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NATIONAL BUREAU OF STANDARDS REPORT

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Final Report on Tests of Prestressed Cellular Slabs (Series of Slabs Nos. 1 through 29)

by

Arthur F. Kirstein

Report to

Bureau of Yards and Docks
Department of the Navy

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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Final Report on Tests of Prestressed Cellular Slabs
(Series of Slabs Nos. 1 through 29)

Arthur F. Kirstein

This report presents a summary of the findings in the study of the properties of twenty nine 5- by 5-ft prestressed cellular slabs tested under concentrated loads. Deflections, strains, crack patterns, and load-carrying capacities were recorded. The data reported herein indicate that the primary mode of failure is diagonal tension, that suitable jointing material between the units is necessary, that web reinforcement of the units is required to increase the load-carrying capacity of the slabs, and that the proper selection of jointing material is important.

1. INTRODUCTION

At the request of the Bureau of Yards and Docks, the Structural Engineering Section initiated a study of the properties and behavior of prestressed cellular slabs subjected to "punching" shear tests.

This is the final or summary report of this investigation which includes the study of a series of prestressed cellular slabs composed of six types of cellular units. Many variables were introduced to cover a broad scope and to develop a slab that could support a fairly large concentrated load at midspan. These variables were type and arrangement of units, jointing materials, amount of prestress, and method of supporting the slabs.

2. DESCRIPTION OF TEST SPECIMENS

2.1 Cellular Blocks

Six types of cellular concrete blocks were examined in this investigation. They were designated as Preload blocks, unreinforced NBS blocks, stirrup reinforced NBS blocks, NBS blocks reinforced with welded wire fabric, clay tile, and pavement blocks. The principal dimension of these blocks are shown in figure 1.

The Preload blocks were 6-in. cubes having an opening 4.5- by 5-in. in cross section. There was a 1- by 2-in. elliptical hole in each web through which the prestressing unit could pass. The outside dimensions of those blocks that were selected at random for measurement were found to vary as much as 1/8 in. from the specified dimensions. The reinforcement in the blocks consisted of a single layer of 1- by 1-in. galvanized welded wire fabric of 15/15 gage. These blocks were furnished to the National Bureau of Standards by Preload Corporation which had procured them from a commercial concrete products plant. Therefore, the proportions of the concrete mix used in the blocks are not known. However, a 3/4- by 2- by 6-in. strip of concrete was removed from one of the blocks and was tested to determine the modulus of elasticity, Poisson's ratio, and the compressive strength of the concrete. Both static and sonic tests were performed on this specimen which yielded an average modulus of elasticity of 2.74 x 10^6 psi. The compressive strength and Poisson's ratio were 4710 psi and 0.12 respectively, as determined by the static test.

The three types of NBS blocks were hollow 6-in. cubes having an opening 4.5- by 4.5 in. in cross section. There was a 1- by 2-in. elliptical access hole in each web to permit the passage of the prestressing units. These blocks were cast in steel three-unit gang molds that were constructed to very close tolerances. The blocks made in these forms were of superior quality and the exterior dimensions of the blocks were within 0.01 in. of the nominal values. The only difference between these types of blocks was in the reinforcement of the webs. Details of the web reinforcement are shown in figure 1.

The pavement blocks were 6-by 15 5/8- by 7 5/8-in. concrete blocks with one oblong cell through the 6- by 15 5/8 in. face. The cell was bounded by two semi-circles of 2 1/4 in. radii at the ends and straight lines between them. The shell thickness was 3/4 in. One circular hole 1 in. in diameter was made in each 6- by 7 5/8-in. face concentric with the center line of the 7 5/8 in. sides and tangent to the center line of the 6 in. sides. These holes accommodated the passage of the prestressing tendons.

The NBS type blocks and pavement blocks were made of a mix proportioned of one part type III cement and three parts of sand, by weight, with a water-cement ratio of 0.57. This mix had a 7-day compressive strength of approximately 6000 psi as determined by tests of 2-in. cubes. However, the actual units were moist-cured for a considerably longer period of time and then some of them were put in dry storage before being assembled into slabs. Therefore, the compressive strength of the concrete in the individual units should be expected to be somewhat greater than 6000 psi.

Additional tests were conducted on the concrete to determine the Young's modulus and Poisson's ratio. Axial compression tests were made on columns of three blocks that were grouted together in such a fashion as to make the direction of the loading coincide with the axis of the cell. Sonic modulus tests were also performed on 0.75- by 0.80- by 6-in. strips that were cut from the cellular blocks. The results obtained by both methods indicated an average Young's modulus of 4×10^6 psi with a variation of ± 10 percent. Poisson's ratio was found to be approximately 0.15.

The cellular clay tile blocks were made of a high grade vitrified clay by the Federal Seaboard Terra Cotta Corporation. The principal dimensions of the tile blocks were approximately the same as those of the NBS blocks except that the tile had circular instead of elliptical holes in the webs. The tile blocks had a good texture but the overall dimensions varied as much as 1/4 in.

Several of the clay tile were tested in axial compression with the load applied in the direction of the cell. The average compressive strength was approximately 12,000 psi. The typical stress-strain relationship for this was essentially linear up to the failure load an yielded a Young's modulus of 4.4×10^6 psi and a Poisson's ratio of 0.15. Even though the tile exhibited a compressive strength that was approximately twice that of the concrete, the tensile strength was presumably not much greater than that of concrete.

2.2 Prestressing steel

Two types of steel bars were used as prestressing tendons in this investigation. They were "Stressteel" and "Elastuff" bars that were 5/8 in. in diameter. The anchorage for these bars consisted of hexagonal nuts 1 1/4-in. long which bore on 5 3/4- by 5 3/4- by 3/4-in. anchor plates.

The tensile strength of unthreaded Stressteel bars was found to be 163,000 psi, whereas threaded bars supported by fully tightened nuts developed a tensile strength of 152,000 psi. The yield strength of this steel as determined by the 0.2 percent offset method was 142,000 psi. The stress-strain characteristic was a straight line up to 65,000 psi, giving a Young's modulus of 30×10^6 psi; the secant modulus at 100,000 psi was 28.2×10^6 psi. The reduction in area at the point of fracture was 35 percent.

Tensile tests of the Elastuff steel indicated a stress-strain relationship that was essentially linear up to 95,000 psi, and exhibited a Young's modulus of approximately 30×10^6 psi. The yield strength of the bar was found to be 120,000 psi as determined by the 0.2 percent offset method and the tensile strength was found to be 133,000 psi. Although Elastuff bars are made of cold-worked high carbon steel, they are fairly ductile and can be machined easily.

2.3 Description of prestressed slabs

The nominal dimensions of each slab containing 100 cellular blocks were 5 ft by 5 ft by 6-in. The arrangement of the blocks in the slabs of this investigation are described as "crisscross", and "aligned". The crisscross assemblies contained blocks arranged so that the axis through the open ends of one block was perpendicular to the axis of each adjacent block, while the aligned assemblies were arranged so that the axes through the open ends of all blocks were parallel. Both assembly arrangements positioned the holes in the webs of each block in such a fashion to permit the prestressing tendons to be staggered with respect to the mid plane of the slab. Thus, the resultant prestressing force produced an axial compression in two directions through the slab.

The principal variables in this test series were the method of support, type of block, amount of prestress, arrangement of blocks, and jointing material. A complete summary of these variable factors is shown in Table 1 along with the maximum load-carrying capacity and the deflection sensitivity of each slab.

Most of the slabs were assembled by placing the blocks in position on a large flat table. This method of fabrication produced slabs that were essentially flat while in the unprestressed condition. Slabs Nos. 3, 4, and 9 were assembled in two stages: First, the blocks were assembled into 5-ft beams with about 1/8-in. grout joints. The beams were then assembled together with 1/8-in. grout joints between them. These slabs became slightly warped upon prestressing as did the slabs that were assembled without jointing material.

Slab No. 25 was made of hollow pavement blocks which were arranged as shown in figure 2 to produce a slab with the nominal dimensions of 64- by 64- by 6-in. Auxialiary tests of prestressed beam assemblies of these blocks indicated that they required more rigid end anchorage than that provided by the 6-in. blocks in order to obtain 1000 psi prestress in the concrete without causing distress in the individual units. To produce a more rigid end anchorage for this slab the 12 blocks bordering the slab shown in figure 2 were solid concrete. All of the bars in the transverse direction were placed one-half bar diameter above the mid-plane, and all of the bars in the longitudinal direction were placed one-half bar diameter below the mid-plane.

2.4 Jointing material

There were six types of joints used in this investigation as indicated in Table 1. The grout was a 1:3 mixture of type III cement and sand and the neat cement paste was made of type III cement. The polyester resin (Selectron 5119)* contained Cab-o-sil*, a finely divided silica, as a filler and was activated by Lupersol DDM* which is 60 percent methyl ethyl ketone peroxide in dimethyl phthalate. The epoxy resin (Epon 828)* was also filled with Cab-o-sil*

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*A list of manufacturers and distributors from whom these materials were obtained is given in the Appendix along with the mix proportions of the various jointing materials.

to give the consistency of petroleum jelly and was activated with diethylenetriamine. The epoxy/Thiokol adhesive contained Epon 828*, a polysulfide polymer, (Thiokol LP-3)*, a resin coated $CaCO_3$ (Surfex)*, Cab-o-sil*, and was activated with a mixture of DMP-30 and DMP-10* which are dimethylaminomethyl phenols.

2.5 Prestressing procedure

Experience in prestressing operations indicates that it is not necessary to apply prestress simultaneously to all bars. Large amounts of prestress may be applied safely if the prestressing force is applied in small equal increments to all tendons. Approximately one-half of the prestress was applied to the slab in small increments by tightening the anchorage nuts with a wrench. The remaining prestressing force was applied by means of a hydraulic jacking rig. This final stage of the prestressing operation was accomplished by using a suitable sequence of stressing the tendons so that no unduly large differences in strain would be induced in the blocks.

The hydraulic jacking rig was equipped with a dynamometer which had two electrical resistance wire strain gages bonded longitudinally and two transversely on the calibrated section. Each pair was connected in parallel and the two pair of gages served as measuring and compensating gages, respectively. The calibration curve for the dynamometer is shown in figure 3.

3. TESTING PROCEDURE

3.1 Test setup

All of the slabs were tested to failure in a 600,000 lb capacity hydraulic testing machine. They were simply supported on a 54-in. span along either two or four edges as indicated in Table 1. A single concentrated load was applied to the center of the slab through a 12- by 12- by 6-in. concrete loading block. Three different methods of supporting the slabs on the testing machine platen were used. Slab No. 1 was supported by 3/4-in. pipe rollers that rested on 2- by 6-in. timbers. This frame was found to be lacking in rigidity and

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*A list of manufacturers and distributors from whom these materials were obtained is given in the Appendix along with the mix proportions of the various jointing materials.

accordingly was replaced by one consisting of 6-in. I-beams. The frame consisting of 6-in. I-beams was used to support all the rest of the specimens except for Slabs Nos. 4, 5, 7, 8, and 9. These slabs were tested on a frame made of 6- by 12-in. reinforced concrete beams supported by six 6-in. concrete cylindrical pillars as shown in figure 4. This method of support elevated the slabs about 5-ft above the testing machine platen to facilitate the inspection of the crack pattern during the load test. All of the bearing surfaces in each method of support were set firmly with high strength gypsum plaster to ensure intimate contact between individual members.

3.2 Instrumentation

The instrumentation used in this series of tests was altered at times to make the tests more flexible and to obtain certain associated data that was peculiar to certain specimens and types of supports. A complete description of the instrumentation and gage location in this report is unwarranted as they have been discussed in detail in earlier reports. Therefore, Table 2 is included to give direct reference to the NBS Report and figure which describes the instrumentation of each slab. However, instrumentation diagrams for Slabs Nos. 28 and 29 are presented in this report in figures 5 and 6 respectively, since the results from the tests of these slabs have not been reported previously.

All of the deflections of the specimens were measured with micrometer dial gages. However, these gages were supported in different ways to accommodate the measurement of the deflection of slabs having two and four edge supports. The slabs having four edge supports indicated the characteristic "curl-up" of the corners and required a frame to hold the dial gages that had a reference datum plane that would not warp. Therefore, most of the slabs having four edge supports were equipped with dial gage frames that used the testing machine platen as the datum plane. A refinement in the measurement of the deflection of slabs having four edge supports was introduced later in the test series. In this method of measurement the dial gages were attached to two steel frames each of which was supported on three points. These points were located on the top surface of the slab directly over the supports, and at the center of the support where, theoretically, no deflection takes place. Figure 5 shows the location of the dial gages and the position of the frame supports on Slab No. 28. The deflection measurements

of slabs which were supported along two edges were made in a different manner. Since there is no characteristic curl-up associated with the deflection of these slabs, the dial gages were attached to steel angles which rested on the slab directly over the supports. Thus, the dial gages indicated directly the deflections with respect to the supported edges of the slab.

