NATIONAL BUREAU OF STANDARDS REPORT

3792

TEST OF PRECAST PRESTRESSED
ROOF PANEL NO. 3
(Type B)

by

L. F. Skoda, J. O. Bryson and D. Watstein

Report to
Bureau of Yards and Docks
Department of the Navy

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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NATIONAL BUREAU OF STANDARDS REPORT

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NBS REPORT 3792

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Abstract

A prestressed thin-shell roof panel 5- by 24-ft in plan was tested under a uniformly distributed load to determine its strength and stiffness. The panel was subjected to the load test twice. During the first test, a load of 70 lb/sq ft was applied in several increments. The longitudinal reinforcement began to yield at 70 lb/sq ft and the center deflection of the panel was 2.9 in. Upon removal of the load, the panel had recovered to within 0.19 in. of its initial position during the recovery period of about 18 hr. During the second load test, the specimen was again loaded in increments of 10 lb/sq ft until failure occurred at approximately 80 lb/sq ft.

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1. Introduction

The study of precast - prestressed concrete roof panels was initiated in the National Bureau of Standards at the request of the Bureau of Yards and Docks for the purpose of establishing design data for prestressed thin-shell ribbed panels of various cross-sections.

The following report presents the data obtained in the test of one prestressed roof panel of type B.

2. Description of Test Specimen

Construction of the test specimen was accomplished in accordance with the Bureau of Yards and Docks plans (Sketch A-2, May 18, 1953) and specifications. The 5- by 24-ft panel was essentially a thin slab stiffened by two edge beams and two transverse ribs. The longitudinal edge beams were 8-in. deep and 2-1/2 in. wide at the base. The outer surfaces of the edge beams were plumb; the inner surfaces tapered up at a slope of 1 1/2 in. in 8 in. and became an integral part of the slab. At a distance of 9 in. in from either end, there were two transverse ribs. The transverse ribs were 7 7/8 in. deep, 2-in. wide at the base and tapered up at a slope of 1-in. in 7 7/8 in. until they merged into the slab. The portion of the slab enclosed by the longitudinal beams and transverse ribs was 1-in. deep. At the two extremities of the panel, the slab was 3-in. deep.

The slab and the stiffening members were reinforced with 2- by 2 in. by 12 ga welded wire fabric. Each transverse rib also included two No. 4 deformed reinforcing bars, one at the top and one at the bottom, bent 6 in. into the longitudinal beams. These bars met the requirements of ASTM Specifications A 305-50T and A 15-50T for deformed reinforcing bars of intermediate grade. Each longitudinal edge beam contained one 1/2 in. Stressteel prestressing bar housed by 3/4-in. rigid conduit and placed in a parabolic curve (See figure 1).

3. Fabrication of Specimen and Description of Material

3.1 Forms

Since the prestressing bars were to be post-tensioned and the specimen had to be supported along its entire length prior to prestressing, the forms were constructed so as to permit stripping of the side surfaces of the longitudinal and transverse edge beams while continuing to support the base of the longitudinal beams. Wood trestles were used to elevate the forms to permit working beneath the specimen without moving it. The trestles were joined with 2-in. by 4-in. pieces of lumber and leveled with an engineer's level. The 2- by 4-in. struts were then grouted with Hydrocal to assure even bearing thereby eliminating deflections of the form under the weight of the concrete. Plywood was used for all cast surfaces of the specimen to assure smooth surfaces. The web of the specimen was supported with wedge shaped 2- by 6-in. pieces of

lumber spaced 14 in. on center. The wedges were cut so as to permit complete support of the web and inner surfaces of the edge beams. The outer surfaces of the edge beams were supported 14 in. on center.

3.2 Prestressing units

The prestressing units consisted of a 1/2 in. Stressteel bar of high tensile alloy steel, end anchorage components (bearing plates, nuts, washers) and the tensioning apparatus consisting of a hydraulic jack, adapter bar and bridge. The adapter bar and bridge were devised at the National Bureau of Standards and fabricated in the Bureau's shops from steel conforming to ASTM Specification A7-50T. A sample of the Stressteel bars was tested in tension in a 60,000 lb testing machine, and the ultimate tensile stress indicated was 167,000 psi.

3.3 Welded wire fabric

Two inches by 2-in. by 12 ga welded wire fabric, obtained from the American Steel and Wire Company was used to reinforce the web and edge beams of the specimen. The wire fabric met the requirements of ASTM Specification A185-37. One-half in. slab bolsters were used as support for the wire fabric.

3.4 Concrete

Proportions of the cement mix used were 1:2.47:2.02, by weight. The cement factor was seven bags per cu yd White Marsh, Maryland sand and pea gravel were used as fine and coarse aggregates. The pea gravel was passed through a 3/8 in. standard sieve to obtain 3/8 in. top size aggregate. High-early strength portland cement was used with calcium chloride (2 percent by weight of cement) to permit early stripping and prestressing. Five 5 cu ft batches of concrete were used with slumps varying from 2 in. to 5 1/2 in. The specimen was cured under wet burlap for four days, then air dried for three days to permit attachment of bonded wire strain gages. Ten standard 6 in. by 12 in. cylinders were cast and cured in a curing chamber until they were tested. Cylinder tests were performed during the time of prestressing and during the time of testing, with two cylinders tested in each case, and the average compressive strengths were 6,410 psi and 7,210 psi, respectively.

3.5 Prestressing technique

Prestressing was applied to the specimen 21 days after the concrete was placed. First the Stressteel bars were slipped into their respective conduits which were cast in each longitudinal edge beam of the specimen. The bars were then anchored at the ends opposite to the jacking point, as shown in figure 2. Dynamometers were inserted at the jacking points between the bearing plates and the prestressing apparatus. The dynamometers were used to control the load applied to the specimen. A close up view of the dynamometers and prestressing apparatus in place for prestressing is shown in figures 3 and 4. The bars were stressed in both edge beams simultaneously until a load of 18,500 lb was obtained. The jacks were released and the load immediately dropped to 17,200 lb. Twelve days later, the load had dropped to 16,800 lb. The Stressteel bars were then tensioned to 19,500 lb and the tension dropped to 19,200 lb immediately after the release of the jacks. This tension was maintained within a reasonable tolerance up to the time of test.

4. Testing Procedure

4.1 Test set-up

Eight days after the prestressing was applied, the specimen was placed on the testing piers by means of a lifting jig and a 3-ton bridge crane. Two by 2 1/2- by 3/4-in. bearing plates and 2 1/2-in. rollers 3/4-in. in dia were used to provide simple supports. The span length between supports was 22 ft 4 in. The specimen was mounted on the testing piers by lowering the bridge crane and positioning one end accurately in place with the other end coming to rest on 5 ton hydraulic jacks and lowered gently into place. Hydrocal was used between all bearing surfaces to assure complete bearing of the specimen.

