that was on top of the 2-in. steel plate and parallel to the inside face of the specimen. The 1- x 1-inch steel bar was located at a distance of one-third the thickness of the specimen from the inside face of the wall. The distance from the back of the wall to the position of the applied load, for each type of wall specimen, is given in Table 1. At the request of E. M. Smith, Jr., the thickness of the "In-Block" wall panels was taken as the thickness of the conventional masonry units plus 2 inches. This arbitrarily established thickness determined the position of the eccentric load for "In-Block"

wall panels. The applied load was 2/3 in. closer to the center of the conventional backup masonry units in the "In-Block" wall panels than in the conventional walls of the same units.

The lower end of the conventional wall panels was set in mortar in a length of structural steel channel. The lower end of "In-Block" walls was set in mortar on a 1 1/2-inch thick base of high strength mortar (5700 psi) precast in a structural steel channel to provide clearance under the lower extremity of the first course of "In-Block" units. Width of the base was 2 1/4 inches plus width of the conventional back-up units (7 3/4 or 9 5/8 inches) used and was chamfered at the front edge to accommodate the lower lug of the "In-Block". A section of "In-Block" wall panel base is shown in Figure 3d. Typical construction details of the "In-Block" wall panels are shown in Figure 4. A sketch of a wall specimen showing the method of load and support conditions is presented in Figure 1.

Four compressometers and two deflectometers were attached to all of the wall specimens as shown in Figure 2. The gage length of the compressometers was 88 inches. Linear variable differential transformers measured the shortening of the wall panels and the mid-height deflection to the nearest 0.0001 inch, (reported to nearest 0.001 in.). Initial instrument readings were recorded under an initial load of 5000 lb.

The load was applied at a rate of 50,000 lb/min. by a 600,000 lb. capacity testing machine in increments of 10,000 lb. after a first increment of 5000 lb. Readings were taken at each increment of load up to a load estimated as that permitting safe removal of instrumentation prior to failure. After each increment of applied load, the load was reduced to

5000 lb. and readings of the compressometers and deflectometers were taken to determine the sets. After removal of instruments, load was increased continuously to a maximum value at failure. Data were recorded automatically by an electronic digital tape scanner.

4. Results

The compressive strength of the 15 wall panels are given in Table 1. Also included in Table 1 are the average compressive strengths of three wall panels of each of the five types of walls. The compressive strength of the first wall tested (10-1) was not included in the average compressive strength of its type because Celotex was used between the steel carrying channel and the steel bearing blocks. All other walls were tested using high strength plaster instead of Celotex under the steel channel. An examination of the graphs of the load-deflection relationship in Figure 13 indicates that at the higher loads wall 10-1 deflected considerably more than the other walls of this type. The increased deflection and reduced compressive strength are attributed to the increased rotation at the bottom of the wall specimen due to deformation of the Celotex bearing strip.

Graphs of the load-shortening deformation, load-shortening deformation set, load-deflection and load-deflection set are shown for each type of wall panel in Figures 7 through 16. In accordance with ASTM Standard E-72 the open points of these figures represent shortening or deflection and the solid points represent shortening set or deflection set for individual wall panel tests. Both the shortening deformation and the deflection were measured over a span of 88 in. However, the deformation data were extrapolated to 8 ft. for presentation in Figures 7 through 11. The solid and dashed lines on the graphs

represent the average of 3 wall tests in Figures 7 through 16 and are not plotted to the maximum load at failure. As mentioned previously, the instrumentation used to measure the deformation and deflection was removed from the wall specimens prior to failure. Data from only two wall panels were included in the load-deflection relationship in Figure 15 because of deflectometer malfunction during test of specimen 8-I-2.

Typical failures of wall panel specimens are shown in Figures 5 and 6. In general, failure of the wall panels occurred in the same way in all specimens; vertical cracking, when detected before maximum load, was seen to develop in an edge (or edges) of the wall in the visible webs of the upper courses of conventional units (Fig 5b, 6a). In the case of "In-Block" panels, development of cracking and progressive deformation in the back-up units during continuous loading after instrument removal, were sometimes accompanied or followed by instances of horizontal cracking above the bottom lug in the "In-Block" shingles (Fig. 6a). Maximum load occurred with collapse of specimens (Fig. 5a, 5d) or with partial collapse evidenced by crushing near a bed joint on the back surface (Fig. 5b, 5c). In some of the "In-Block" wall panels breaking away of shingles occurred at maximum load (Fig. 6a). There was no case of shingle fragmentation before maximum load, however. Additional applicable comments regarding manner of failure, load at initial cracking, etc., are recorded in the Remarks Column of Table 1.

TABLE 1. PROPERTIES OF WALL PANEL SPECIMENS

Wall Panel Specimen No.	Test Sequence Order No.	Type of Wall Specimen	Maximum Load (lb)	Average Maximum Load (lb)	Width of Wall Panel (in.)	Distance of Load From Back of Wall (in.)
8-1	2		193,000			
8-2	7	Conven- tional	244,000	220,700	48	2 9/16
8-3	14		225,000			
10-1	1		192,500			
10-2	8	Conven- tional	234,000	247,000[1/]	47 1/2	3 3/16
10-3	13		260,000			
12-1	6		306,000			
12-2	11	Conven- tional	311,000	301,000	48	3 15/16
12-3	15		286,500			
8-I-1	3		235,000			
8-I-2	5	"In- Block"	261,000	243,700	48	3 1/4
8-I-3	10		235,000			
10-I-1	4		231,500			
10-I-2	9	"In- Block"	286,500	257,700	47 1/2	3 7/8
10-I-3	12		255,000			

1/ Average of 10-2 and 10-3 only

TABLE 1 (cont.) PROPERTIES OF WALL PANEL SPECIMENS

Wall Panel Specimen No.	Age of Wall at Time of Test (days)	Average Compressive Strength of Mortar (psi)	Age of Mortar at Time of Test (days)	Dimensions of Stretcher Units (in.) Width	Height	Length
8-1	36	680	35			
8-2	39	790	35	7 3/4	7 5/8	15 3/4
8-3	39	500	36			
10-1	35	680	35	9 5/8	7 5/8 (whole units)	15 5/8
10-2	39	1120[2/]	35			
10-3	37	950	38	9 5/8	7 5/8 (half units)	15 3/4[3/]
12-1	39	790	35			
12-2	37	500	36	11 3/4	7 5/8	15 3/4
12-3	37	700	37			
8-I-1	35	790	35			
8-I-2	35	1120[2/]	35	7 3/4	7 5/8	15 3/4
8-I-3	36	950	38			
10-I-1	35	1120[2/]	35	9 5/8	7 5/8 (whole units)	15 5/8
10-I-2	36	500	36			
10-I-3	37	950	38	9 5/8	7 5/8 (half units)	15 3/4[3/]

[2/] Mortar left in molds 3 days instead of 1 day

[3/] Half units cut to 7 5/8 in.

TABLE 1 (con.) PROPERTIES OF WALL PANEL SPECIMENS

Wall Panel Specimen No.	Nominal Minimum Face Shell Thickness of Stretcher Units (in.)	Average[4/] Net Area of Stretcher Units (%)	Average Compressive Strength of Stretcher Units (Gross Area) (psi)	Average Compressive Strength of Stretcher Units (Net Area) (psi)
8-1				
8-2	1 1/4	54.2	1120	2070
8-3				
10-1		51.7 (whole units)	1530 (whole units)	2960 (whole units)
10-2	1 1/2			
10-3		57.5 (half units)	1100 (half units)	1910 (half units)
12-1				
12-2	1 3/4	52.9	1250	2360
12-3				
8-I-1				
8-I-2	1 1/4	54.2	1120	2070
8-I-3				
10-I-1		51.7 (whole units)	1530 (whole units)	2960 (whole units)
10-I-2	1 1/2			
10-I-3		57.5 (half units)	1100 (half units)	1910 (half units)

4/ Average of three units.

TABLE 1 (cont.) PROPERTIES OF WALL PANEL SPECIMENS

Wall Panel Specimen No.	Dimensions of Header Units (in.) Width	Height	Length	Nominal Minimum Face Shell Thickness of Header Units (in.)	Average[4/] Net Area of Header Units (%)	Average[4/] Compressive Strength of Header Units (psi)
8-1						
8-2	-	-	-	-	-	-
8-3						
10-1						
10-2	-	-	-	-	-	-
10-3						
12-1						
12-2	-	-	-	-	-	-
12-3						
8-I-1						1380 (Gross Area)
8-I-2	7 3/4	7 5/8	15 3/4[5/]	1 1/2	63.8	
8-I-3						2160 (Net Area)
10-I-1						1840 (Gross Area)
10-I-2	9 5/8	7 5/8	15 5/8[6/]	1 1/2	57.0	
10-I-3						3230 (Net Area)

4/ Average of three units.