The variation of strain in eight prestressing tendons in a number of slabs was measured by means of bonded wire strain gages. Each of the eight bars was equipped with two gages connected in series to eliminate the effects of any bending that might take place. Four of these bars ran through the center portion of the slab in one direction, and the other four were perpendicular to them. For the exact location of these tendons see NBS Report 4951.

The strain in concrete blocks near the center loading block was measured by eight bonded wire strain gages that were mounted as shown in figures 5 and 6. These measurements were made on all of the specimens except Slab No. 1.

Since it was of some interest to determine whether or not the loading block was punched into the slab before diagonal cracks formed in the webs of blocks containing reinforcement, four dial gages were arranged around the loading block on Slab No. 27 to determine the changes in depth of slab and penetration of the loading block into the slab. See Table 2 for reference to a diagram and photograph of the instrumentation. Two of these gages had extensions that passed through a hole in the top flange of the block and rested in a hole in a steel plate cemented to the interior surface of the lower flange of the block. These gages were expected to indicate when the diagonal cracks formed in the webs. The other two gages were attached to the loading block and rested on the top surface of the slab. These gages were expected to indicate when the loading block was punched into the slab.

3.3 Test procedure

All of the slabs except Slab No. 25 were loaded at the center of the top surface through a 12- by 12- by 6-in. concrete loading block. Since the units in Slab No. 25 were 16-in. long, a concrete loading block 16- by 16- by 6-in. was used to apply the load to this slab.

The slabs were first flexed by applying a load equivalent to one increment of the loading schedule. This load was then removed and the slab was allowed to recover for several minutes. All gages were read at this zero load condition, and the readings were compared with the initial zero load readings. After this flexing procedure the load was applied in increments, and gages were read for each increment until the maximum load was reached. The load increments applied varied from 1000 to 5000 lb for the slabs depending on the maximum load expected and the type of measurements that were made.

4. TEST DATA

4.1 Deflection and load-carrying capacity of slabs

Figures 7, 8, and 9, show the observed relationship between the applied load and center deflection of the slabs. The reciprocal of the slope of the linear or elastic portions of these curves can be considered to be a measure of the deflection sensitivity of the slabs, and is expressed in terms of micro inches of deflection per pound of applied load (μ in./lb). Table 1 shows a comparison of the deflection sensitivities and the load-caryying capacities of the slabs.

Since the supports did not restrict the upward movement of the slab, the twisting moments induced by the applied load caused a "curl-up" action to take place at the corners of the slabs simply supported along four edges. The amount of curl-up was measured by the upward movement of the corners with respect to some fixed datum plane. Figure 10 shows the experimentally determined relationship between the applied load and the vertical upward displacement caused by the twisting moments.

4.2 Variation of prestressing force

After the prestress is applied to the slab it may diminish slowly due to the following causes: (1) readjustment of contact of cells, (2) relaxation of steel, (3) creep of concrete, (4) shrinkage of concrete, and (5) movement in the anchorage. In view of the fact that the Preload blocks used to make Slabs Nos. 1, 2, 3, and 4, were about one year old, the shrinkage of the concrete was negligible. Since Slabs Nos. 3 and 4 had grout joints, they were monolithic structures

and no readjustment of cells occurred. Therefore, the loss indicated by the decrease in strain of bars in these slabs must be attributed to causes (2), (3), and (5). The loss of prestress with time for Slab No. 3 is shown in Table 3. However, in the case of Slabs Nos. 1 and 2 the loss of prestress due to readjustment of the cells was observed from the time when the anchorage nuts were tightened by wrench. When the full prestress was applied to Slabs Nos. 1 and 2, most of the readjustments of the cells had already taken place but the process continued for a few days before it tapered off. Since SR-4 gages were installed on some prestressing bars in Slab No. 2 these losses were measurable. It was noted that the loss of prestress in Slab No. 2 due to its being moved from the working platform to the test frame constituted 25 percent of the total strain due to prestressing.

Figure 11 shows the loss of strain in the prestressing tendons in Slabs Nos. 5, 7, 8, and 9. The Slab No. 9 made of clay tile exhibited an average loss of strain in the tendons of 4 percent at three days and 8 percent at seven days, while the tendons in the concrete slabs lost 8 percent of their strain at three days and 13 percent at seven days. It is evident from these data that the loss of strain in the tendons is not only a function of time but also depends on the material being prestressed. Since the concrete blocks used to make Slabs Nos. 5, 7, and 8, were moist-cured until they were assembled and prestressed, a portion of the loss in strain in the tendons can be attributed to shrinkage of the concrete. However, the shrinkage of the clay tile slab can be considered to be negligible.

Since the prestressing tendons were either located at or near the midplane of the slabs, no large changes in the strain in the tendon were expected during the application of load on the slabs. Measurements made during the tests indicated that in general this was the case, as a maximum loss of about 2 percent of the initial prestress was observed for Slabs Nos. 5, 7, and 9. However, Slab No. 2 lost about 8 percent of its initial strain during the load test. The larger loss in initial prestress was attributed to the readjustment of blocks, as Slab No. 2 contained no jointing material.

4.3 Concrete strains

The loss of strain in the concrete due to shrinkage, creep, and readjustment of the ungrouted block of Slab No. 5 is presented in figure 12. The average loss of strain for a six day period was 37 percent of the original strain.

Previous NBS Reports Nos. 4396, 4951, 5212, and 5714, have presented the observed relationship between applied load and strain in the concrete for all of the slabs in this investigation except Slabs Nos. 28 and 29. Therefore, it will suffice to present only typical results here and the unreported results from Slabs Nos. 28 and 29. Figure 13 represents typical results of slabs simply supported along two edges with the blocks arranged in a crisscross fashion and prestressed to 1000 psi in both the longitudinal and transverse directions. The observed relationships between applied load and concrete strain are presented for Slab Nos. 28 and 29 in figures 14 and 15, respectively. The legend in figure 13 also serves as a legend for figures 14 and 15 except that Slab No. 28 was simply supported along four edges and the strain in the concrete cannot be considered as longitudinal or transverse.

4.4 Crack patterns

The crack pattern observed in Slab No. 24, which was constructed of unreinforced NBS blocks, was typical of the diagonal tension failures reported in NBS Report No. 5212. The top view of the crack pattern in Slab No. 24 is shown in figure 16. This widespread cracking of the flanges of the blocks was accompanied by extensive crack formations in the webs of the blocks. In contrast to this widespread cracking of unreinforced blocks a typical top view of the crack pattern in the NBS blocks reinforced with welded wire fabric of Slab No. 27 is shown in figure 17. This localized punching failure around the loading block was accompanied by only minor cracks in the webs of a few blocks immediately surrounding the loaded area of the slab.

As mentioned previously in the text, measurements were made on Slab No. 27 to determine the punching action of the loading block and the vertical movement of the lower flange with respect to the upper flange in the blocks around the loaded area. The results of these observations are shown in figure 18. Attention is directed to the fact that the dial gages measuring the extension of the block webs did not indicate a sudden extension in the web associated with the formation of large cracks until the ultimate load was reached and

the loading block punched into the top surface of the slab. It is realized that the measurements made with the dial gages mounted on the loading block contain minor errors due to the local deformation around the loaded area. However, no attempt was made to correct these errors as they were considered to be quite small.

5. DISCUSSION

The slope of the load-deflection curves in figures 7, 8, and 9, and the deflection sensitivities given in Table 1 indicate that a much larger deflection is exhibited by slabs containing no jointing material. This large deflection with load is especially pronounced in those slabs composed of the blocks having poorer dimensional tolerances. However, when jointing material is used in slabs composed of either the NBS type blocks or the blocks with poorer dimensional tolerances the slabs deflect less and carry a greater load as indicated in Table 1.

In general, the data presented herein indicate that the load-carrying capacity of slabs containing reinforced NBS blocks can be increased by using stronger jointing materials, but no increased capacity was exhibited by slabs containing unreinforced NBS blocks. This is probably due to the premature failure of the weaker webs of the unreinforced blocks.

Upon evaluation of the testing method and considering that the manner of failure was punching or diagonal tension failure, it is evident that assemblies of this type that are subjected to such severe shear conditions require reinforcement of the block webs to increase the load-carrying capacity.

Figure 10 shows the observed relationship between the applied load and the vertical upward displacement of the corners of the slabs which were supported along four edges. Since the upward displacement of the corners was not restricted in these tests, no measurements were made of the force necessary to arrest this movement. If slabs of this type are used in structures that do not permit this displacement of the corners, the theory given in NBS Report No. 4396 should be adequate to predict strains and deflections.

As previously stated slabs of this type lose prestress due to four major causes: (1) readjustment of contact of units, (2) relaxation of steel, (3) creep of concrete, and (4) shrinkage of concrete. The first cause is eliminated when jointing materials are used in construction. Thus, the primary causes of stress loss are the same for this type of construction as for conventional post tensioned prestressed concrete.

The typical crack patterns shown in figures 16 and 17 indicate that the use of reinforcement in the block webs is very beneficial in reducing the widespread cracking exhibited by Slab No. 24 shown in figure 16 to the localized cracking of Slab No. 27 shown in figure 17.

Comparison of the two curves in figure 18 indicates that an increase in the rate of penetration of the loading block in the slab is associated with the first measurable change in the depth of the web of the cells adjoining the loaded area. Although these displacements appeared to develop simultaneously, it is worth noting that the large values of penetration by the loading block of loads approaching the maximum cannot be accounted for by the much smaller value of extension of the block web. It is probable, therefore, that punching shear was the primary cause of failure in slabs of the type exemplified by Slab No. 27.

6. CONCLUSIONS

The results of this investigation can be summarized in the following conclusions:

1. A suitable joint material must be provided between the blocks to ensure intimate contact.

2. To improve the load-carrying capacity of these slabs it is necessary to provide suitable reinforcement in the blocks to increase their resistance to diagonal tension failures. An increase in the compressive strength of the material cannot be utilized as long as there is no commensurate increase in the tensile strength.

3. All of the slabs reported herein failed in diagonal tension or punching shear.

4. The theory presented in NBS Report No. 4396 should be adequate to predict strains and deflections in slabs of the type tested in this investigation when they are supported along four edges.

5. When unreinforced NBS blocks are used to fabricate a slab, no strength advantage is derived from the use of the stronger and more expensive epoxy resin over the polyester resin or neat cement paste as a jointing material.

6. The load-carrying capacity of slabs containing reinforced NBS blocks can be increased by using stronger jointing materials.

7. Slabs containing reinforced NBS blocks fail in a pure punching action as the four units directly under the loading block are punched into the slab.

8. Since the pavement blocks are prone to fail by diagonal tension at low loads and since they require special end anchorages to withstand the prestressing force, they were found to be unsuitable for use in prestressed slabs of this type.

APPENDIX

The following is a list of materials used in preparing the adhesives used in these tests and their sources:

Epon 828 - epoxy resin

Shell Chemical Corporation
380 Madison Avenue
New York 17, N. Y.

Cab-o-sil - finely divided silica

Godfrey L. Cabot, Inc.
Mineral and Chemical Division
77 Franklin Street
Boston 10, Mass.

DMP-10) - Dimethylaminomethyl phenols
DMP-30)

Rohm and Haas Company
Washington Square
Philadelphia 5, Penna.

Diethylenetriamine

Chemical Rubber Company
8616 Georgia Avenue
Silver Spring, Md.

Selectron 5119 - polyester resin

Pittsburgh Plate Glass Company
One Gateway Center
Pittsburgh, Penna.

Lupersol-DDM - 60% Methyl ethyl Ketone peroxide in dimethyl phthalate

Novadel-Agene Corporation
Lucidol Division
1740 Military Road
Buffalo, N. Y.

Thiokol LP-3 - polysulfide polymer

Thiokol Chemical Corporation
Trenton 7, New Jersey

APPENDIX (continued)

Surfex - resin coated calcium carbonate

Diamond Alkali Company
12 S. 12th Street
Philadelphia 7, Penna.

The following are the proportions used to mix the jointing materials used in this investigation:

Grout - 1 part type III cement to 3 parts of sand, by weight.

Neat cement - type III cement.