4.2 Method of loading

Water was used to apply the uniform load to the specimen during test. Since large deflections were anticipated, it was felt that the use of a single tank would cause too uneven a distribution of the water at large deflections. Therefore, four individual 5- by 6-ft tanks 2 ft deep were used to minimize the concentration of load near the center of the panel. The tanks were made of No. 8 treated duck and were coated with a fatty acid pitch material to make them watertight. The tanks were loaded simultaneously and at the same rate. The total

quantity of water entering the tanks was measured with individual water meters. Figure 5 shows the overall view of the test set up with the water tanks in place.

4.3 Instrumentation

Deflections of the slab under load were measured with 0.001 in. micrometer dial gages and taut-wire mirror-scale devices. During the load test, the dial gages were located on the underside of the slab at the same points at which measurements were taken on the top of the slab during the prestressing. Four dial gages were placed across the center cross-section of the span and four were placed at both ends over the supports. Taut-wire mirror-scale gages were located on the outside of the edge beams of the center section and quarter point sections of the span. An overall view of the location of the gages is shown in figure 5.

Bonded wire strain gages were placed longitudinally on the specimen on top and bottom of the slab. A total of 16 gages were used to measure strain in the concrete. All strain gages were located across the center section of the specimen. The location of strain gages, dial gages and the mirrored scales is shown in figure 6.

4.4 Description of test

The specimen was loaded in increments of 10 lb/sq ft and readings of all gages were recorded after each loading. The first noted crack occurred in the center section of the east edge beam at 50 lb/sq ft. The specimen was loaded to 70 lb/sq ft and that load was maintained for 1 1/2 hr at which time an additional set of readings of the gages was recorded. (See figure 7). The load was then removed from the specimen by siphoning the water from the tanks. The center section of the specimen recovered to within 0.2 in. of its original position and the tensile cracks closed up. Figure 9 shows the same crack as figure 8 with the load removed. The next day, the specimen was reloaded and additional measurements were recorded.

It is noted here that the micrometer dial gages at the center section had to be removed before the 70 lb/sq ft load was reached due to excessive deflections of the slab and the readings obtained from them was later eliminated because of inconsistencies.

5. Test Results

The observations made during the prestressing operations included the measurement of tension in the prestressing units by means of dynamometers, the strain on the surface of the concrete at the transverse center section of the specimen and the deflections at the center and quarter points of each edge beam. The variation of the strain with the tension in the prestressing units is shown in figures 10 and 11; the tensioning loads are shown plotted in figure 12 against the average values of strains representing pairs of corresponding gages arranged symmetrically about the longitudinal axis of the panel. The maximum value of prestress observed at a point 1/2 in. above the bottom of the edge beam during the initial prestressing was 150 x 10^{-6} in./in., or about 750 psi, at a tension of 19 kips. The maximum stress at the outermost fiber was estimated to be about 800 psi at the bottom of the edge beam and about 150 psi at the top.

The relationship between the tensioning force and the strain in the edge beam was fairly linear up to about 12 kips. Above that load, the strain at the bottom of the edge beam increased more rapidly with the tensioning force, while the strain at the top reached its peak value at a load of 14 kips and decreased from then on. It is noted that the relationship between the tensioning force and the deflection at the center shows substantial linearity up to about 12 kips, and a sharp increase in deflection at a tensioning force over 18 kips. (See figure 13). As might be expected, at the quarter points the force - deflection relationship was linear up to about 17 kips but the same sharp increase in deflections was observed at a tensioning force of 18 kips.

The load test was conducted over a period of two days (April 29 and 30, 1954). On the first day, at the design load of 20 lb/sq ft, a deflection of 0.21 in. was observed at the center section and at a load of 40 lb/sq ft a deflection of 0.48 in. was noted. At those loads, the tension in the prestressing units increased over the initial value by 0.5 and 2.9 percent, respectively. (See figures 14 and 15). No cracks were observed until a load of 50 lb/sq ft was applied and the deflection of the center section at that load was 0.89 in. At 70 lb/sq ft the steel began to yield with the center deflection being 2.9 in. The specimen continued to deflect under this load and the deflection increased to 3.07 in. after 1 1/2 hr, at which time the load was removed. Prior to applying the

load the following morning it was observed that the center section of the panel had recovered to within 0.19 in. of its initial position, and the tension in the prestressing units was on the average 2000 lb less than at the outset of the test.

The distribution of strain in the edge beams was observed during the first application of load. As can be seen in figure 16, the distribution was quite linear up to a load of 30 lb/sq ft and was only slightly curvilinear up to a load of 40 lb/sq ft. Although the first crack was observed at a load of 50 lb/sq ft, it is probable that cracks too fine to be seen formed soon after the application of the load of 40 lb/sq ft. The maximum observed tensile strain at that load was 380×10^{-6} in./in., and recalling the fact that the prestressing strain was 150×10^{-6} in./in., we may conclude that the actual tensile strain at the bottom of the edge beam at a load of 40 lb/sq ft was about 230×10^{-6} in./in., a value having an order of magnitude of extensibility of concrete in flexure.

On the second day of test, the specimen was again loaded in increments of 10 lb/sq ft until failure occurred at approximately 80 lb/sq ft. The variation of the tension in prestressing units with the applied load is shown in figure 17, and the load-deflection relationship is shown in figure 18. The deflections of the specimen at the center section and the quarter points were substantially the same during the second load test as in the first one, up to the design load of 20 lb/sq ft. However, for higher loads the deflections in the second load test were significantly greater than those in the first load test. The increases in the deflections during the second test were 115 percent, 55 percent and 26 percent at loads of 40, 60 and 70 lb/sq ft, respectively.

The primary cause of failure was yielding of the longitudinal reinforcement accompanied by compressive failure at the top of the edge beams and the adjacent portion of the slab. The view of the panel at failure is shown in figure 20 and a close-up of the edge beam is shown in figure 21. The same section of the edge beam after the load was removed is shown in figure 22. It can be seen that fracture occurred in the welded wire reinforcement at that section. An overall view of the specimen after removal of the load is shown in figure 23. The maximum observed deflection of the panel at

center was about 8.2 in., and at that point the panel was temporarily blocked-up to prevent its complete collapse. Upon removal of the load, the panel recovered to within 1.45 in. of its initial position.

The crack pattern observed during the test and after removal of the load is shown in figure 24. It will be seen that tensile cracks developed at the edge beams within approximately the middle half of the span and that longitudinal tensile cracks appeared on the top surface of the slab just inside and parallel to the edge beams. A similar tensile crack, not shown in figure 24, was observed along the longitudinal center line at the bottom of the slab.