5/ "Cutout" dimensions: 4 3/8 in. width x 2 5/8 in. height.

6/ "Cutout" dimensions: 4 1/2 in. width x 2 5/8 in. height.

TABLE 1 (cont.) PROPERTIES OF WALL PANEL SPECIMENS

Wall Panel Specimen No.		Remarks
	lb[7/]	
8-1	100,000	No apparent cracks at 100,000 lb; wall collapsed.
8-2	150,000	No apparent cracks at 150,000 lb; crushing failure back of top 2 courses; Fig. 5a.
8-3	170,000	No apparent cracks at 170,000 lb; crushing failure in back at joint under top course.
10-1	160,000	Channel bedded on Celotex; excessive deformation; last two readings not used; cracks in both ends top 4 courses at 160,000 lb.
10-2	190,000	Crack in one end top course at 190,000 lb; crushing failure in back at joint under top course.
10-3	170,000	Crack in one end top course at 170,000 lb.
12-1	190,000	Audible crack at 185,000 lb; crack in one end top course at 190,000 lb; crushing failure in back at joint under 4th top course.
12-2	180,000	Crack in both ends top 2 courses; crushing failure in back at joint under top course (Fig. 5b).
12-3	180,000	Crack in both ends top course at 150,000 lb; cracks progressed to 2nd top course at 180,000 lb; crushing failure in back at joint under 4th top course.
8-I-1	150,000	No apparent cracks at 150,000 lb; cracks in bottom 1st, 3rd and top shingle courses after 150,000 lb.
8-I-2	140,000	No apparent cracks at 140,000 lb; cracks in 1st and 2nd top shingle courses after 150,000 lb; crushing failure in back at joint under top course (Fig. 5c).
8-I-3	180,000	No apparent cracks at 180,000 lb; crack in bottom shingle course after 215,000 lb; crushing failure in back under 2nd top course.
10-I-1	200,000	Crack in one end 2nd top course at 200,000 lb; crushing in back at joint under 2nd top course (Fig. 6a).
10-I-2	180,000	No apparent cracks at 180,000 lb; crack in one end 2nd top course and 2nd top shingle course at 190,000 lb; wall collapsed; Fig. 5d.
10-I-3	180,000	Crack in one end top course and top shingle course at 165,000 lb; no additional cracks in shingles at 180,000 lb; wall collapsed; Fig. 6b.

7/ Deformation and set observed up to this load.

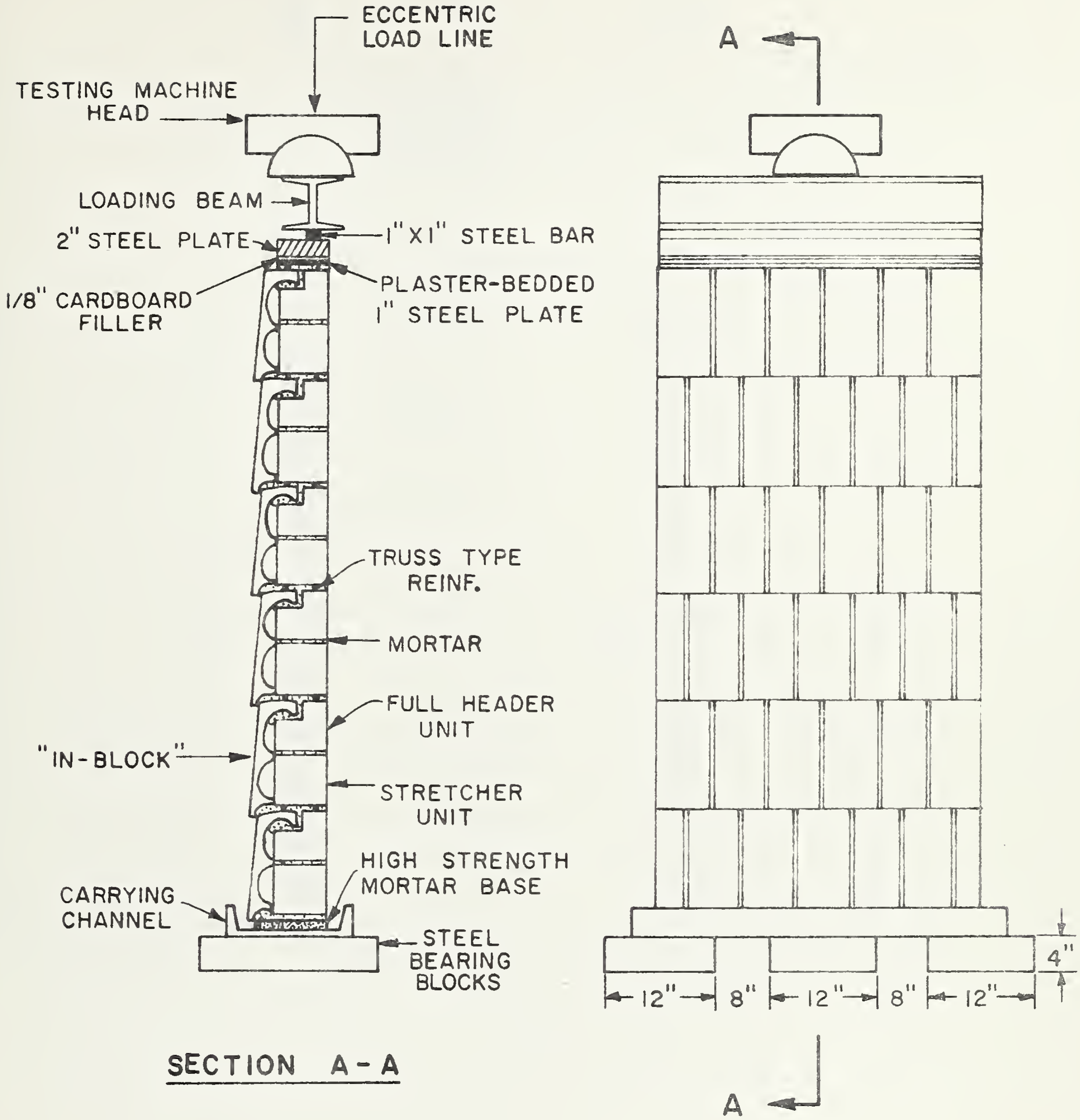


FIG. 1 "IN-BLOCK" WALL PANEL TEST SPECIMEN.