Polyester resin - batch proportions:

200 grams	Selectron 5119
12 grams	Cab-o-sil
2 grams	Lupersol DDM

Epoxy resin - batch proportions:

200 grams	Epon 828
12 grams	Cab-o-sil
16 grams	Diethylenetriamine

Epoxy/Thiokol - batch proportions:

Component A

100 grams	Thiokol LP-3
100 grams	Surfex
10 grams	Cab-o-sil
2.5 grams	DMP-30
2.5 grams	DMP-10

Component B

250 grams	Epon 828
250 grams	Surfex
7.5 grams	Cab-o-sil

Components A and B were proportioned in the ratio of 1:1.

Table 1. Comparison of Test Results

Slab	Method of support	Arrangement of blocks	Amount of prestress	Type of steel	Jointing material	Type of block	Deflection sensitivity	Maximum load
			psi				μ in./lb	kips
1	4 edge	Crisscross	1000 long. 1000 trans.	Stressteel	None	Preload	---	11.80
2	4 edge	do	1000 long. 1000 trans.	do	do	do	3 00	16.25
5	4 edge	do	1000 long. 1000 trans.	Elastuff	do	NBS	0.97	18.00
3	4 edge	do	1000 long. 1000 trans.	Stressteel	Grout	Preload	0.90	35.00
4	4 edge	do	1000 long. 1000 trans.	do	do	do	1.10	34.25
7	4 edge	do	1000 long. 1000 trans.	Elastuff	do	NBS	0.70	27.28
8	4 edge	do	1000 long. 1000 trans.	do	do	NBS*	0.70	39.85
9	4 edge	do	1000 long. 1000 trans.	do	do	Clay tile	0.80	26.80
28	4 edge	do	1000 long. 1000 trans.	do	Neat cement	NBS+	0.67	49.60
16	4 edge	do	1000 long. 1000 trans.	Stressteel	Polyester resin	NBS	0.68	31.50
20	4 edge	do	1000 long. 1000 trans.	Elastuff	Epoxy resin	NBS+	0.80	50.00
10	2 edge	Crisscross	1000 long. 1000 trans.	Stressteel	None	NBS	1.57	17.00
11	2 edge	do	1000 long. 1000 trans.	do	Neat cement	do	1.27	26.25
26	2 edge	do	1000 long. 1000 trans.	Elastuff	do	NBS+	1.21	41.20
19	2 edge	do	1000 long. 1000 trans.	Stressteel	Polyester resin	NBS	1.39	28.00
24	2 edge	do	1000 long. 1000 trans.	Elastuff	Epoxy resin	do	1.41	28.00
21	2 edge	do	1000 long. 1000 trans.	do	do	NBS+	1.23	45.90
29	2 edge	do	1000 long. 1000 trans.	do	Epoxy/Thiokol	do	1.34	42.20
17	2 edge	Crisscross	1000 long. 500 trans.	Stressteel	None	NBS	2.54	11.00
18	2 edge	do	1000 long. 500 trans.	do	Neat cement	do	1.40	24.30
27	2 edge	do	1000 long. 500 trans.	Elastuff	do	NBS+	1.24	40.20
15	2 edge	do	1000 long. 500 trans.	Stressteel	Polyester resin	NBS	1.58	17.60
22	2 edge	do	1000 long. 500 trans.	Elastuff	Epoxy resin	NBS+	1.30	42.00
12	2 edge	Aligned	1000 long. 500 trans.	Stressteel	None	NBS	2.32	13 10
13	2 edge	do	1000 long. 500 trans.	do	Neat cement	do	1.17	18.10
14	2 edge	do	1000 long. 500 trans.	do	Polyester resin	do	1.16	19.60
23	2 edge	do	1000 long. 500 trans.	Elastuff	Epoxy resin	NBS+	1.15	45.00
25	2 edge	Special ‡	1000 long. 1000 trans.	Elastuff	Grout	Pavement	1.41	20.75

* Blocks reinforced with 1/4-in. stirrups.
\+ Blocks reinforced with 1- by 1-in. - 15/15 weld wire fabric.
‡ See arrangement in figure 2.

Table 2. Index to instrumentation diagrams for slabs in this investigation.

Slab	Report	Figure
1	4396	3
2	4396	3
3	4396	3
4	4396	3
5	4951	3
6	disassembled	
7	4951	3
8	4951	3
9	4951	3 and 4
10	5212	3
11	5212	3
12	5212	3
13	5212	3
14	5212	3
15	5212	3
16	5212	4
17	5212	3
18	5212	3
19	5212	3
20	5714	5
21	5714	4
22	5714	4
23	5714	4
24	5714	4
25	5714	6
26	5714	4
27	5714	7 and 8
28	6321	5
29	6321	6

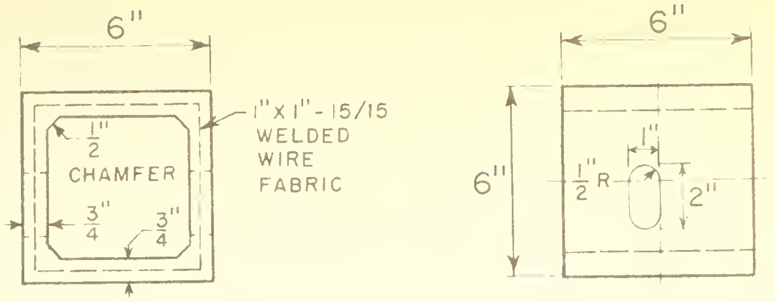
Table 3. Loss of strain in steel and concrete with time in Slab No. 3.

Condition of slab	Prestressing Tendons Nos.							
	1	2	3	4	5	6	7	8
Initial strain, 10^{-6} in./in. (slab on working platform)	1263	1291	1331	1264	1285	1299	1285	1300
Strain increment, 10^{-6} in./in. (slab simply supported 1 day)	0	+3	0	+4	+5	+3	+10	+5
Strain increment, 10^{-6} in./in. (slab simply supported 6 days)	-8	-13	-11	-12	-13	-2	-9	-3

Condition of slab	Gages on Concrete							
	1	2	3	4	5	6	7	8
Initial strain, 10^{-6} in./in. (slab on working platform)	312	375	334	332	245	385	253	274
Strain increment, 10^{-6} in./in. (slab simply supported 1 day)	+17	+6	+4	-6	+125	+241	+65	+100
Strain increment, 10^{-6} in./in. (slab simply supported 6 days)	+17	+20	+3	0	+17	+19	+15	+18

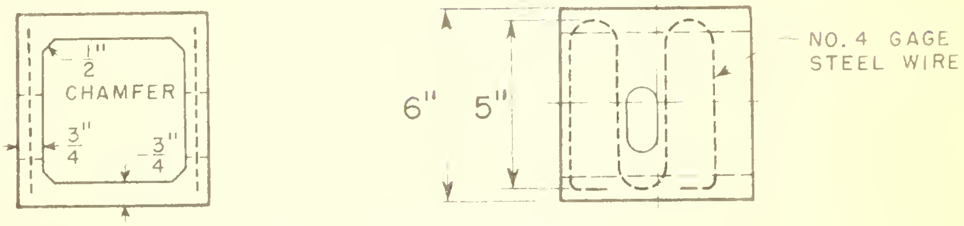
\+ indicates an increase in strain.

\- indicates a decrease in strain.

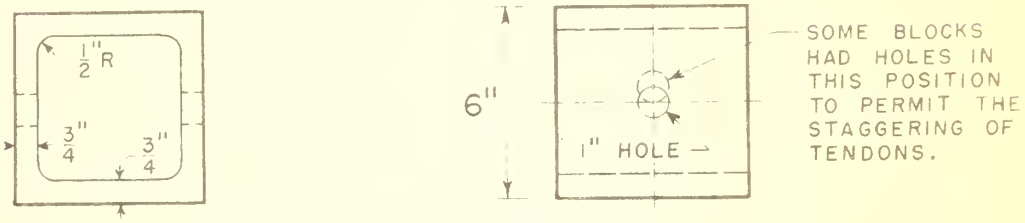


WELDED WIRE FABRIC

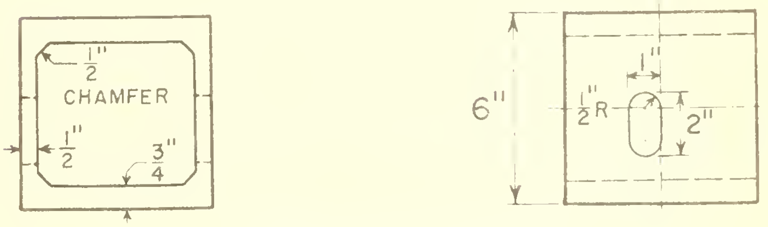
UNREINFORCED



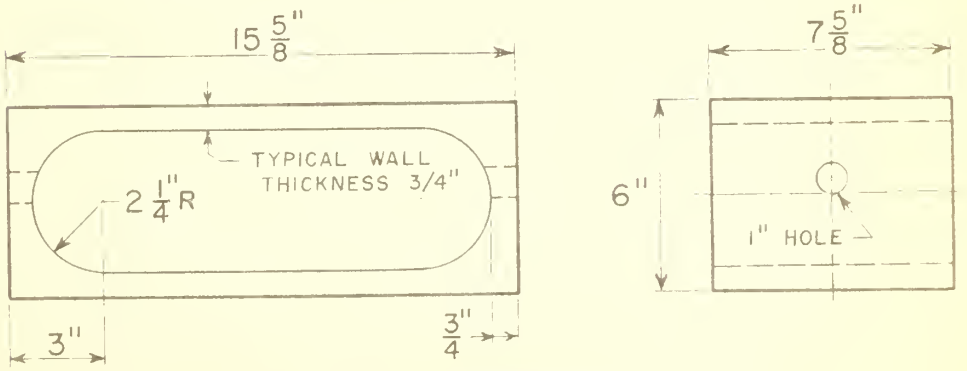
STIRRUP REINFORCED



CLAY TILE BLOCK



PRELOAD BLOCK



PAVEMENT BLOCK

FIGURE 1. DRAWING OF ALL BLOCKS USED IN TEST SERIES.