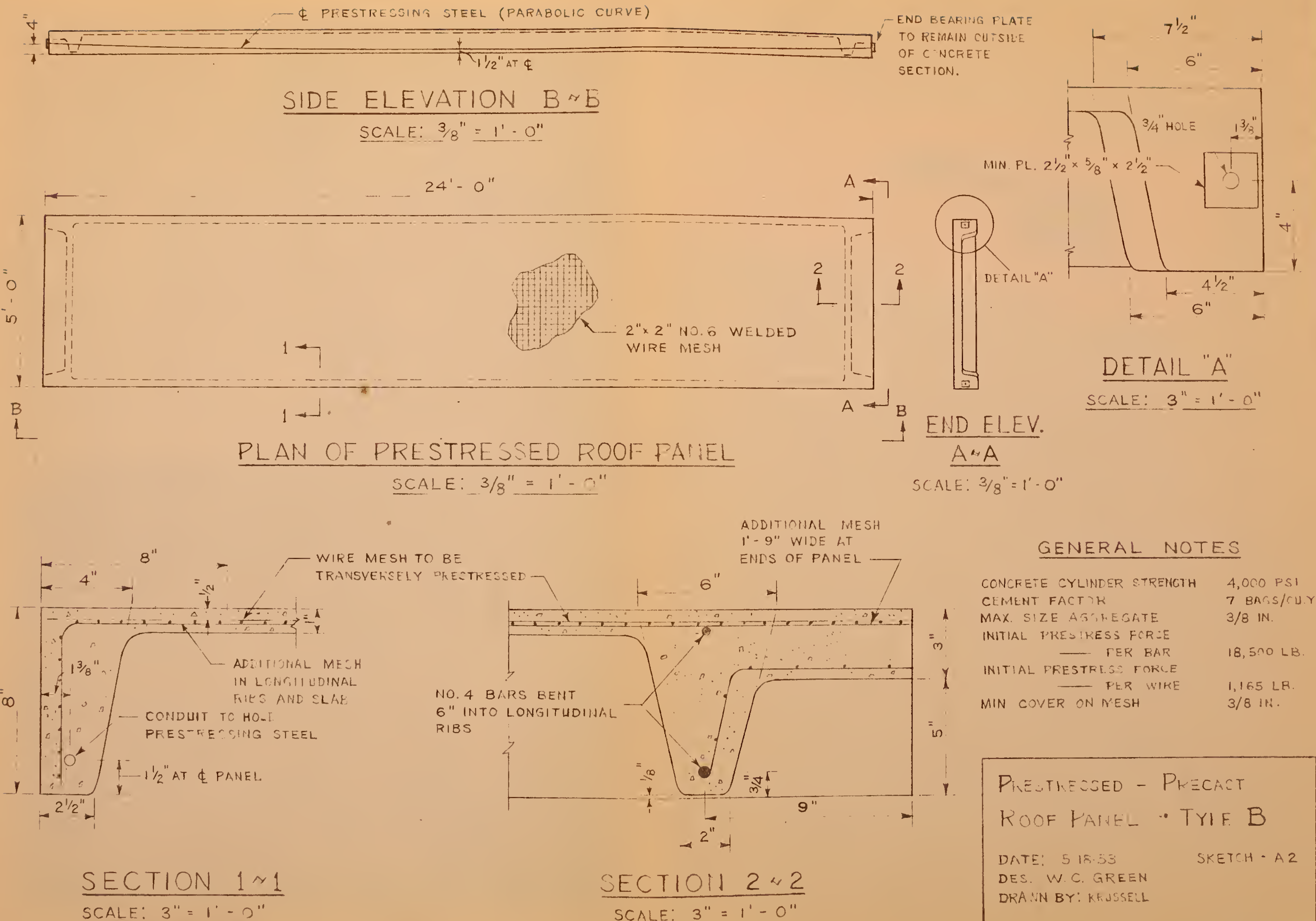
℄ PRESTRESSING STEEL (PARABOLIC CURVE)
END BEARING PLATE TO REMAIN OUTSIDE OF CONCRETE SECTION.
4"
1½" AT ℄
SIDE ELEVATION B~B
SCALE: 3/8" = 1'-0"
24'-0"
5'-0"
2"x 2" NO. 6 WELDED WIRE MESH
PLAN OF PRESTRESSED ROOF PANEL
SCALE: 3/8" = 1'-0"
DETAIL "A"
END ELEV. A~A
SCALE: 3/8" = 1'-0"
7½"
6"
¾" HOLE
1⅜"
MIN. PL. 2½" x ⅝" x 2½"
4"
4½"
6"
DETAIL "A"
SCALE: 3" = 1'-0"
8"
4"
½"
WIRE MESH TO BE TRANSVERSELY PRESTRESSED
ADDITIONAL MESH IN LONGITUDINAL RIBS AND SLAB
1⅜"
CONDUIT TO HOLD PRESTRESSING STEEL
1½" AT ℄ PANEL
2½"
SECTION 1~1
SCALE: 3" = 1'-0"
ADDITIONAL MESH 1'-9" WIDE AT ENDS OF PANEL
6"
NO. 4 BARS BENT 6" INTO LONGITUDINAL RIBS
3"
5"
⅞
¾
9"
2"
SECTION 2~2
SCALE: 3" = 1'-0"
GENERAL NOTES
CONCRETE CYLINDER STRENGTH 4,000 PSI
CEMENT FACTOR 7 BAGS/CU.YD.
MAX. SIZE AGGREGATE 3/8 IN.
INITIAL PRESTRESS FORCE — PER BAR 18,500 LB.
INITIAL PRESTRESS FORCE — PER WIRE 1,165 LB.
MIN COVER ON MESH 3/8 IN.
PRESTRESSED - PRECAST ROOF PANEL - TYPE B
DATE: 5-18-53
SKETCH - A2
DES. W. C. GREEN
DRAWN BY: KRUSSELL

FIG. 1

Fig. 2 - Close-up view of anchorage of prestressing bar.