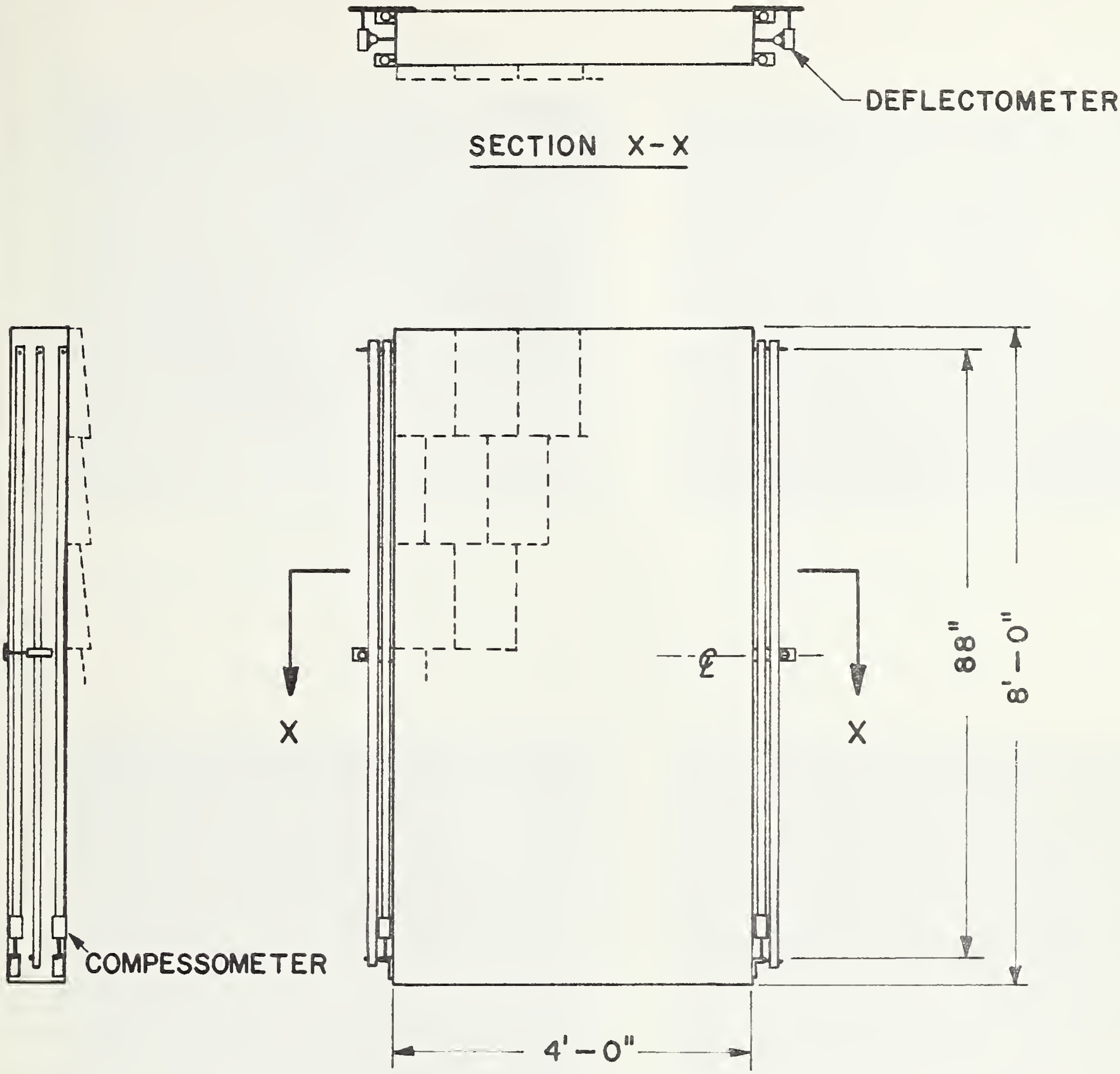
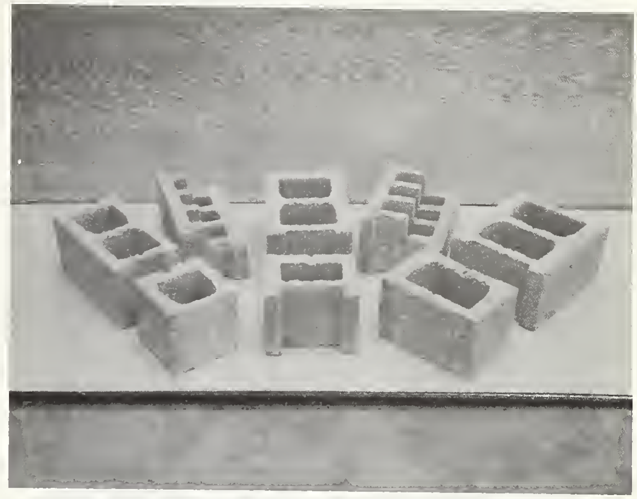
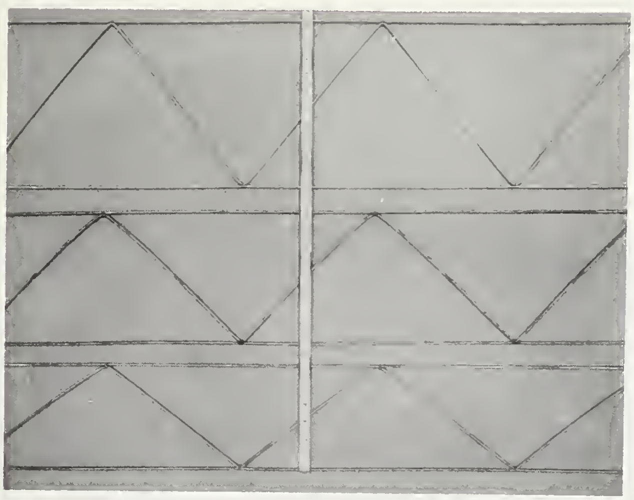


FIG. 2 LOCATION OF INSTRUMENTATION FOR CONVENTIONAL AND "IN-BLOCK" WALL PANEL SPECIMENS

(a) "In-Block" units



(b) Conventional back-up units

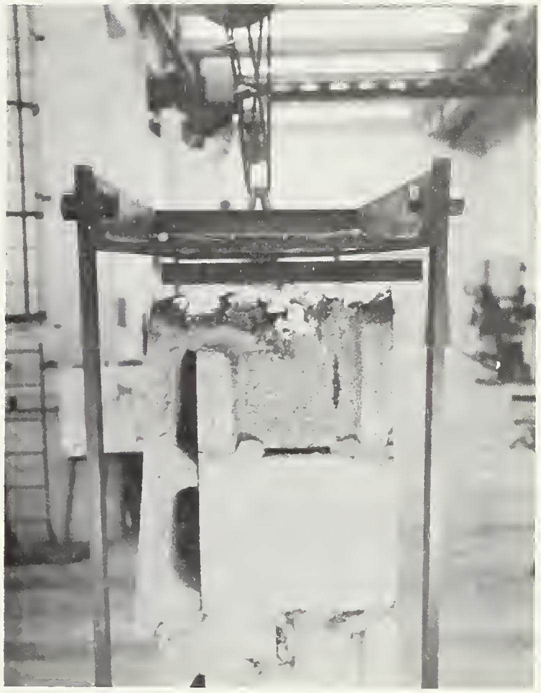


(c) Transverse joint reinforcement

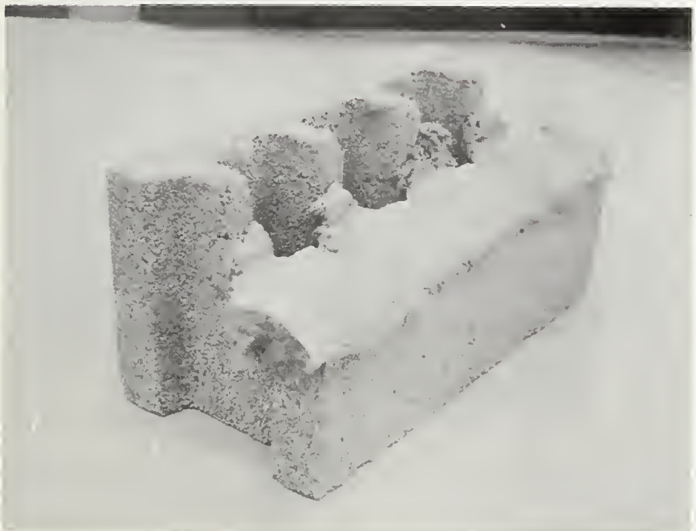
(d) Section of "In-Block" wall panel base

FIG. 3 ELEMENTS OF WALL PANEL SPECIMENS

(a) Bottom of wall



(b) Top of wall



(c) Mortar bedment for "In-Block" units

(d) Instrumented specimen

FIG. 4 CONSTRUCTION DETAILS OF "IN-BLOCK" WALL PANELS

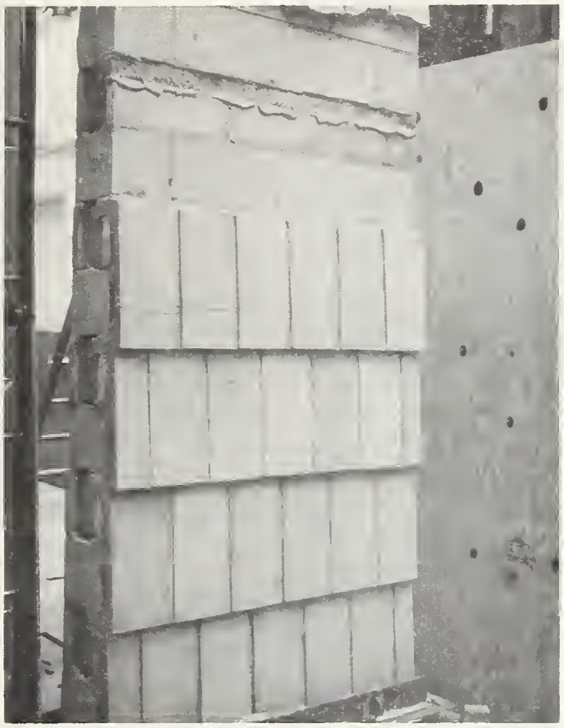
(a) Back of conventional wall (8-2)