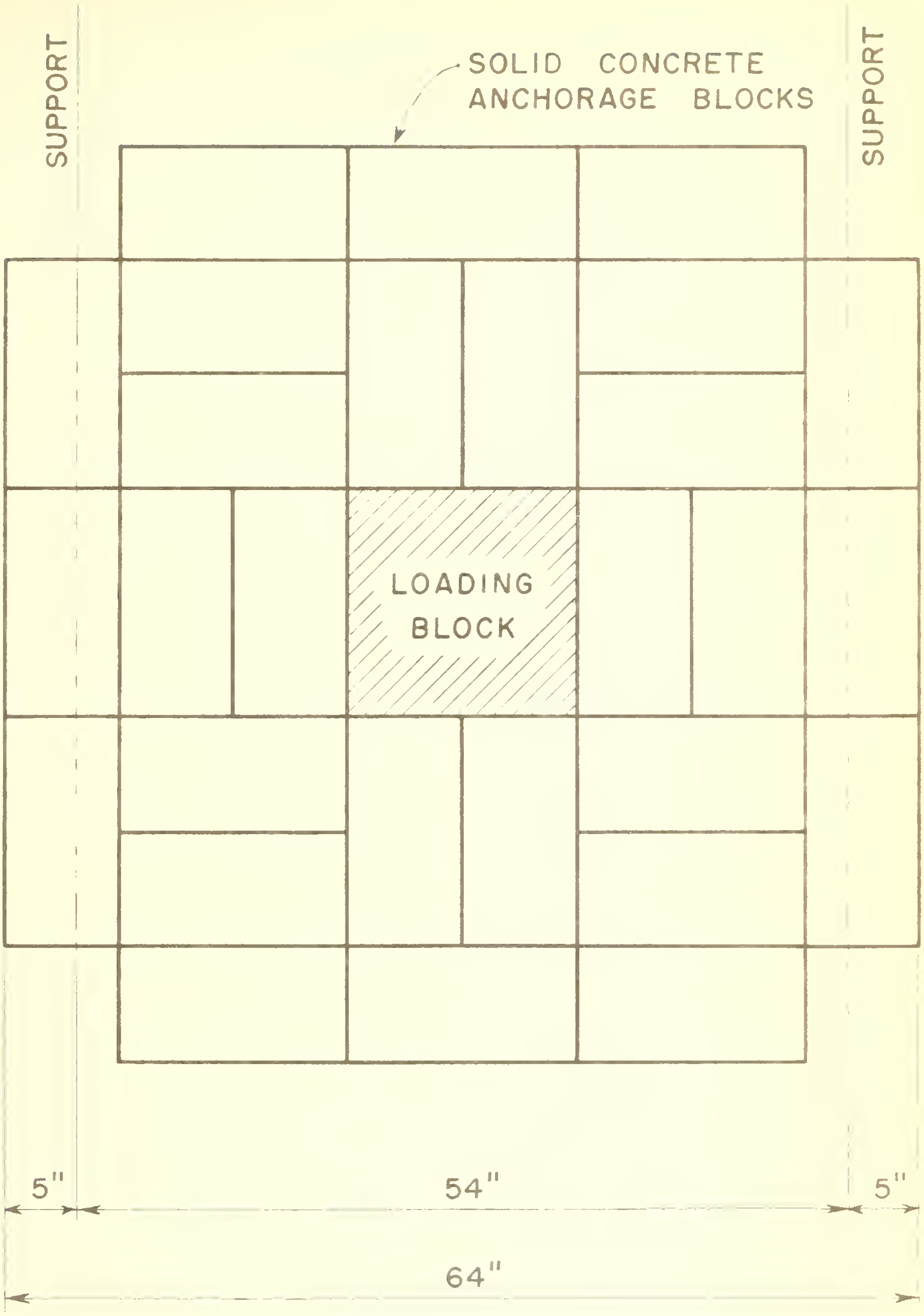


FIGURE 2. ARRANGEMENT OF PAVEMENT BLOCKS IN SLAB NO. 25

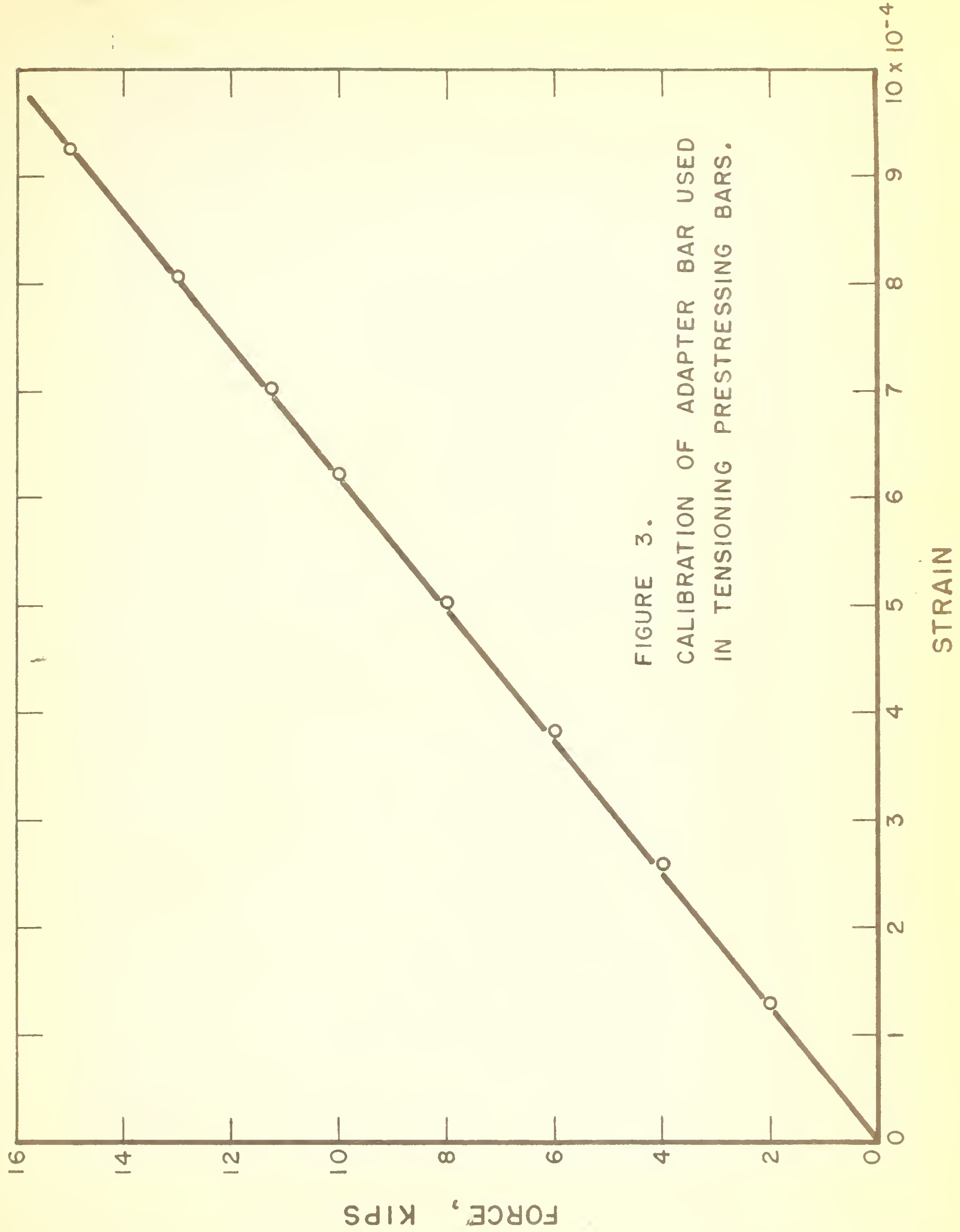


FIGURE 3.
CALIBRATION OF ADAPTER BAR USED
IN TENSIONING PRESTRESSING BARS.

FIGURE 3.

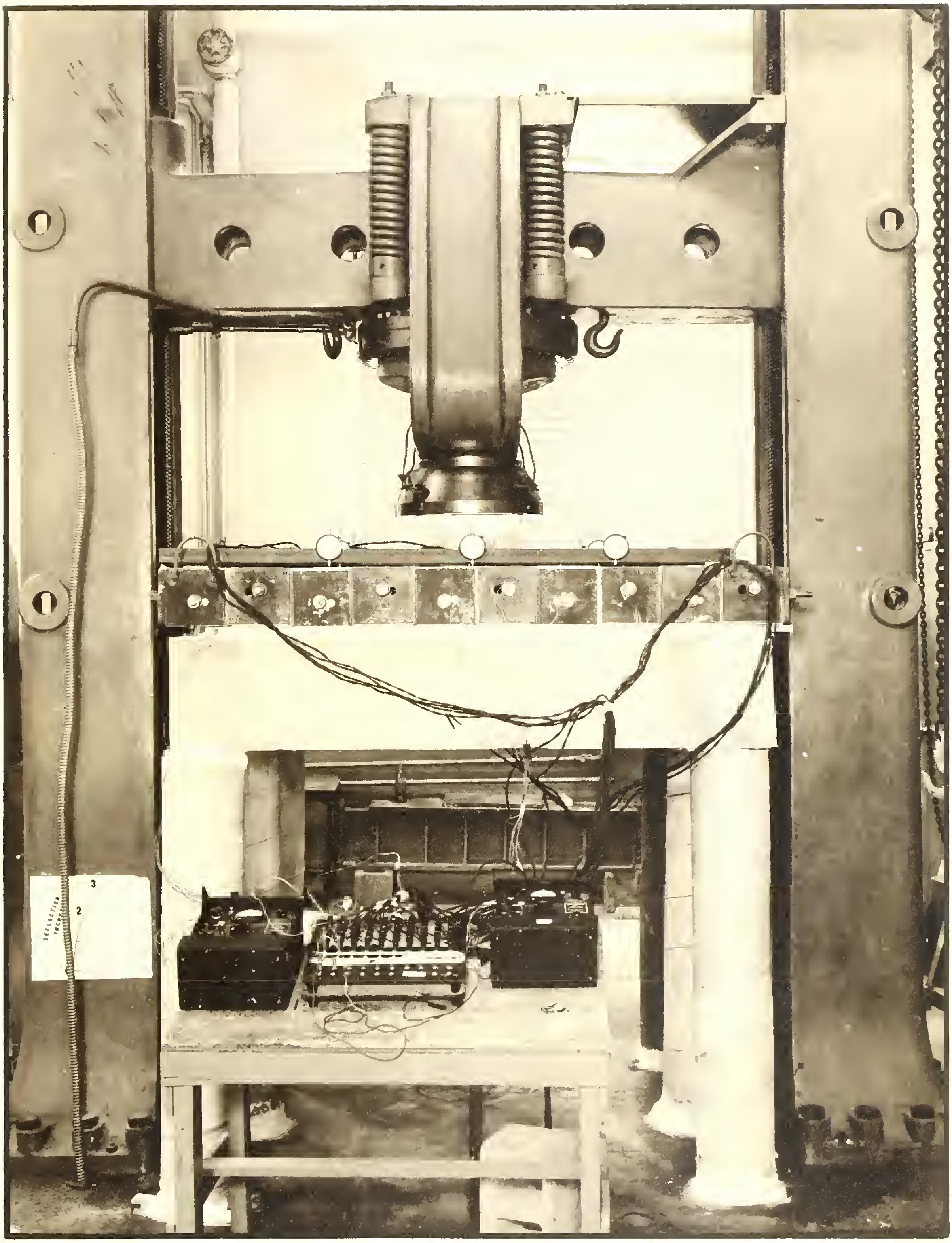
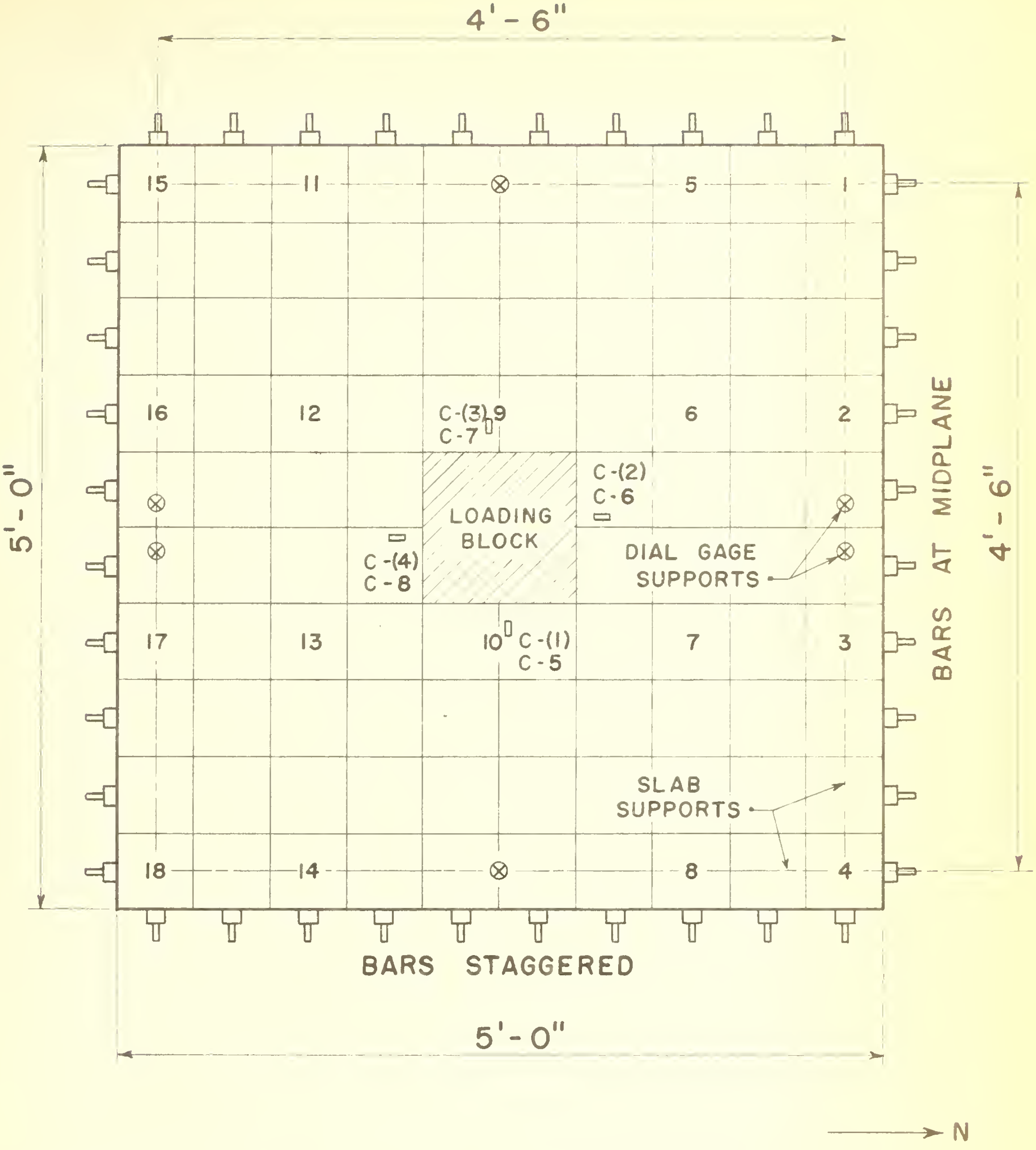