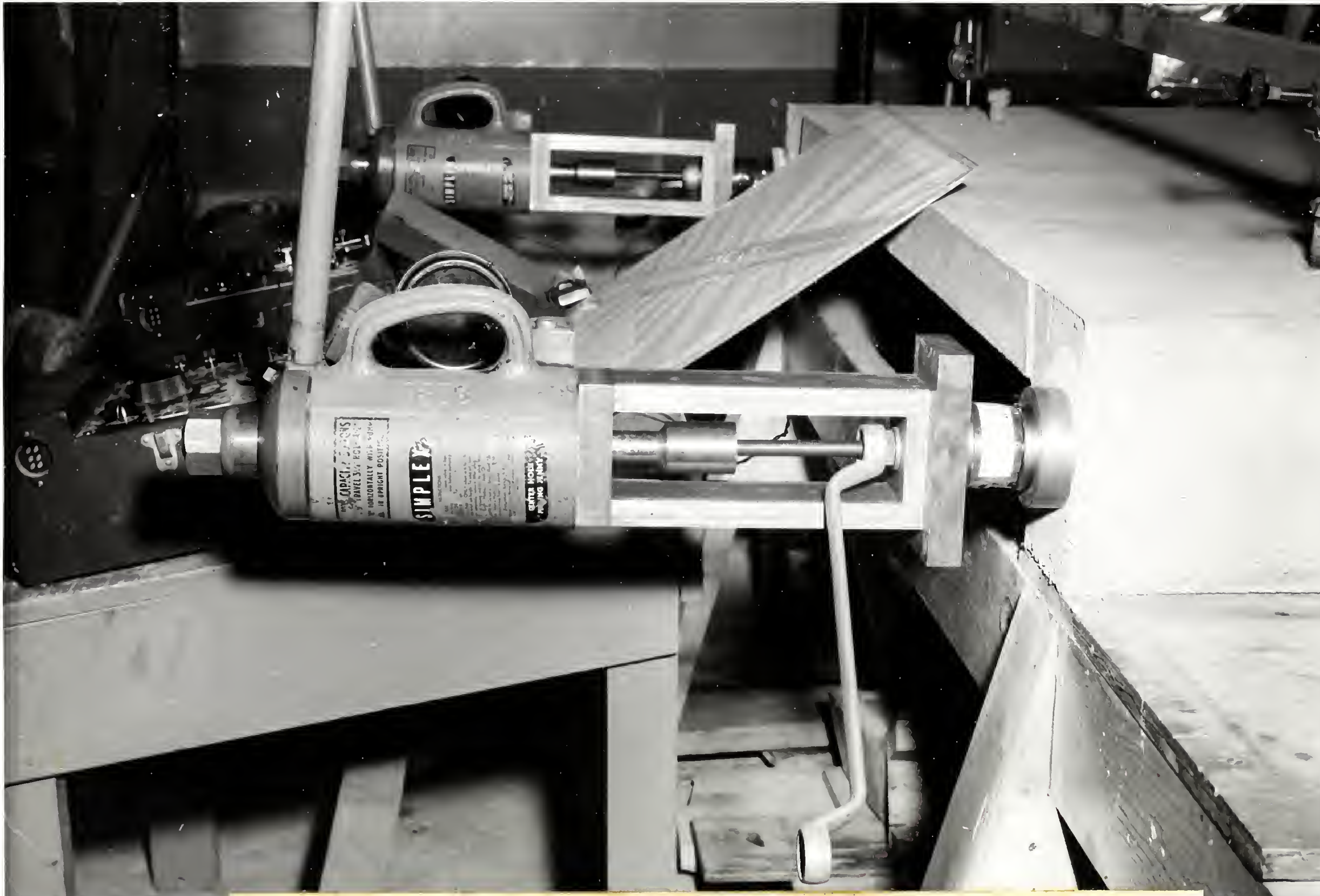

Fig. 3 - Close-up of prestressing apparatus and dynamometer in place.

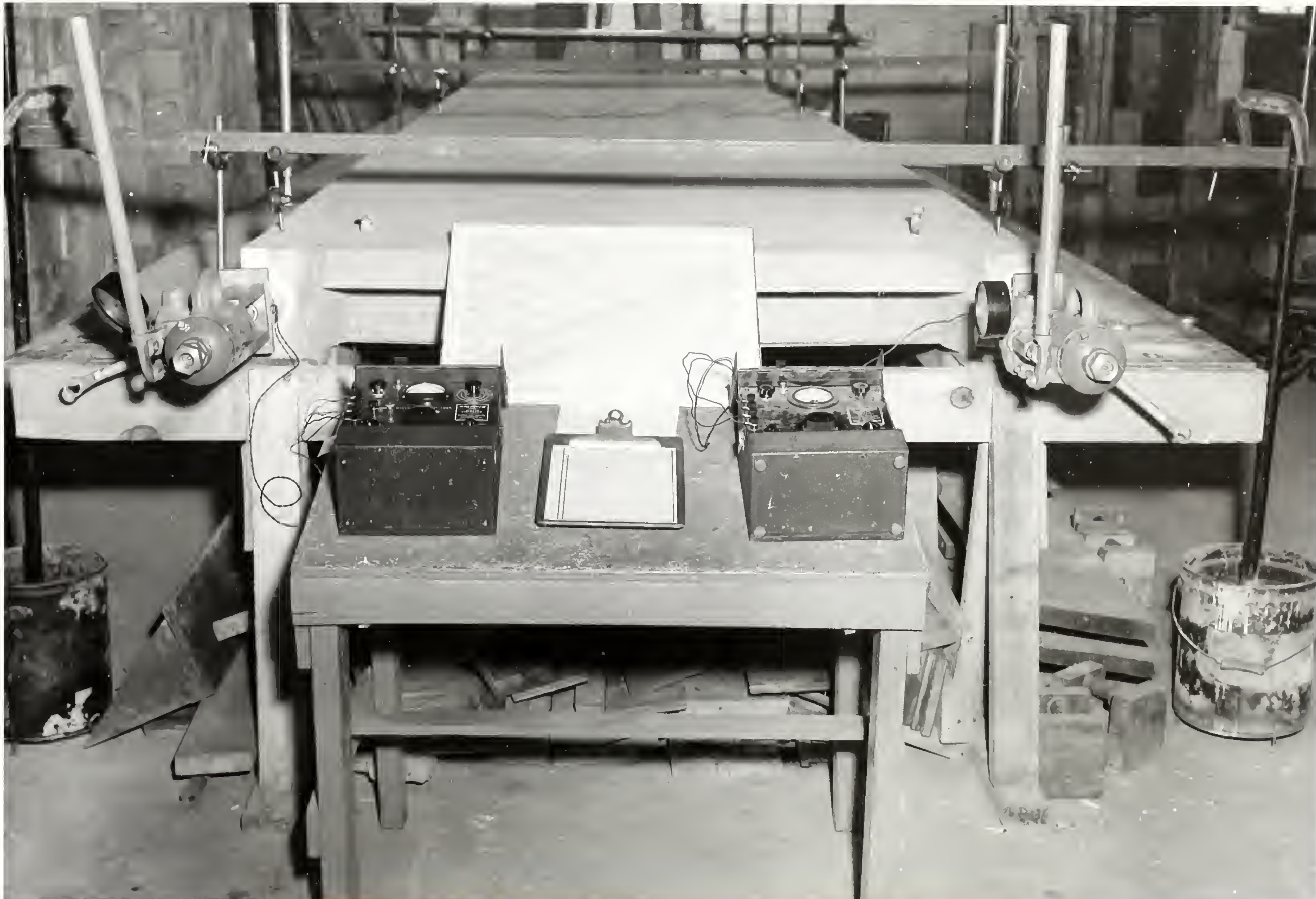

Fig. 4 - Arrangement for prestressing.