(b) Back of conventional wall (12-2)

(c) Back of "In-Block" wall (8-I-2)

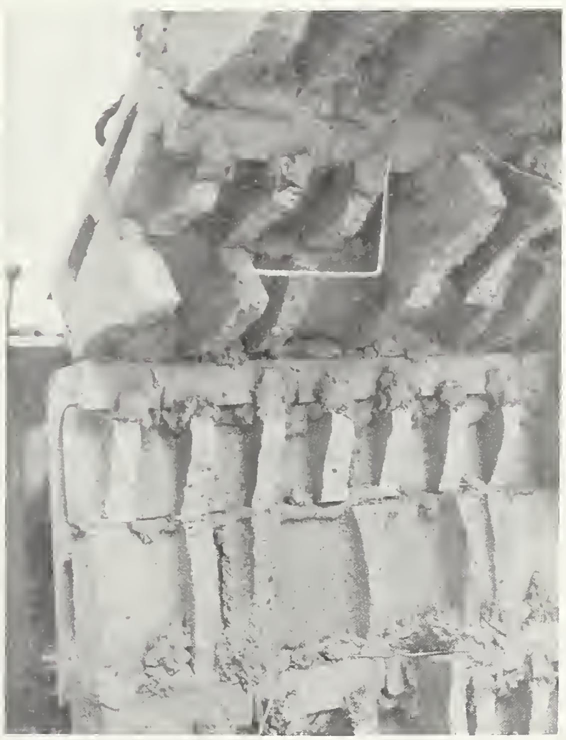
(d) Front of "In-Block" wall (10-I-2)

FIG. 5 TYPICAL WALL PANEL SPECIMEN FAILURES



(a) Front of "In-Block" wall (10-I-1)

(b) Back of "In-Block" wall (10-I-3)



(c) Close-up of "In-Block" wall (10-I-3)

FIG. 6 TYPICAL WALL PANEL SPECIMEN FAILURES

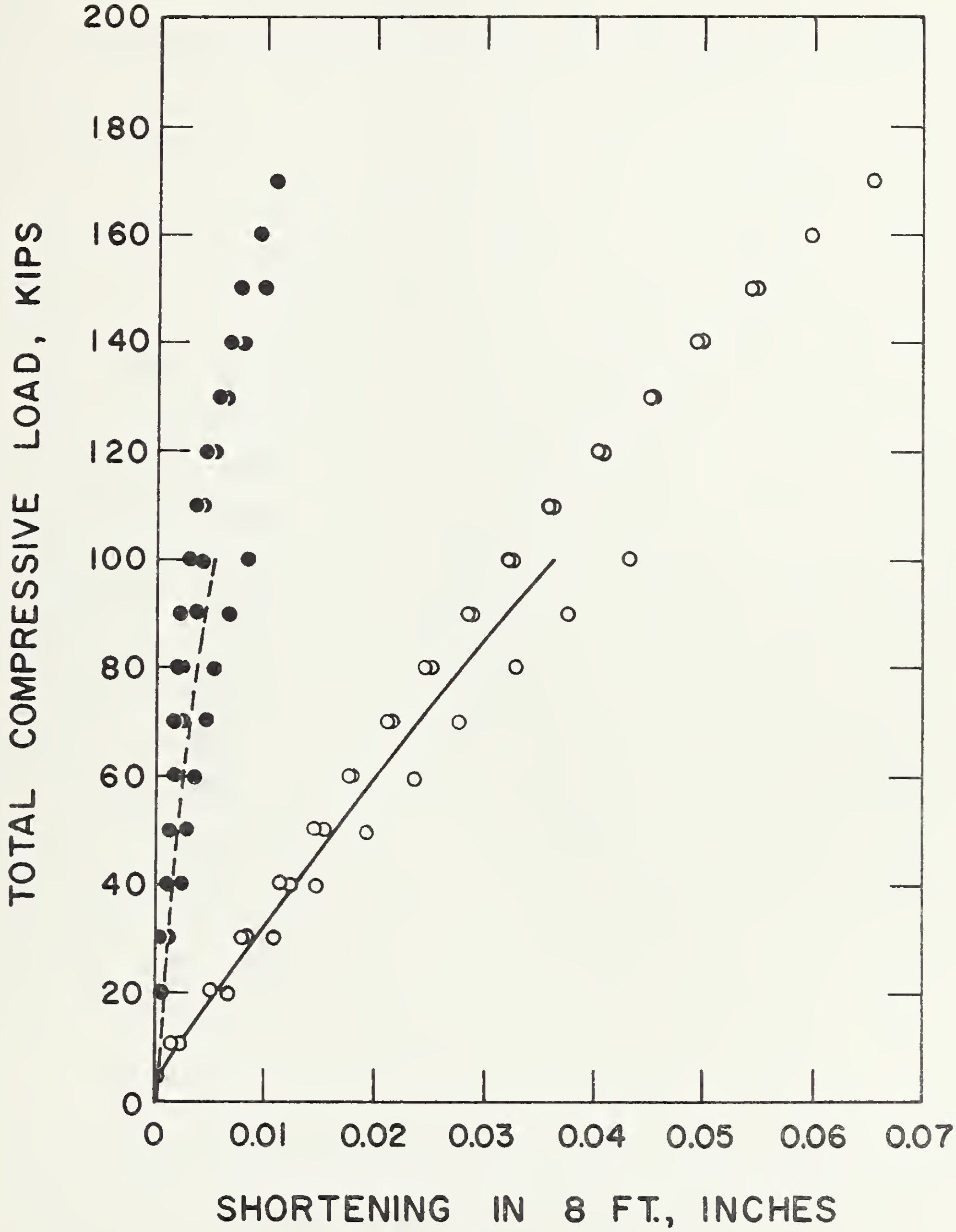


FIG. 7 LOAD-SHORTENING RELATIONSHIP FOR 8-INCH CONVENTIONAL WALL SPECIMENS.