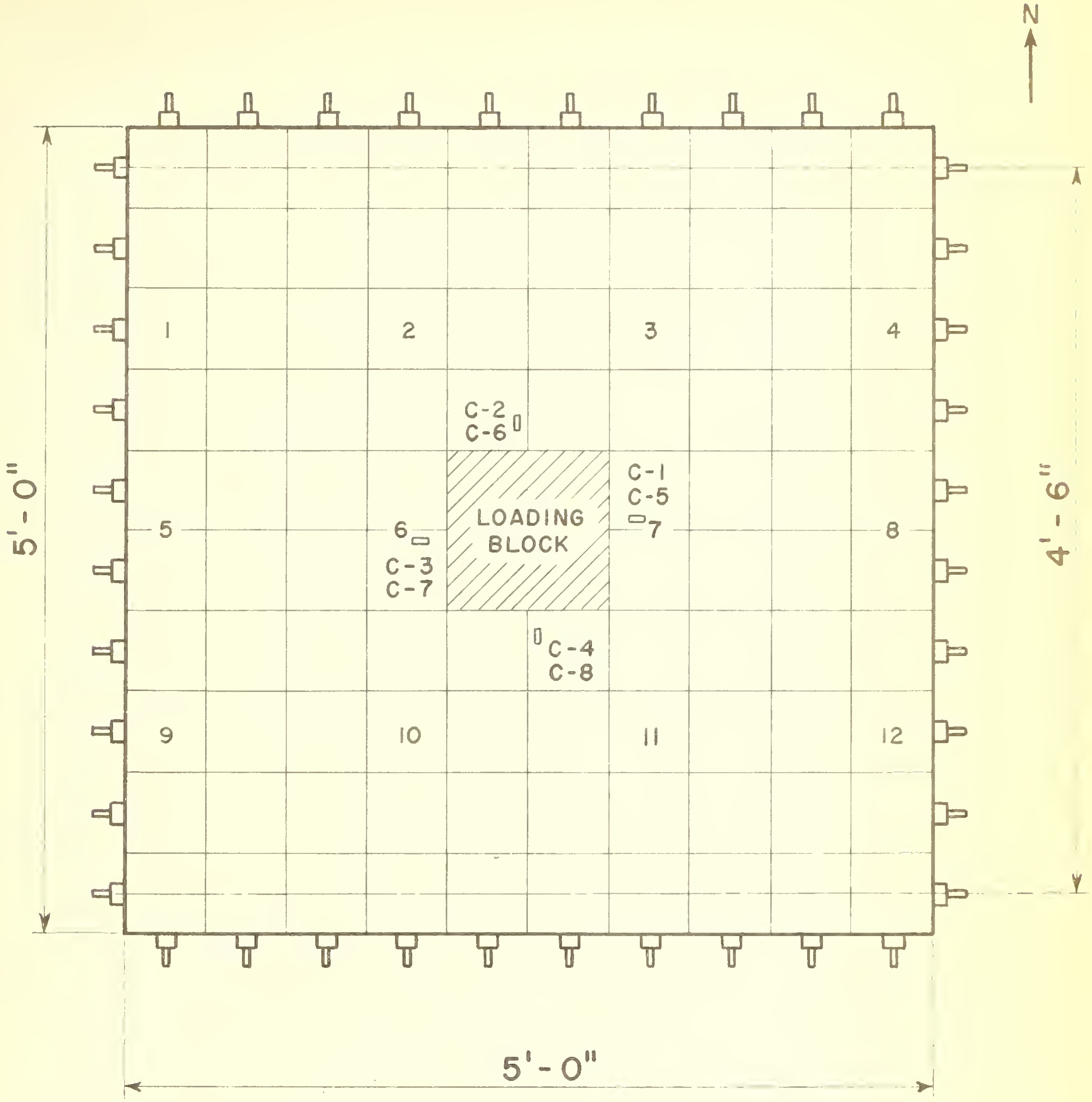
FIGURE 4. TEST SET-UP OF SLAB NO. 9 ON CONCRETE FRAME



LEGEND:

GAGES 1 THROUGH 18 INDICATE DIAL GAGES
C1 - C4 INDICATE SR-4 GAGES ON BOTTOM SURFACE OF SLAB
C5 - C8 " " " " TOP " " "

FIGURE 5. LOCATION OF DIAL GAGES AND STRAIN GAGES ON SLAB NO. 28 (SIMPLY SUPPORTED ON FOUR EDGES).



LEGEND:

GAGES 1 THROUGH 12 INDICATE DIAL GAGES
C1 - C4 INDICATE SR-4 GAGES ON BOTTOM SURFACE OF SLAB
C5 - C8 " " " " TOP " " "

FIGURE 6. LOCATION OF DIAL GAGES AND STRAIN GAGES ON SLAB NO. 29 (SIMPLY SUPPORTED ON TWO EDGES).

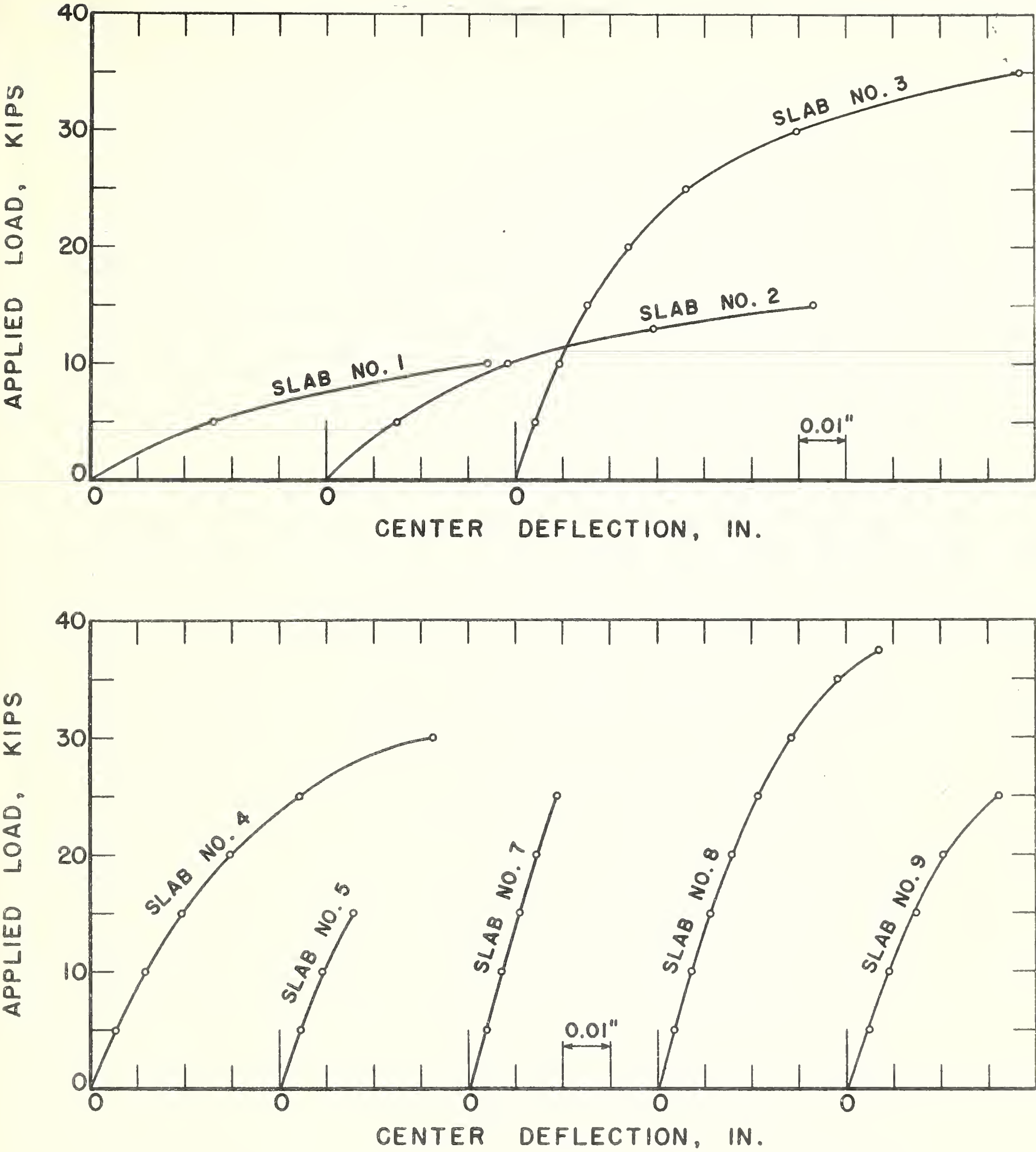


FIGURE 7. OBSERVED RELATIONSHIP BETWEEN APPLIED LOAD AND CENTER DEFLECTION OF SLABS.

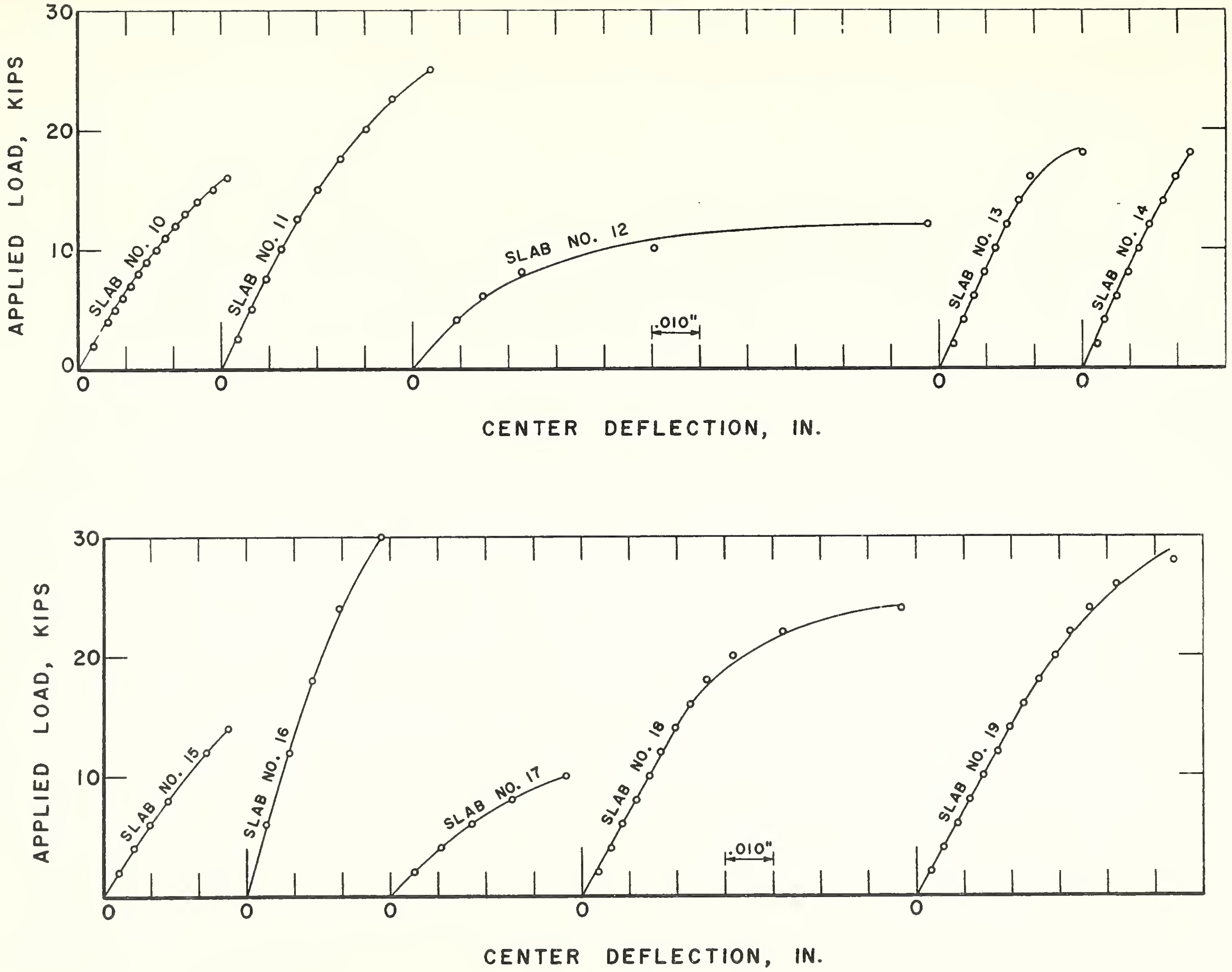


FIGURE 8. OBSERVED RELATIONSHIP BETWEEN APPLIED LOAD AND CENTER DEFLECTION OF SLABS.