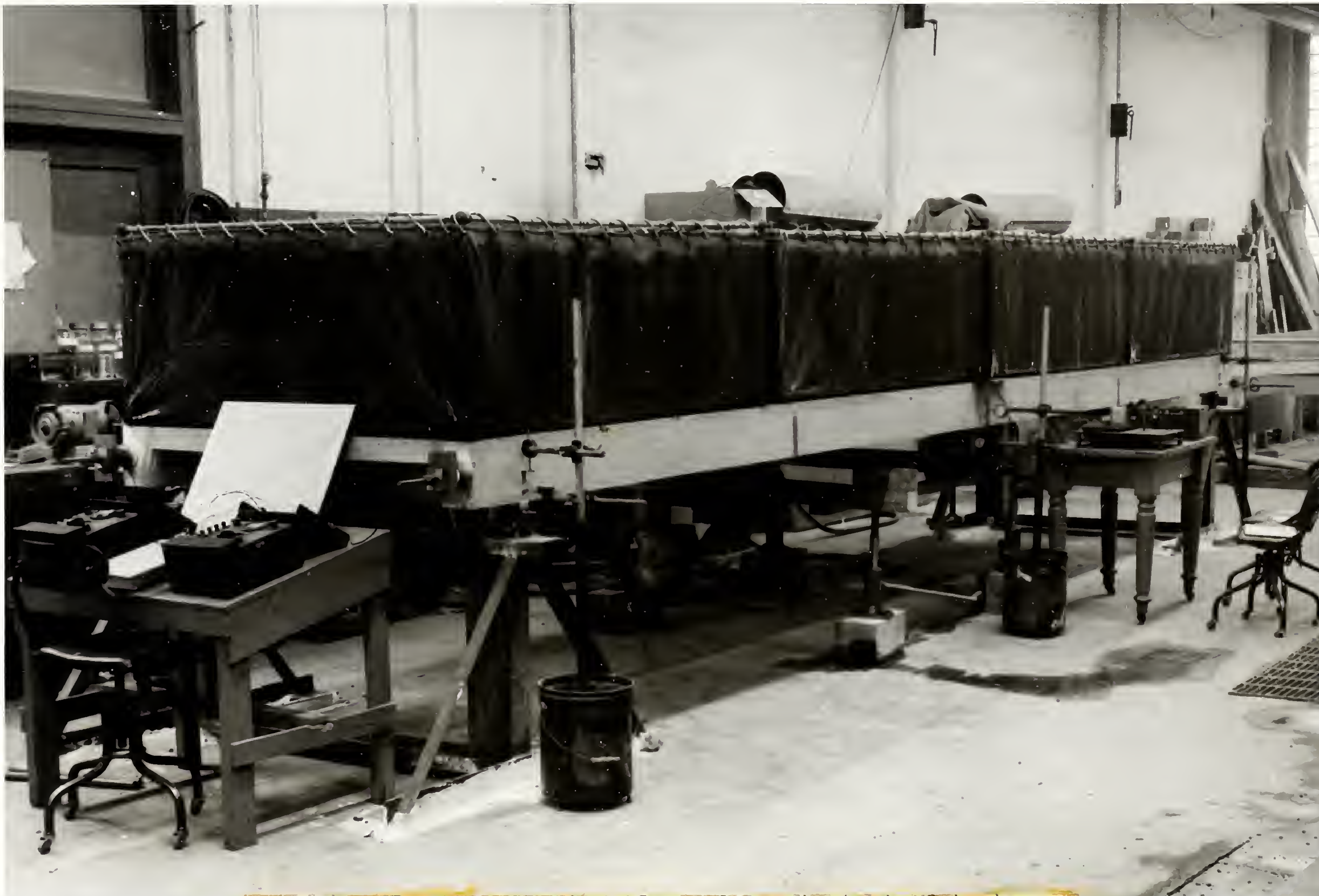

Fig. 5 - Overall view of specimen at start of test.

LOCATION OF SR-4 STRAIN GAGES & MIRRORED SCALES

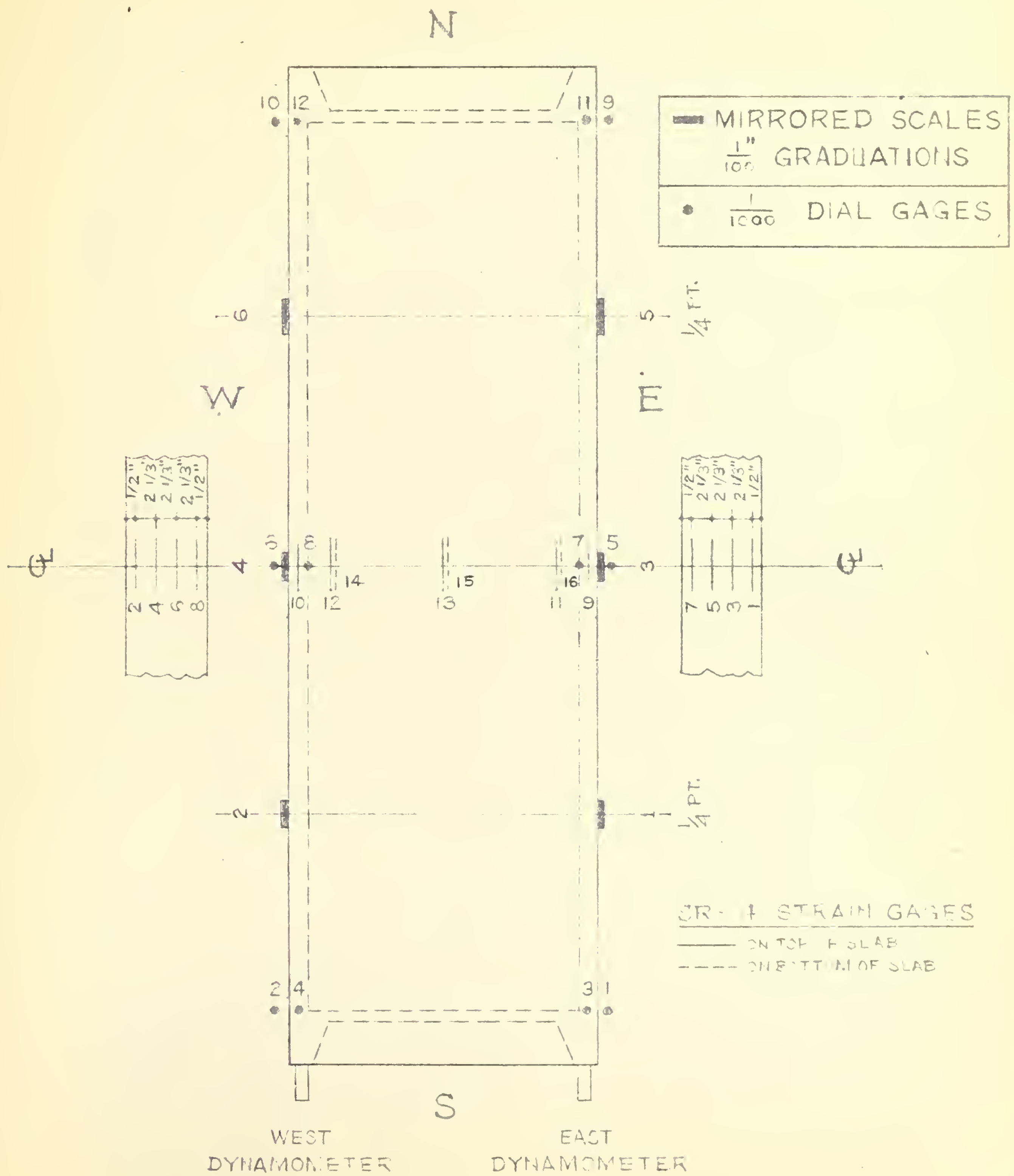

FIG. 6

Fig. 7 - View of specimen under 70 psf loading.