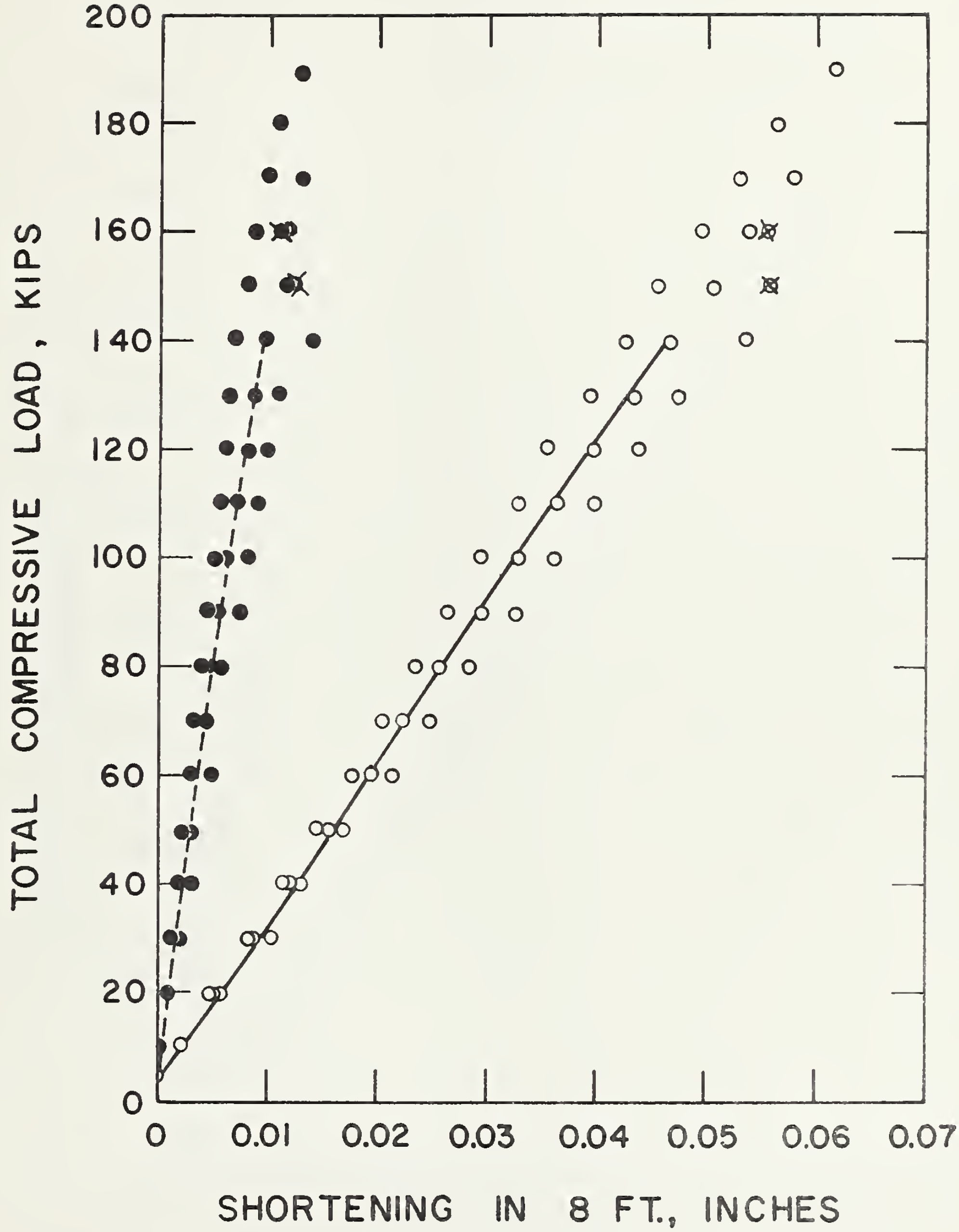


FIG. 8 LOAD-SHORTENING RELATIONSHIP FOR 10-INCH CONVENTIONAL WALL SPECIMENS.

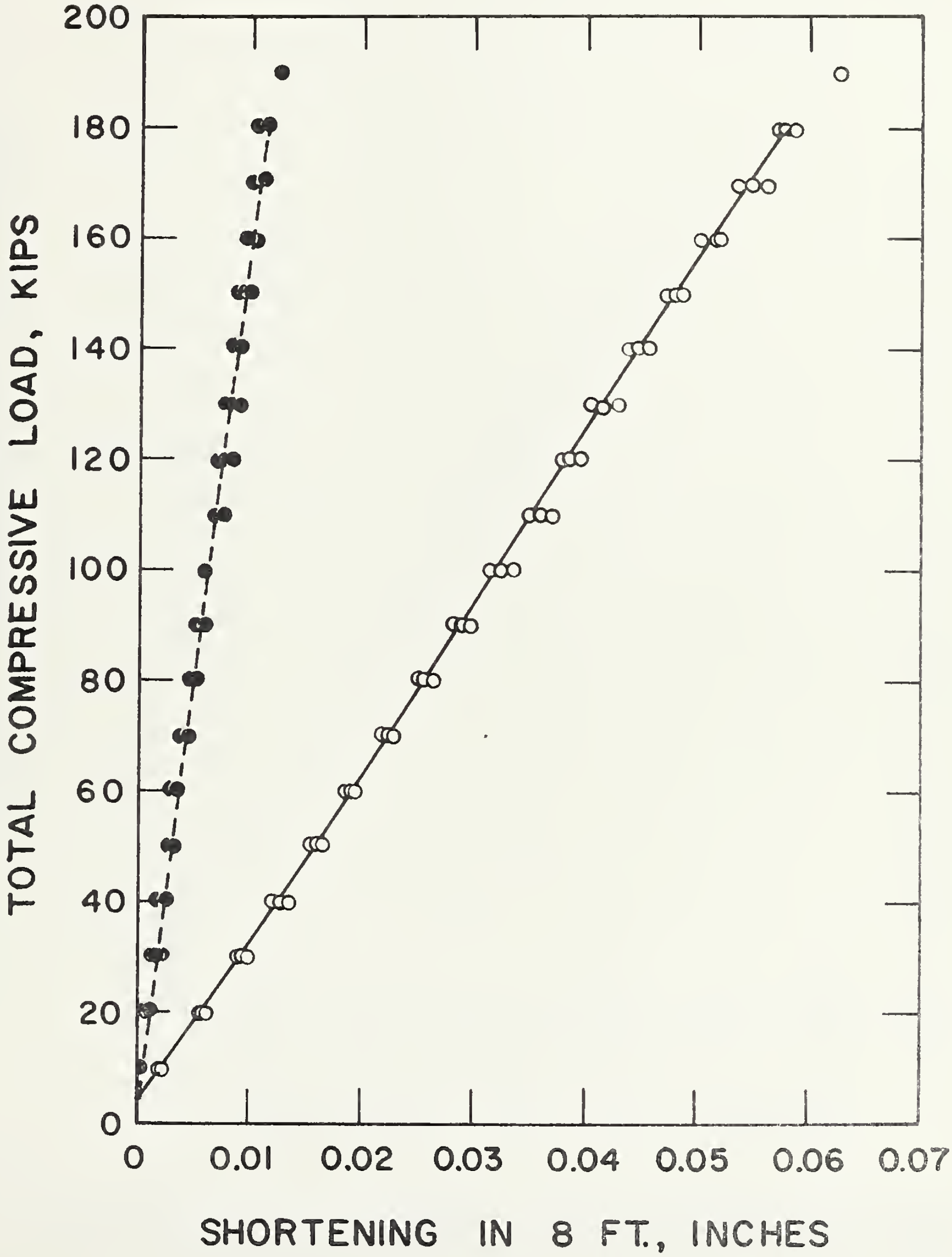


FIG. 9 LOAD - SHORTENING RELATIONSHIP FOR
12-INCH CONVENTIONAL WALL SPECIMENS.