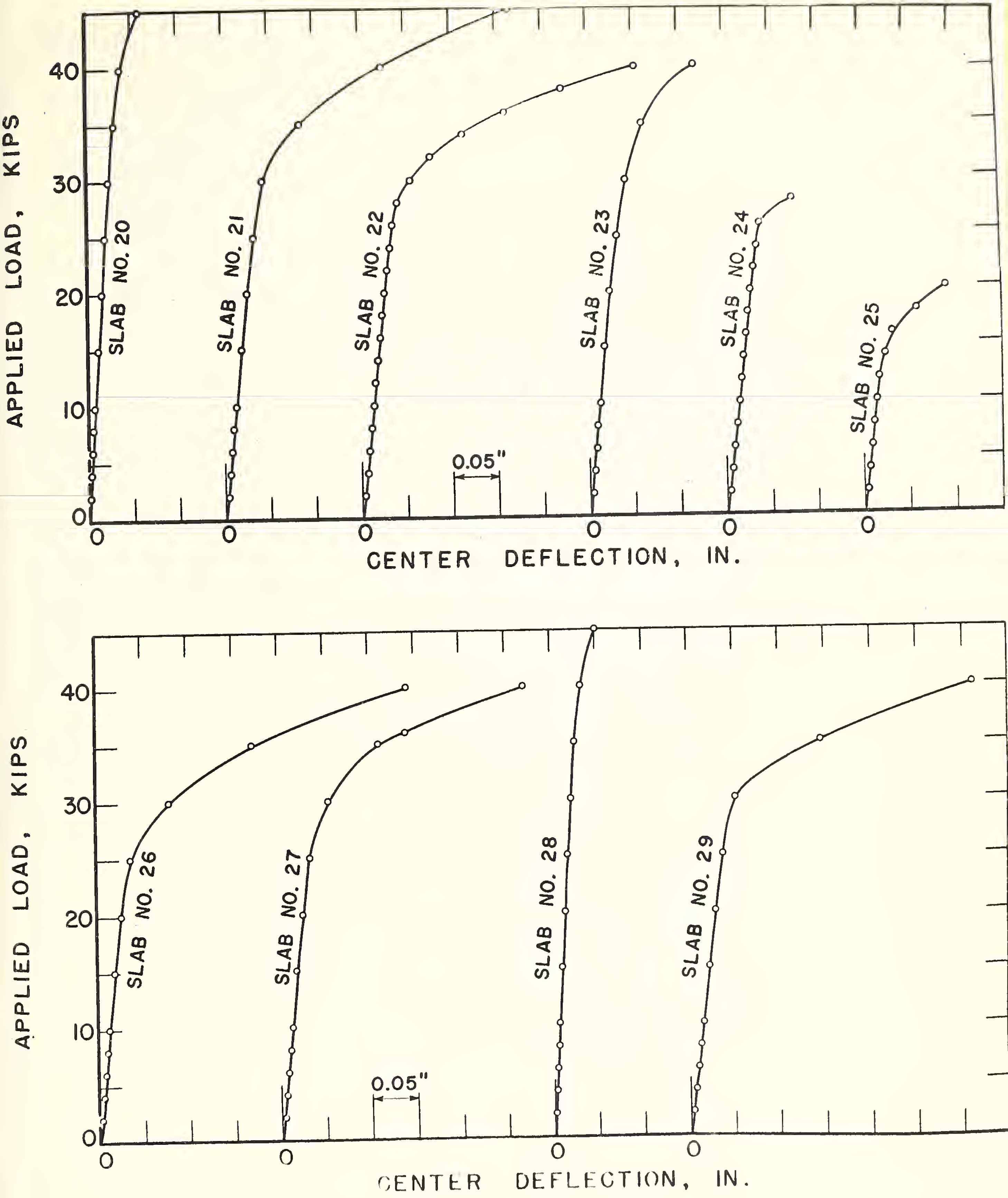


FIGURE 9. OBSERVED RELATIONSHIP BETWEEN APPLIED LOAD AND CENTER DEFLECTION OF SLABS.

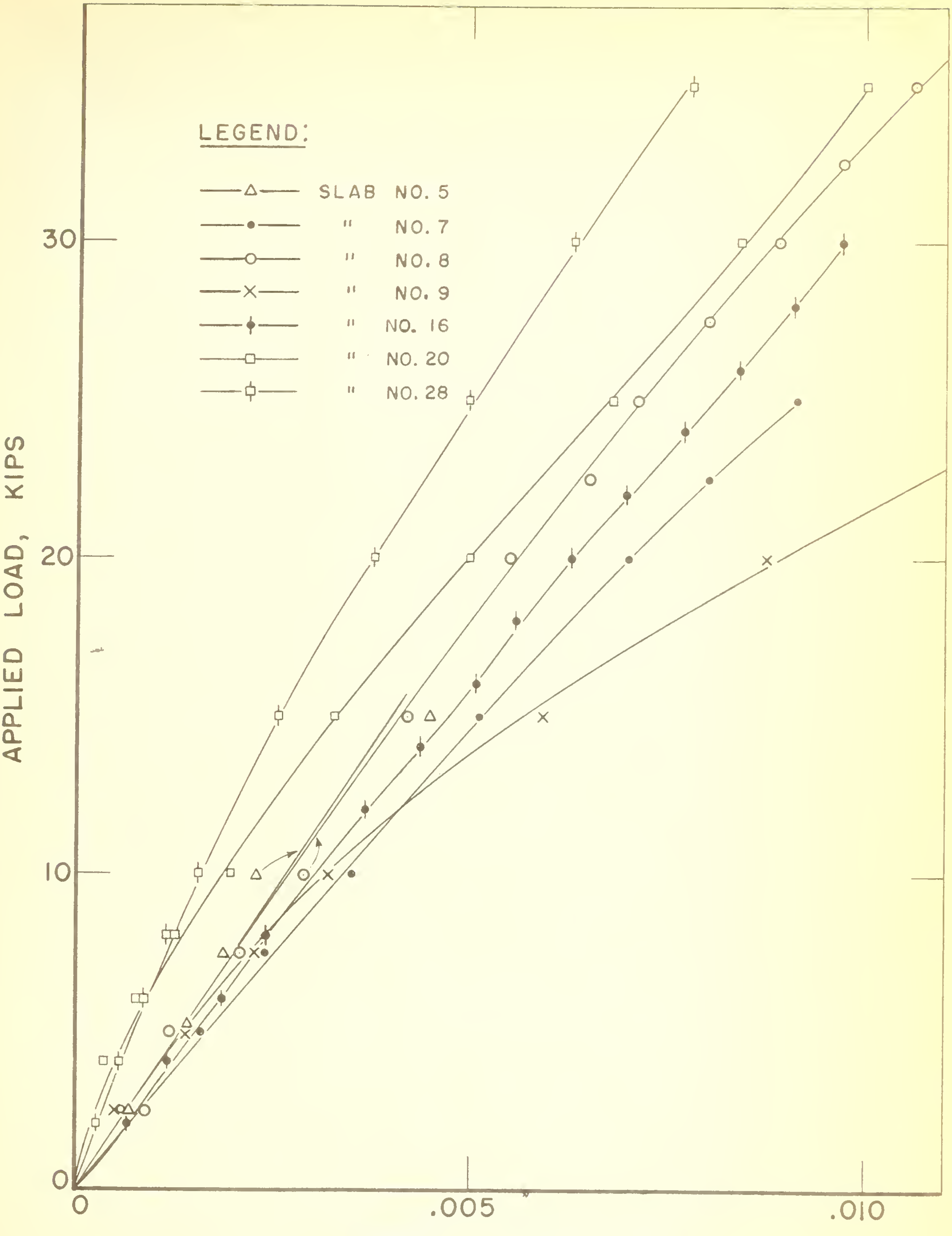


FIGURE 10. EXPERIMENTAL RELATIONSHIP BETWEEN APPLIED LOAD AND VERTICAL MOVEMENT OF CORNERS.

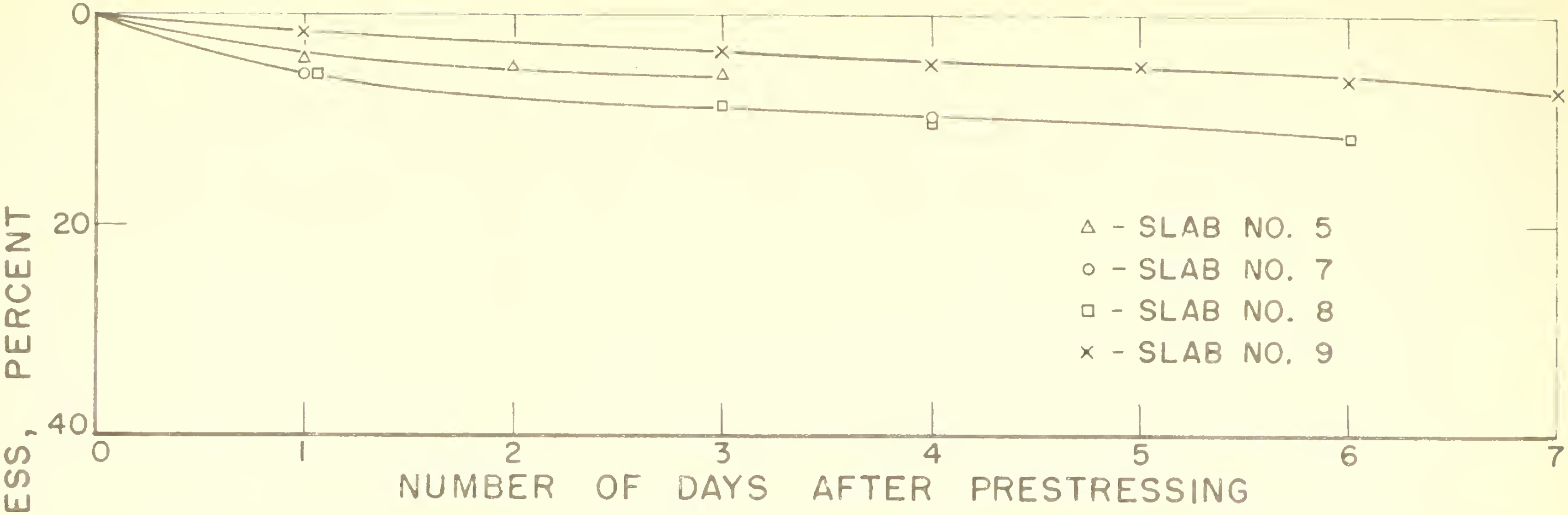


FIGURE 11. LOSS OF STRAIN IN PRESTRESSING TENDONS PRIOR TO TEST.