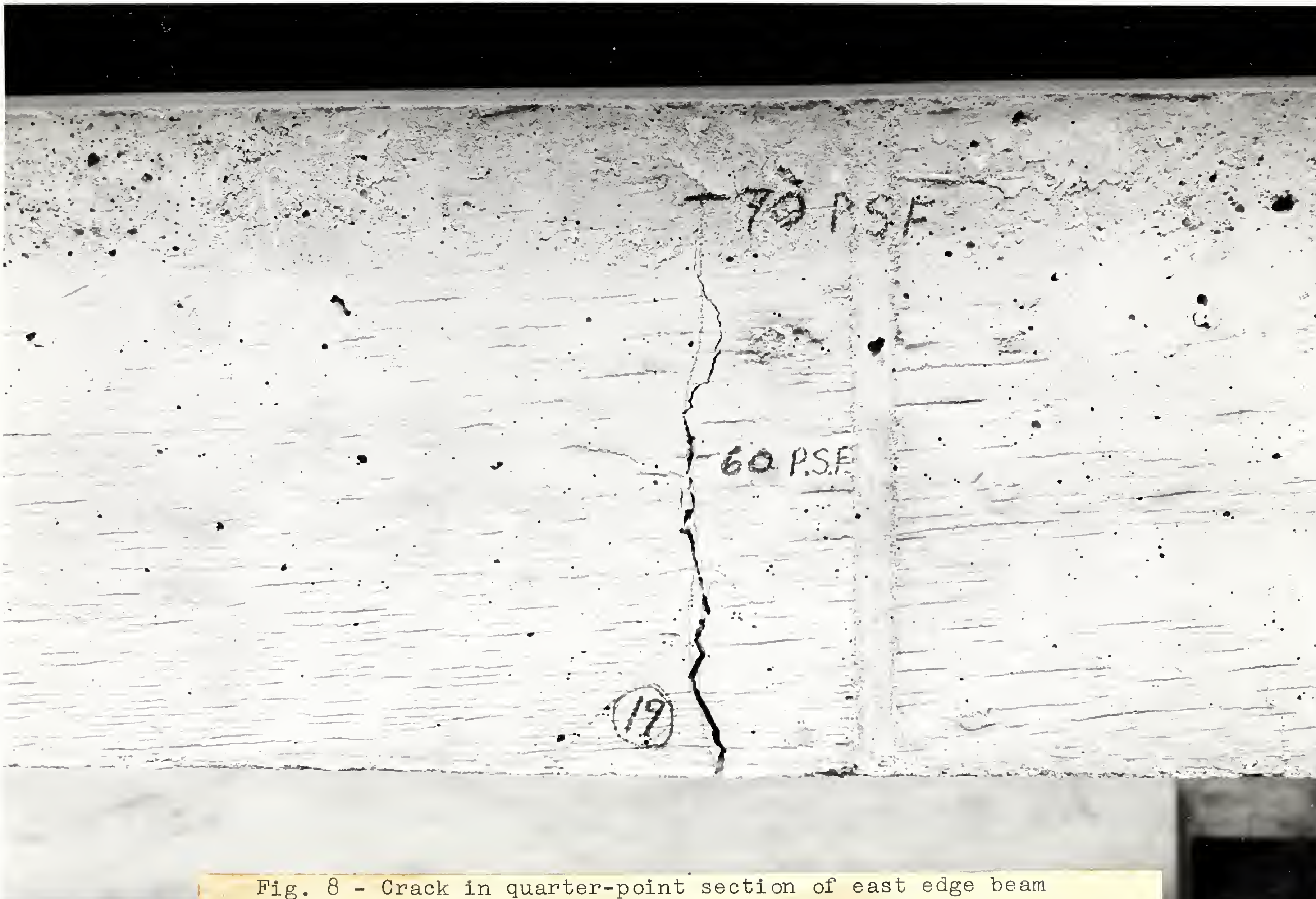

Fig. 8 - Crack in quarter-point section of east edge beam at 70 psf. (First crack opened at center section at approximately 50 psf).