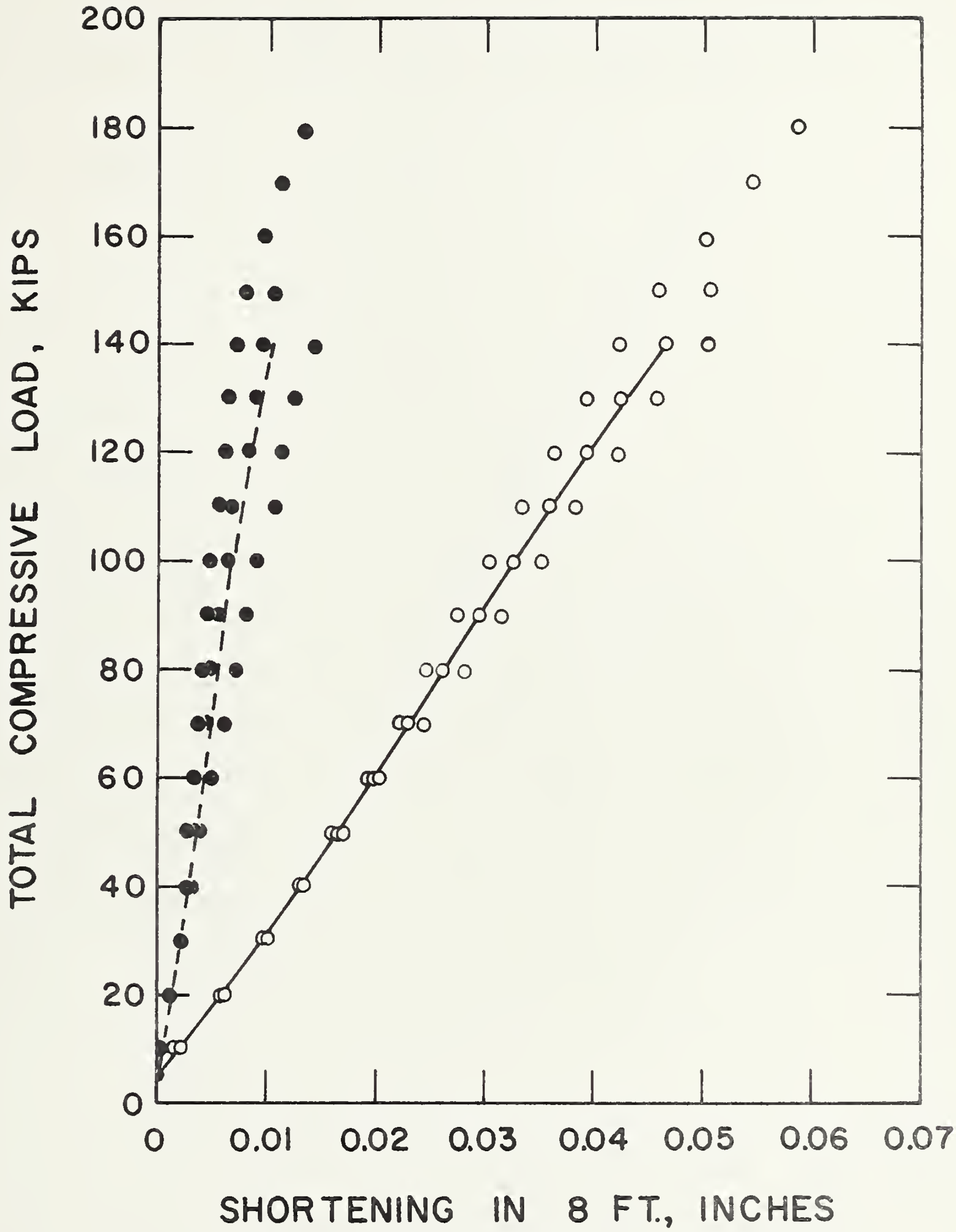


FIG. 10 LOAD-SHORTENING RELATIONSHIP FOR WALL SPECIMENS OF "IN-BLOCK" WITH 8-INCH BACK-UP.

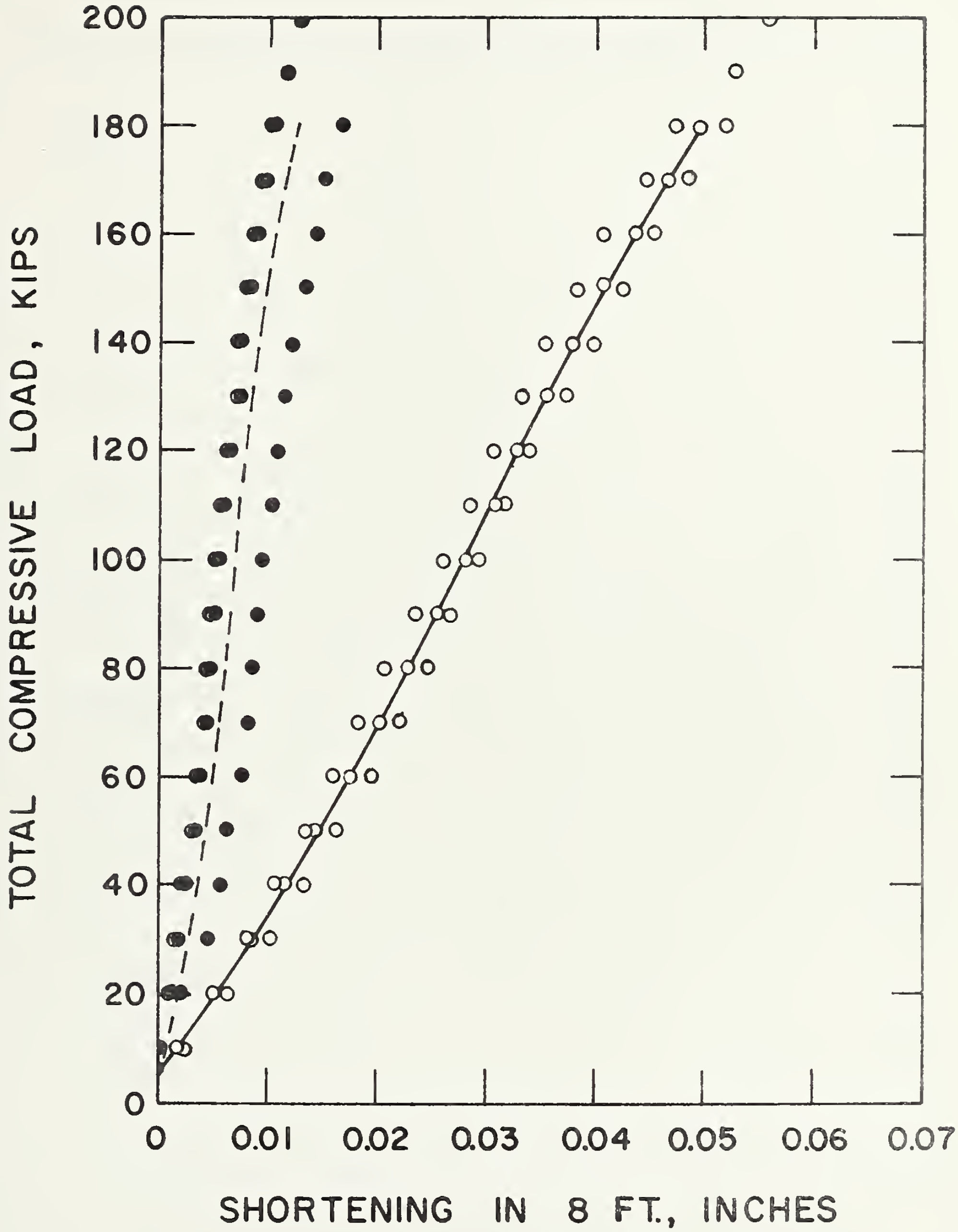


FIG. 11 LOAD-SHORTENING RELATIONSHIP FOR WALL SPECIMENS OF "IN-BLOCK" WITH 10-INCH BACK-UP.

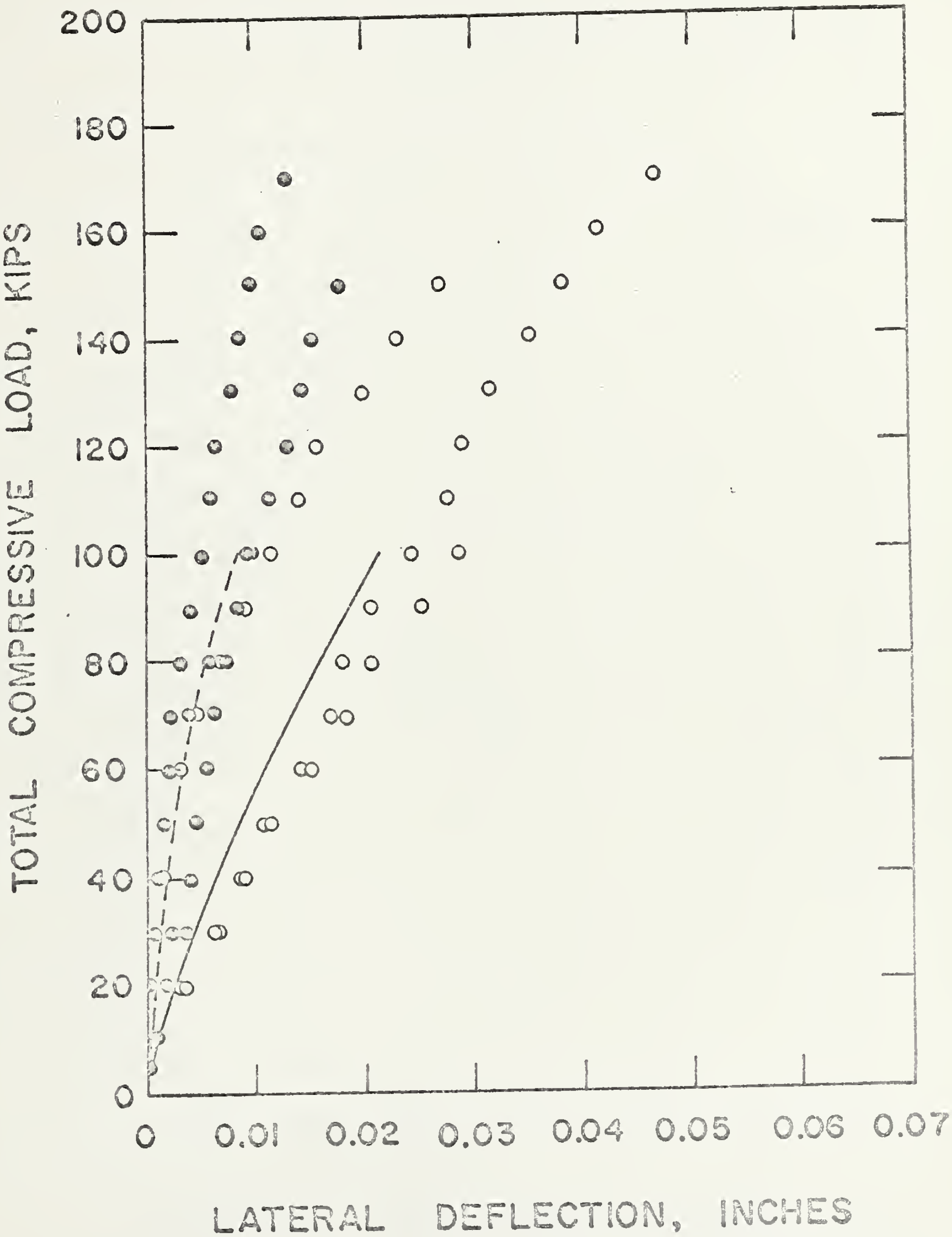


FIG. 12 LOAD-DEFLECTION RELATIONSHIP FOR 8-INCH CONVENTIONAL WALL SPECIMENS.