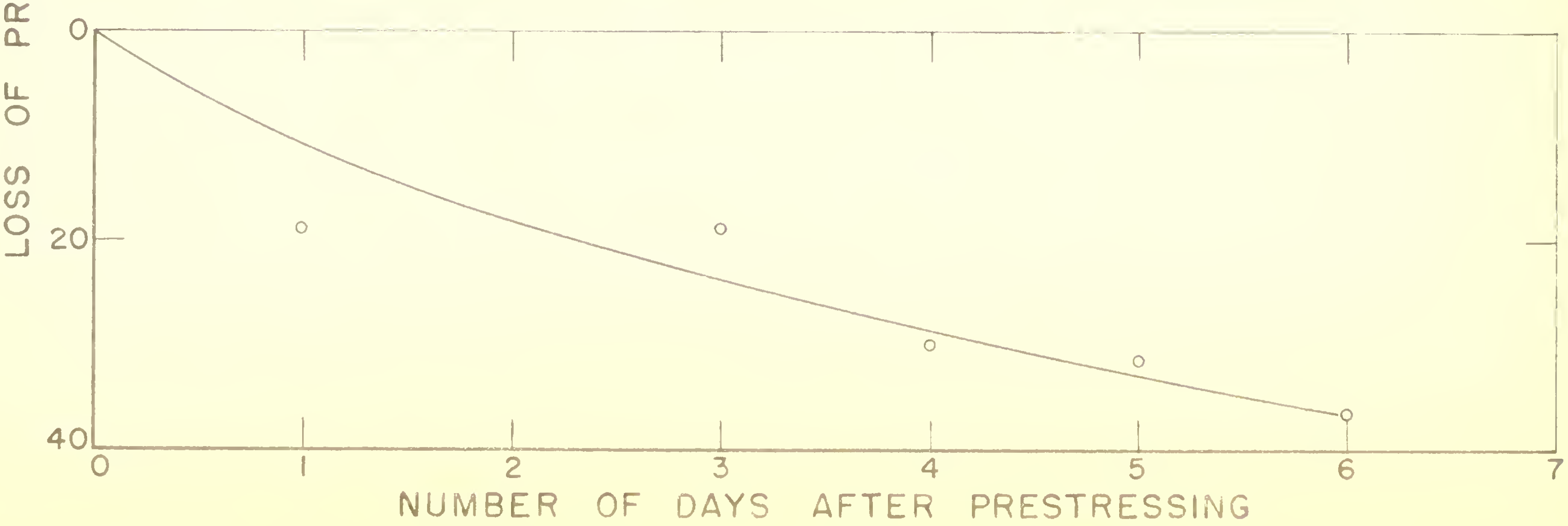


FIGURE 12. LOSS OF PRESTRESS IN CONCRETE OF SLAB NO. 5 PRIOR TO TEST.

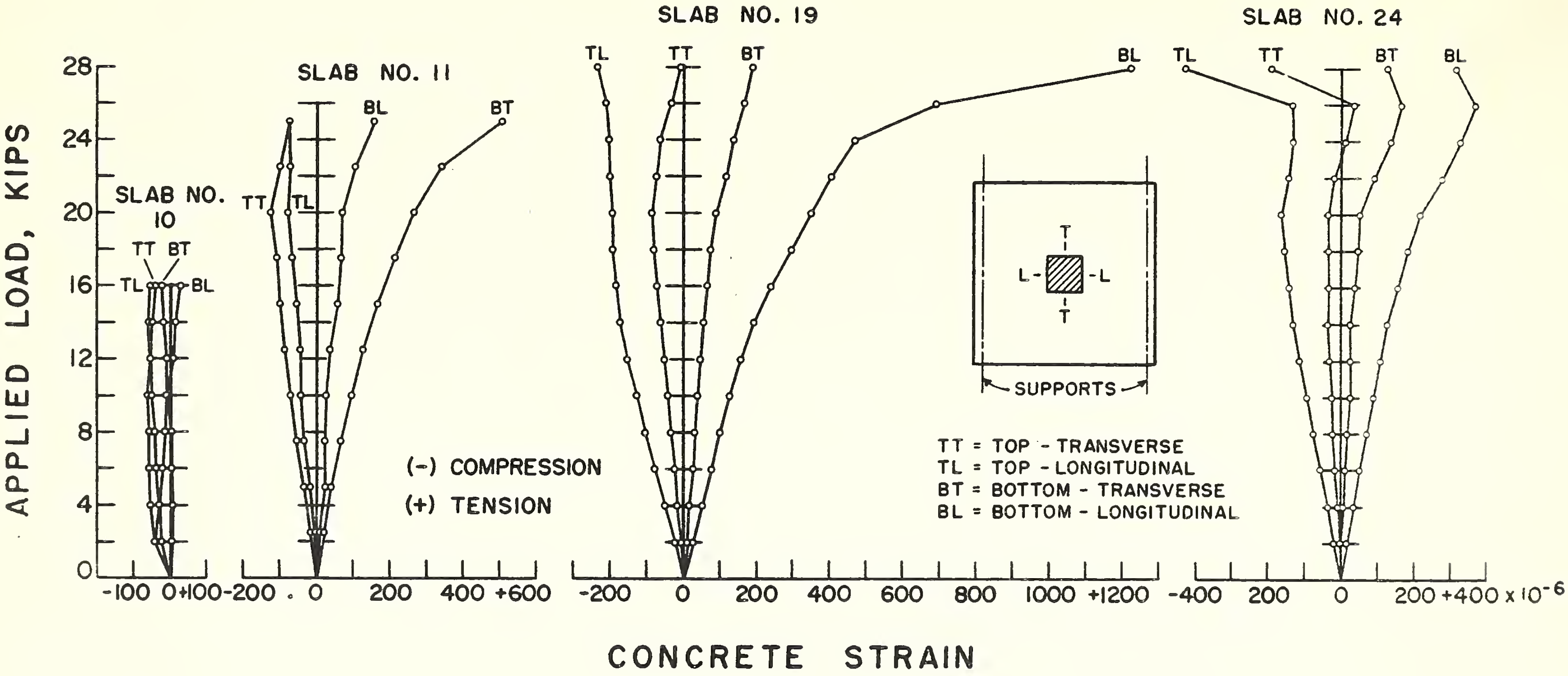


FIGURE 13. OBSERVED RELATIONSHIP BETWEEN APPLIED LOAD AND CONCRETE STRAIN.

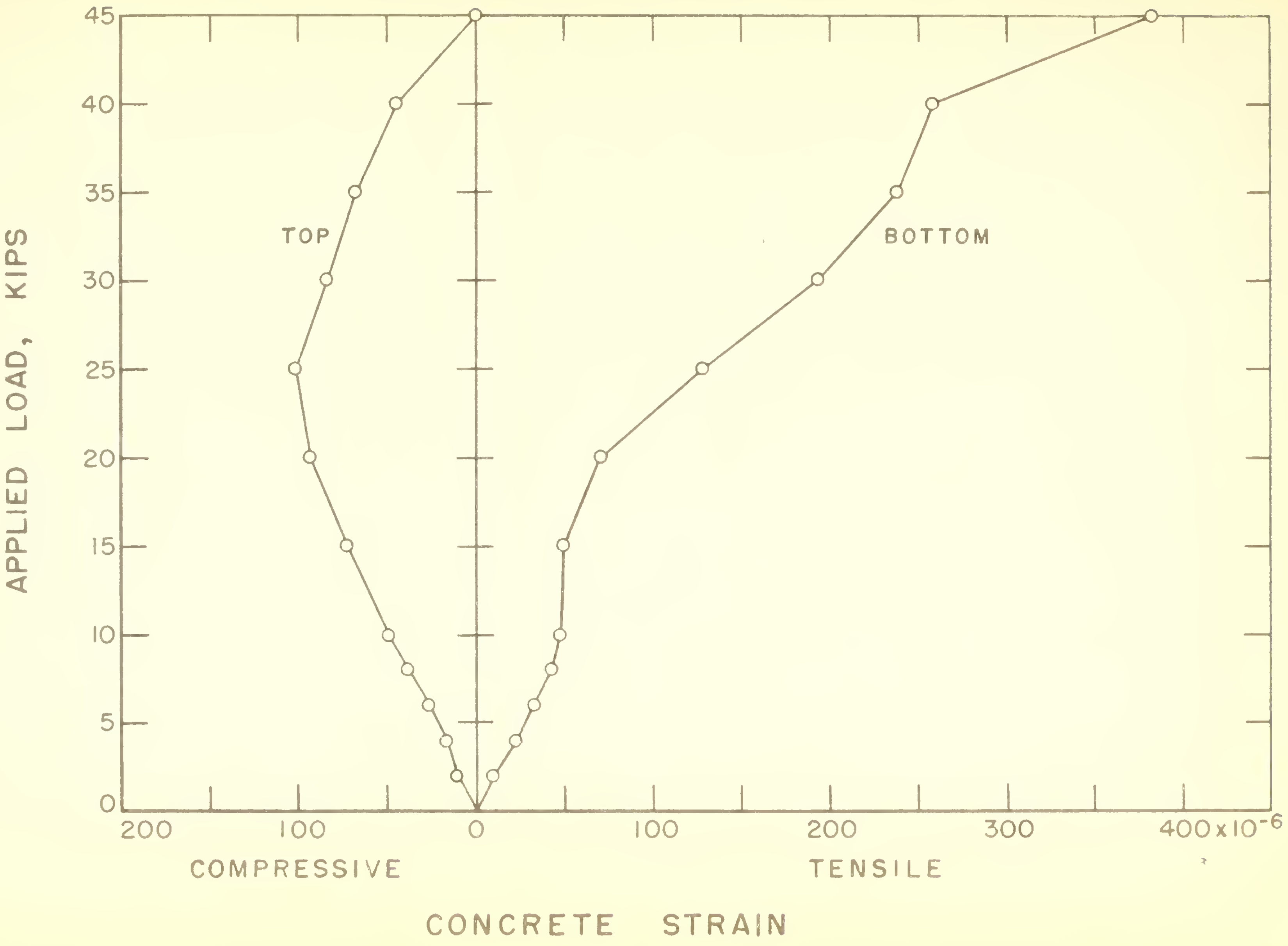


FIGURE 14. OBSERVED RELATIONSHIP BETWEEN APPLIED LOAD AND CONCRETE STRAIN (SLAB NO. 28 - NEAT CEMENT JOINTS).

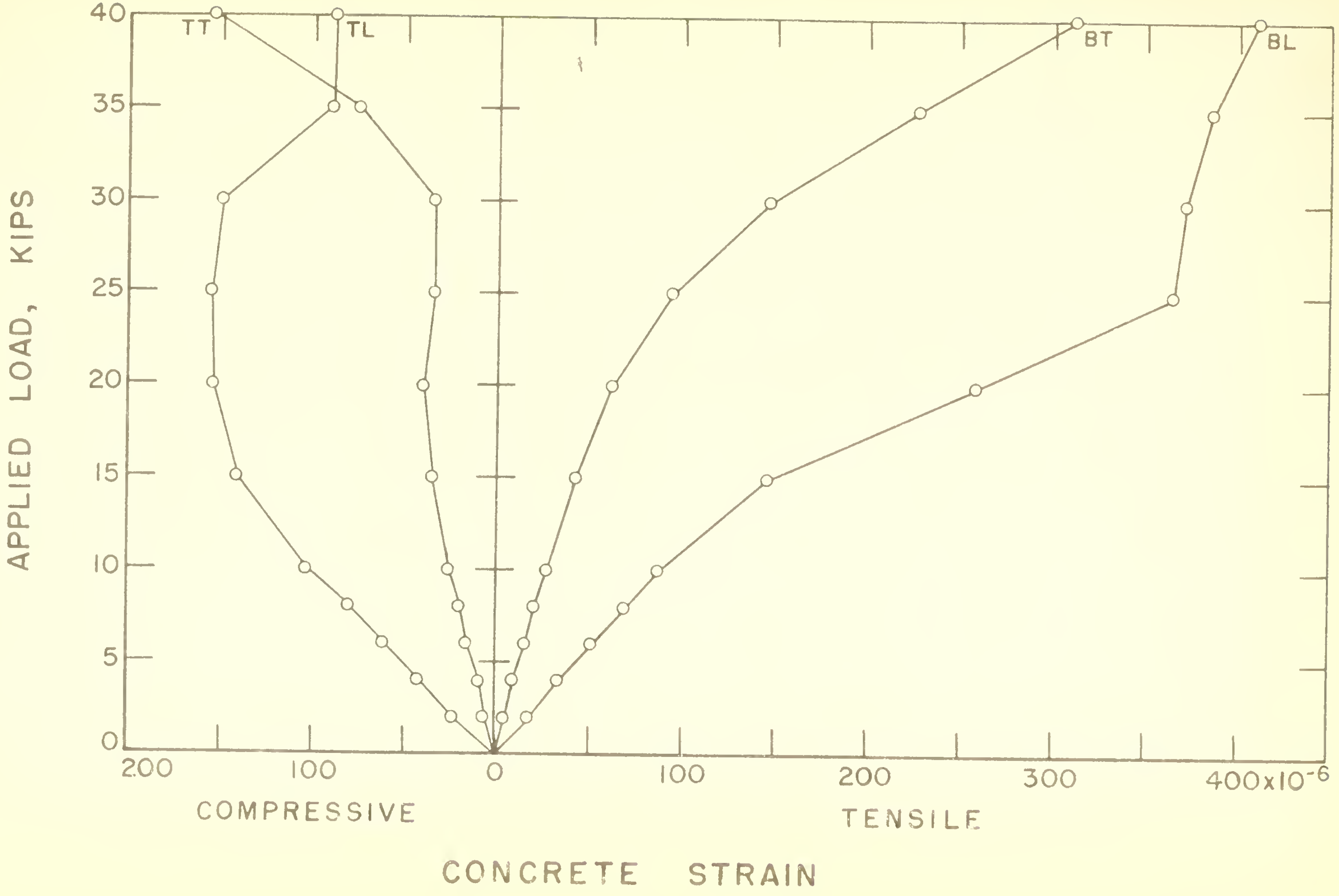


FIGURE 15. OBSERVED RELATIONSHIP BETWEEN APPLIED LOAD AND CONCRETE STRAIN (SLAB NO. 29 - EPOXY/THIOKOL JOINTS).