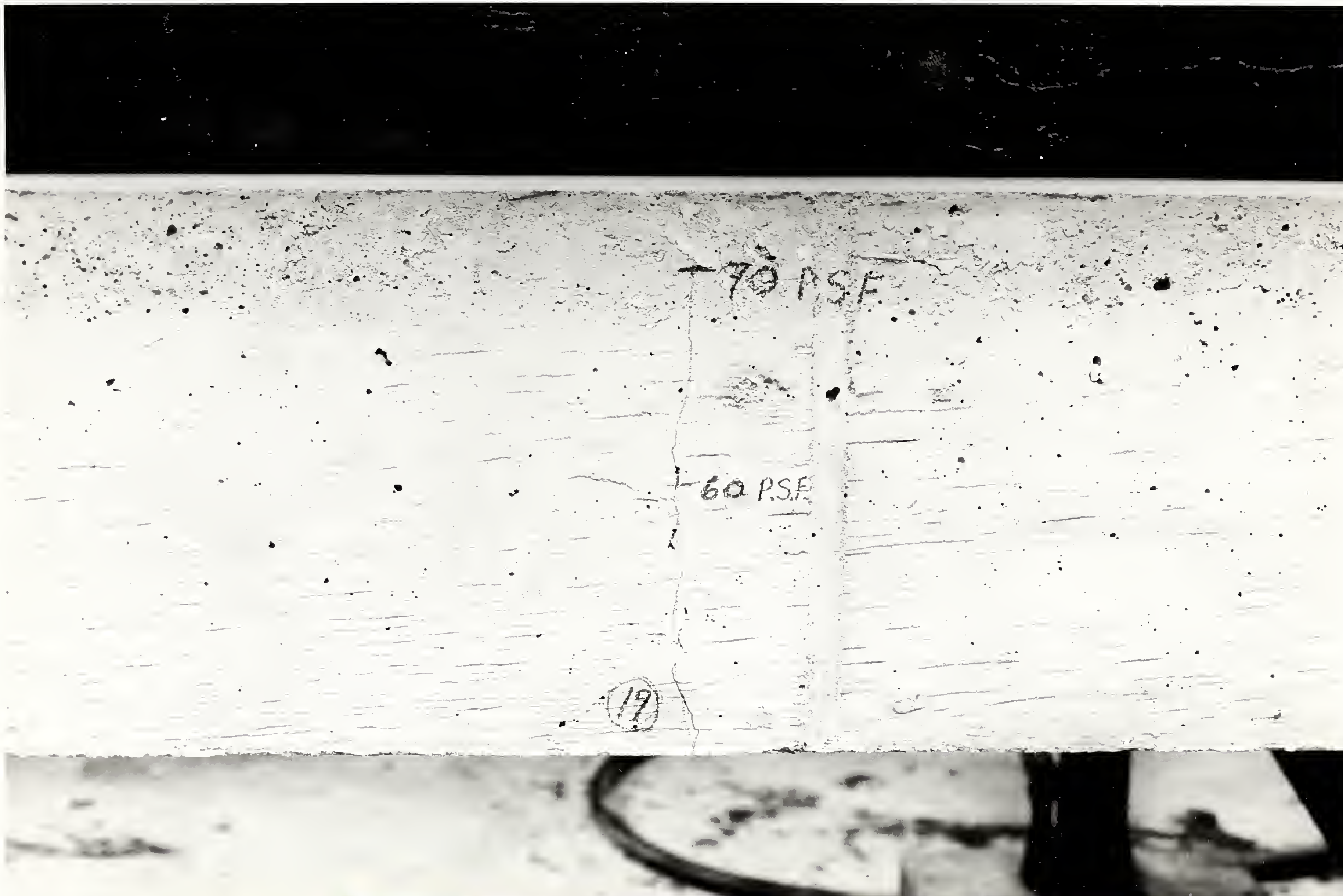

Fig. 9 - Same crack as Figure 8 with load removed.