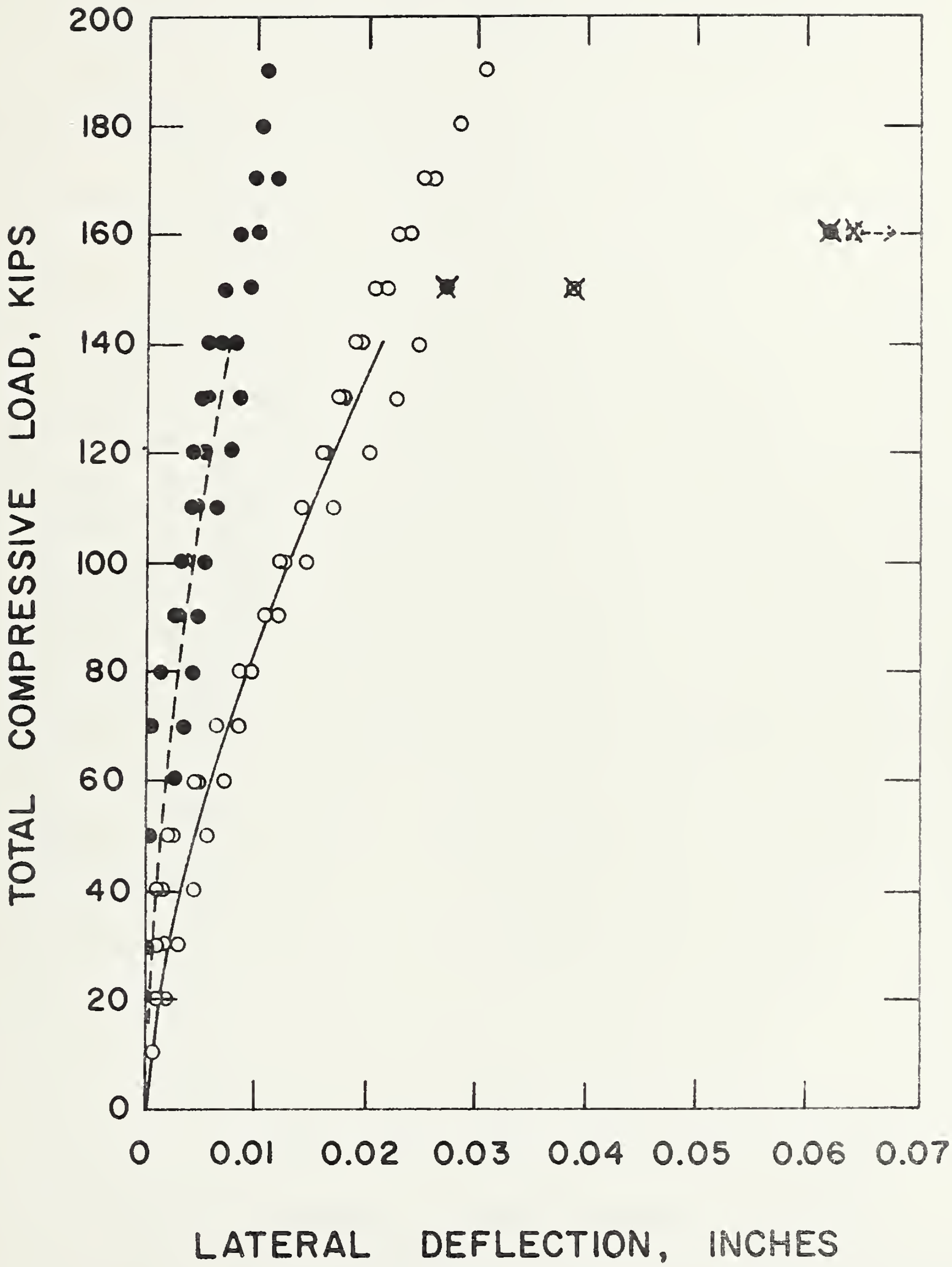


FIG. 13 LOAD - DEFLECTION RELATIONSHIP FOR 10-INCH CONVENTIONAL WALL SPECIMENS.

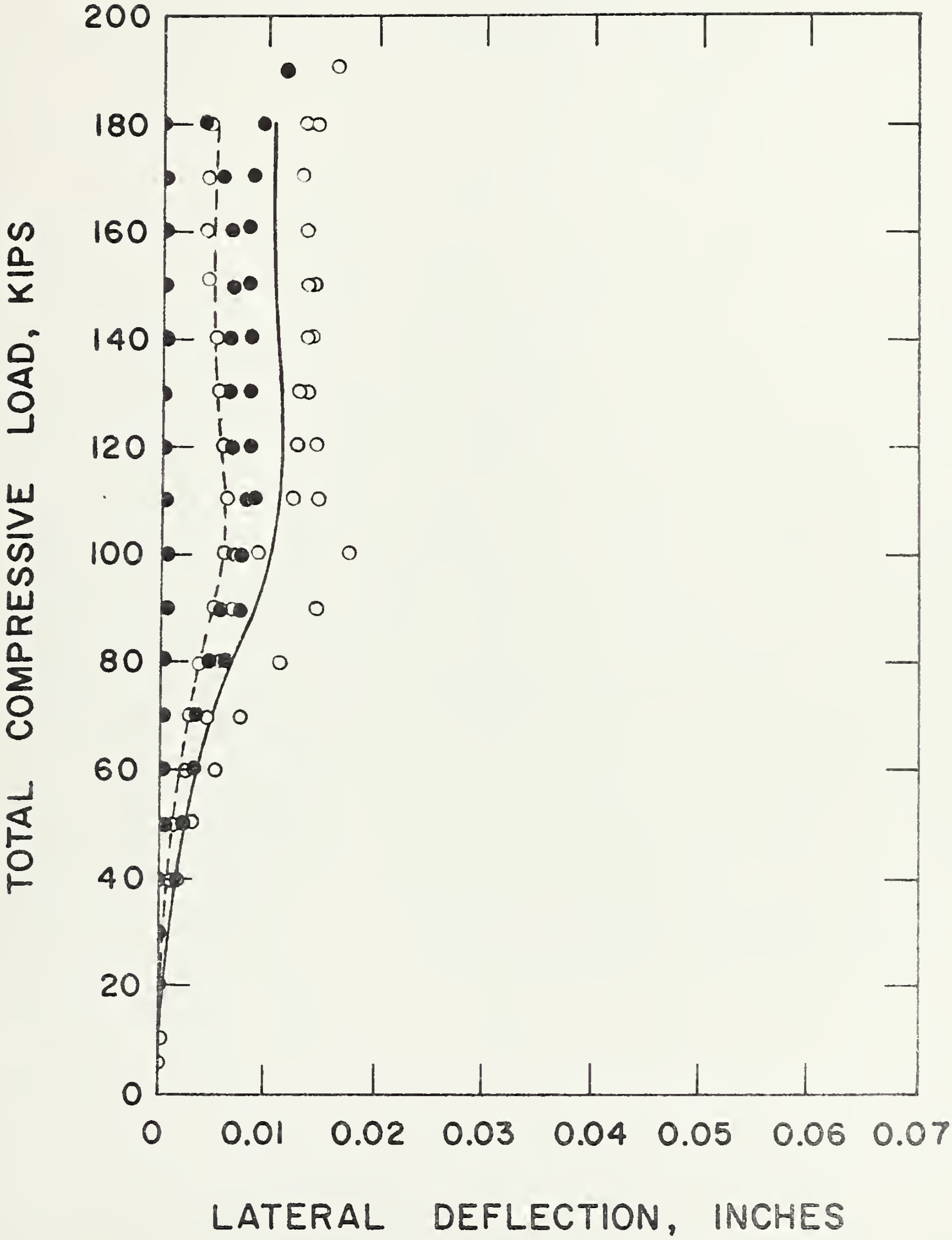


FIG. 14 LOAD-DEFLECTION RELATIONSHIP FOR 12-INCH CONVENTIONAL WALL SPECIMENS.