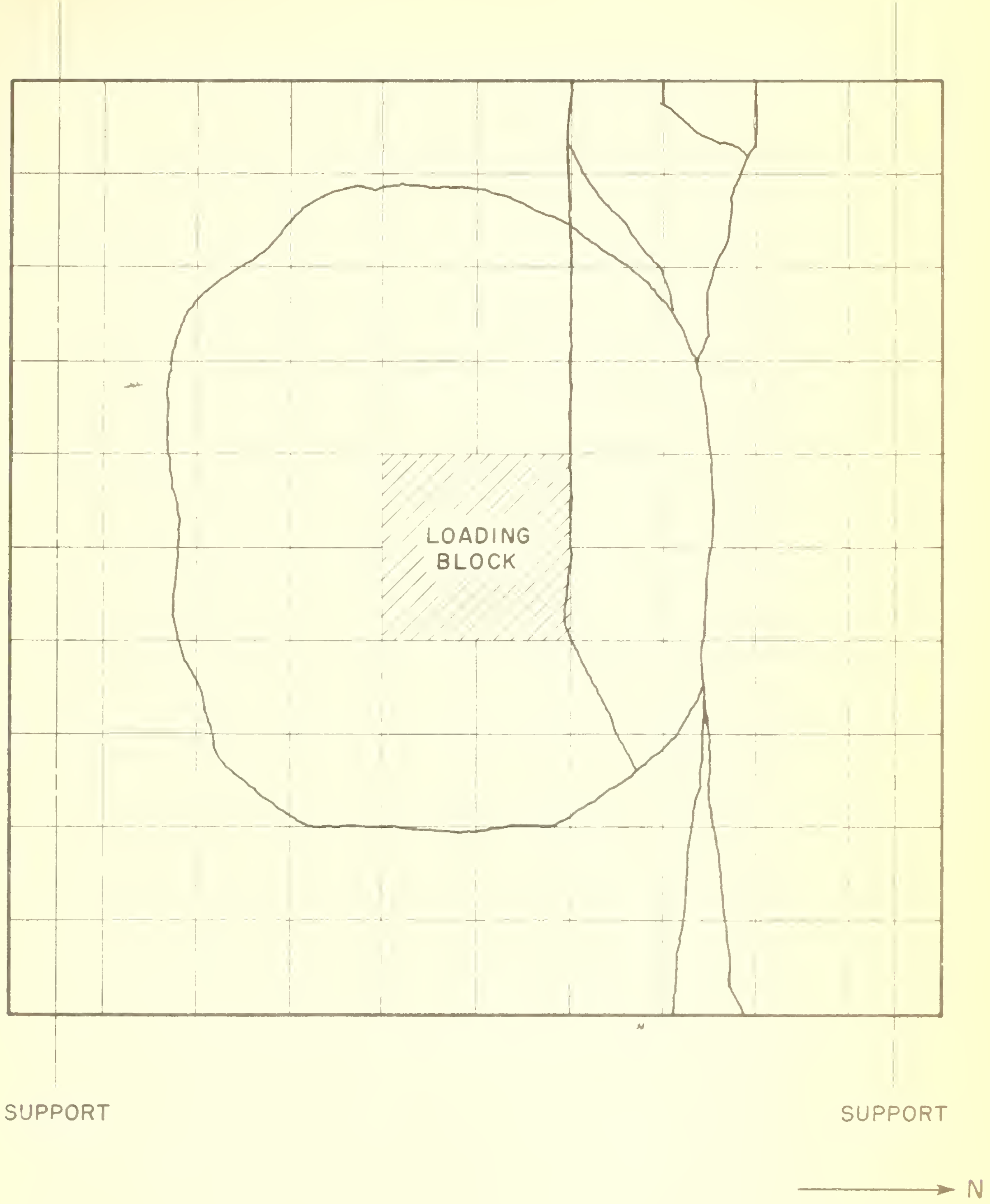


FIGURE 16. TOP VIEW OF CRACK PATTERNS IN SLAB NO. 24.

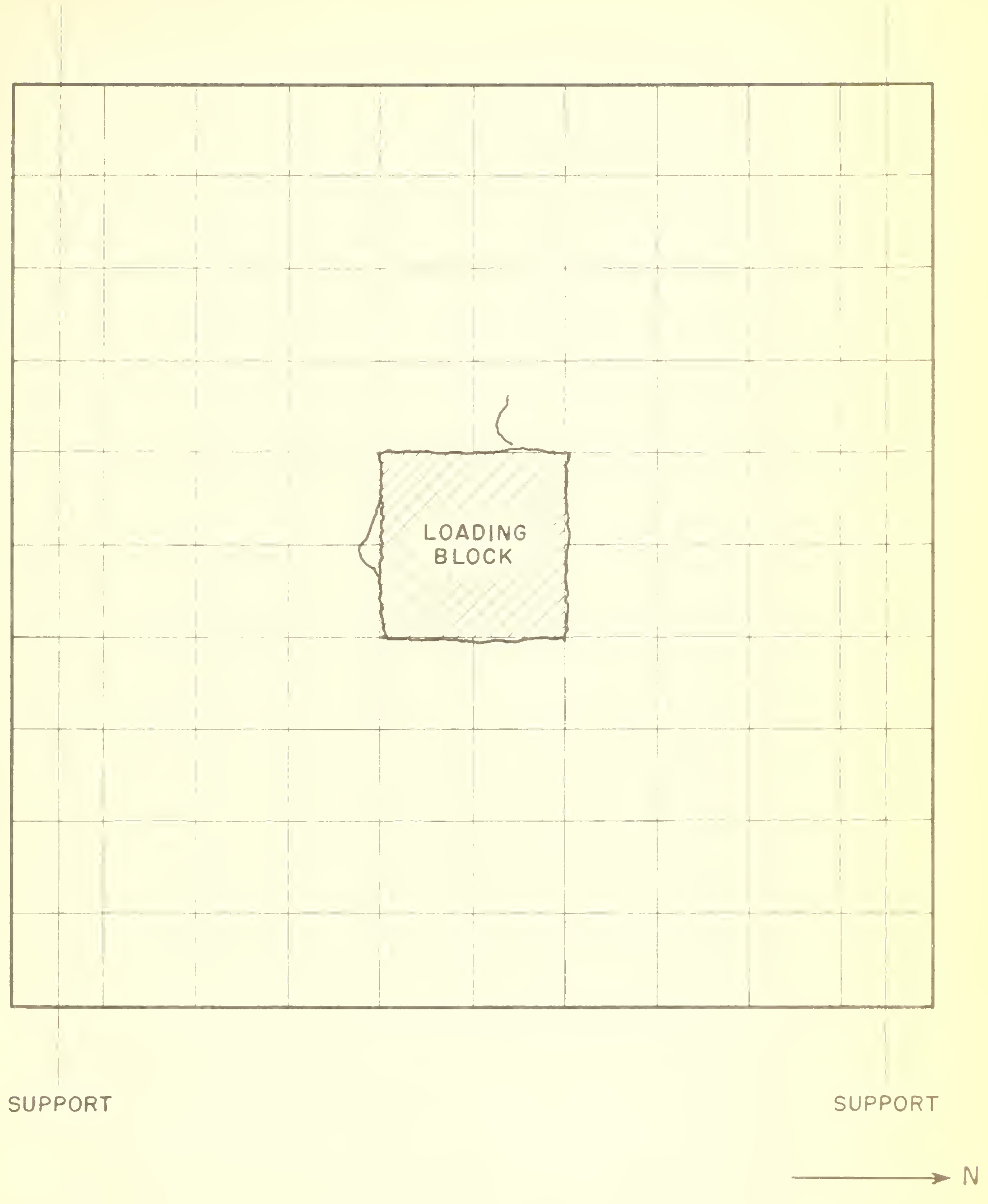


FIGURE 17. TOP VIEW OF CRACK PATTERNS IN SLAB NO. 27.

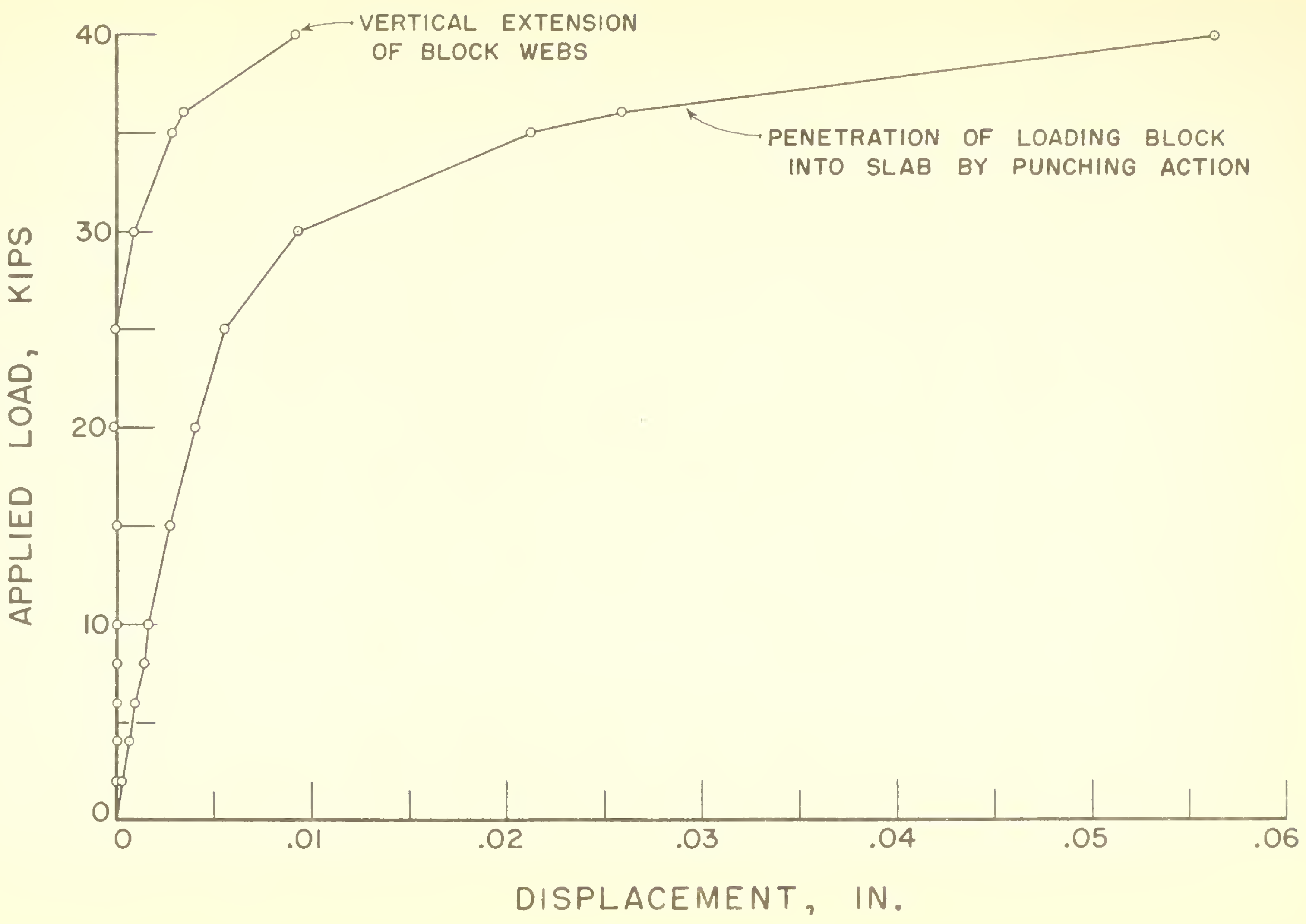


FIGURE 18. PENETRATION OF LOADING BLOCK INTO SLAB AND VERTICAL EXTENSION OF BLOCK WEBS, SLAB NO. 27.

U. S. DEPARTMENT OF COMMERCE
Lewis L. Strauss, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

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