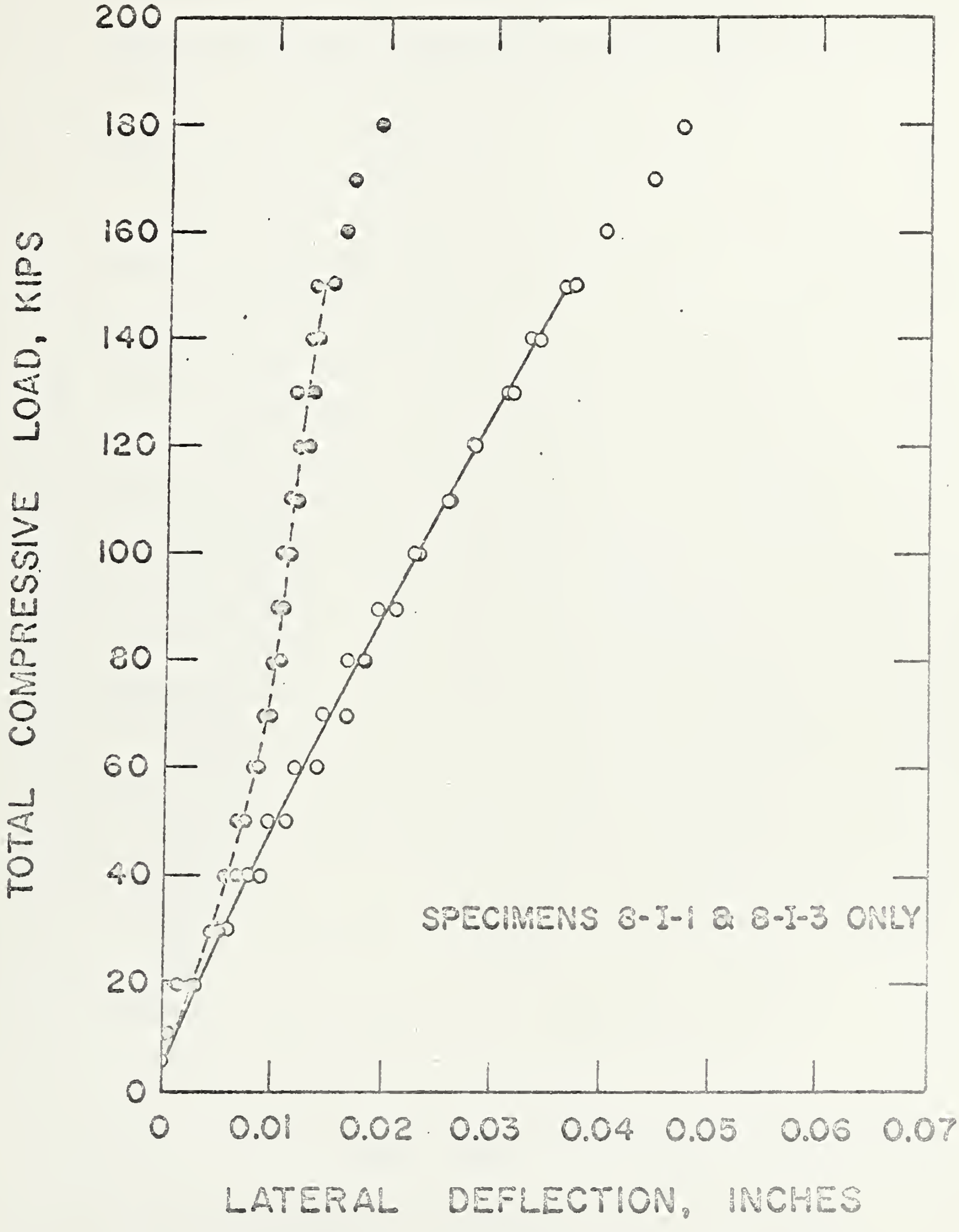


FIG. 15 LOAD-DEFLECTION RELATIONSHIP FOR WALL SPECIMENS OF "IN-BLOCK" WITH 8-INCH BACK-UP

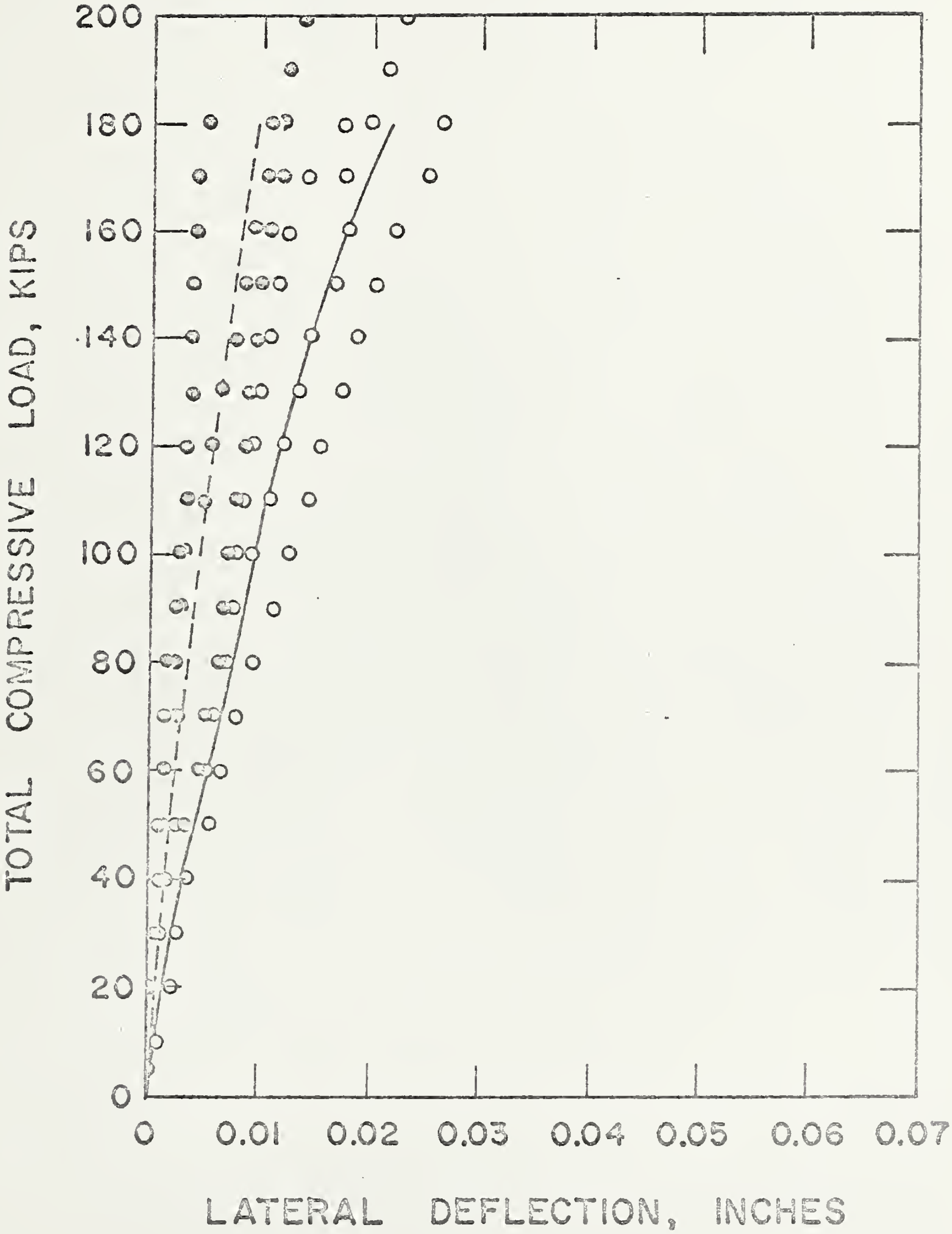


FIG. 16 LOAD-DEFLECTION RELATIONSHIP FOR WALL SPECIMENS OF "IN-BLOCK" WITH 10-INCH BACK-UP

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