PRESTRESSED SLAB NO. 3

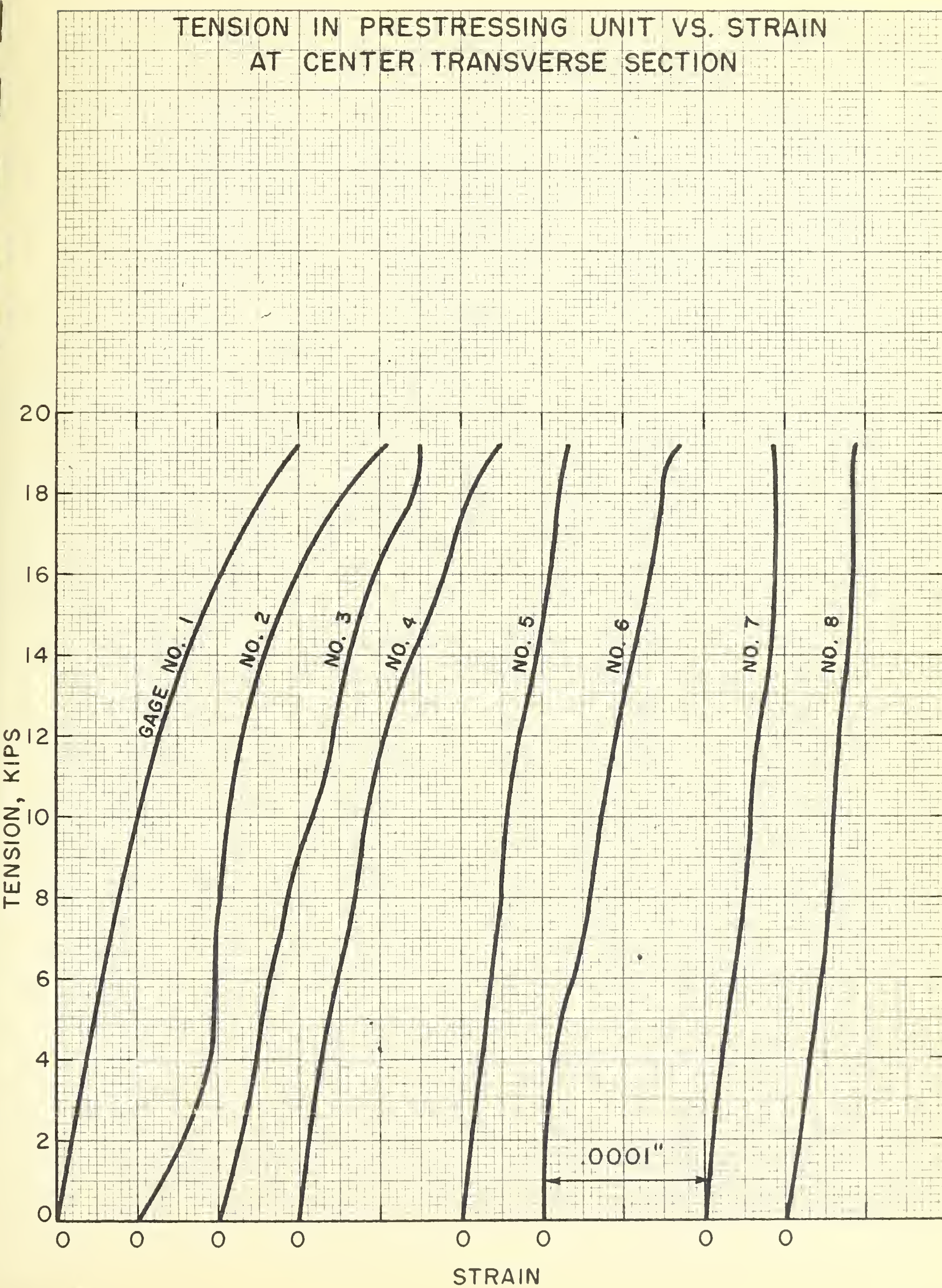

FIG. 10

PRESTRESSED SLAB NO. 3

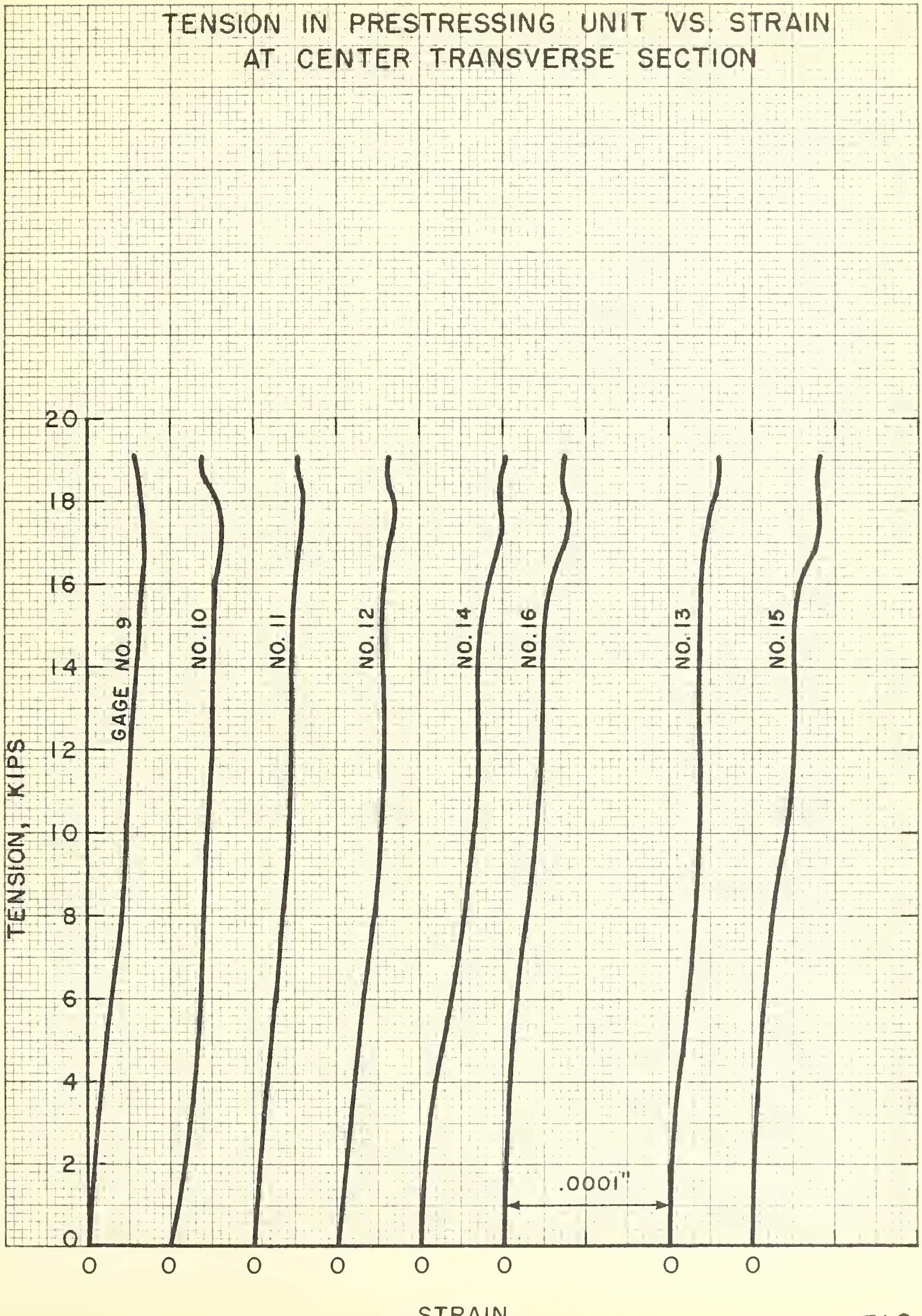

FIG. 11

PRESTRESSED SLAB NO. 3

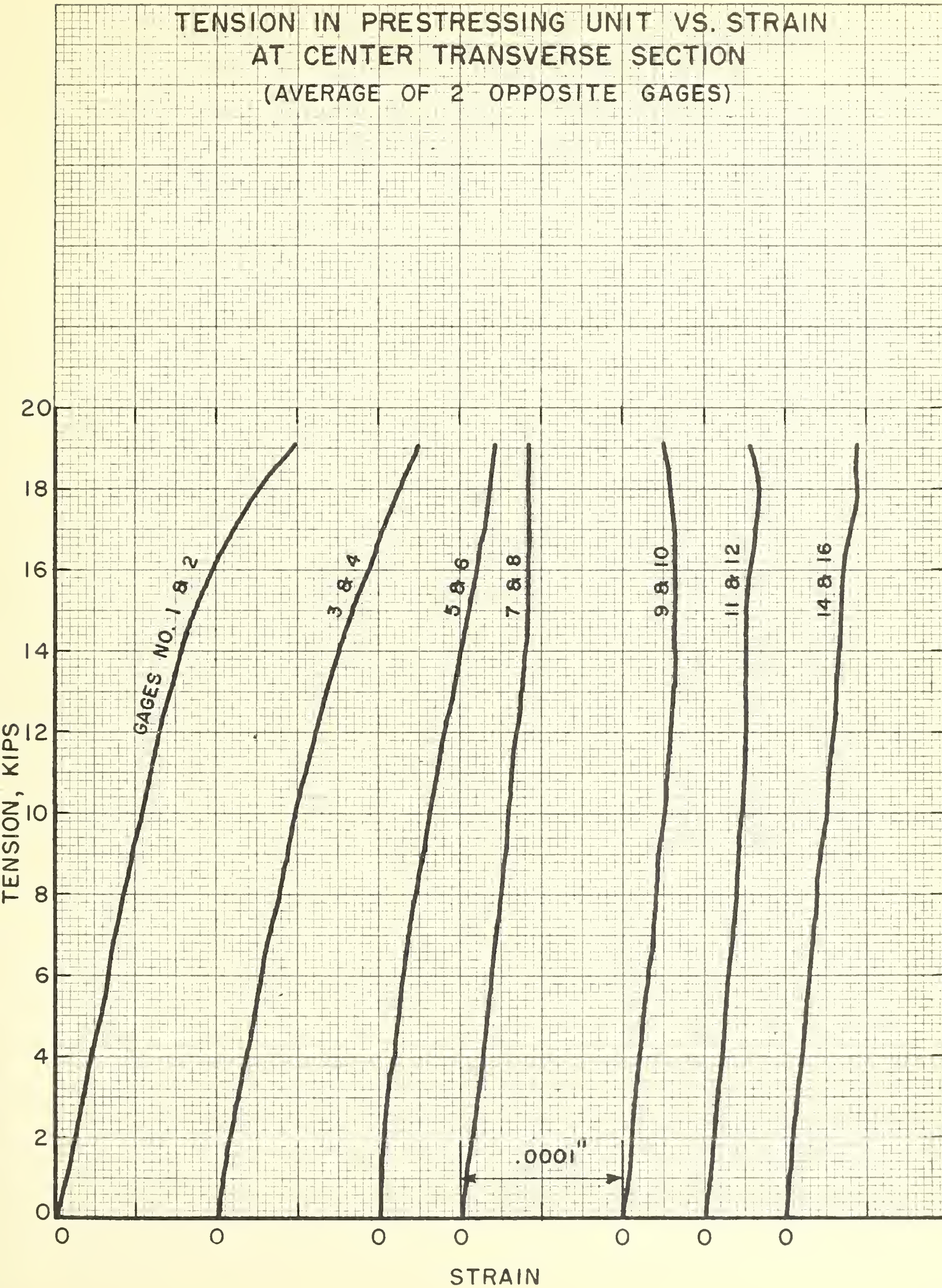

FIG. 12

PRESTRESSED SLAB NO. 3

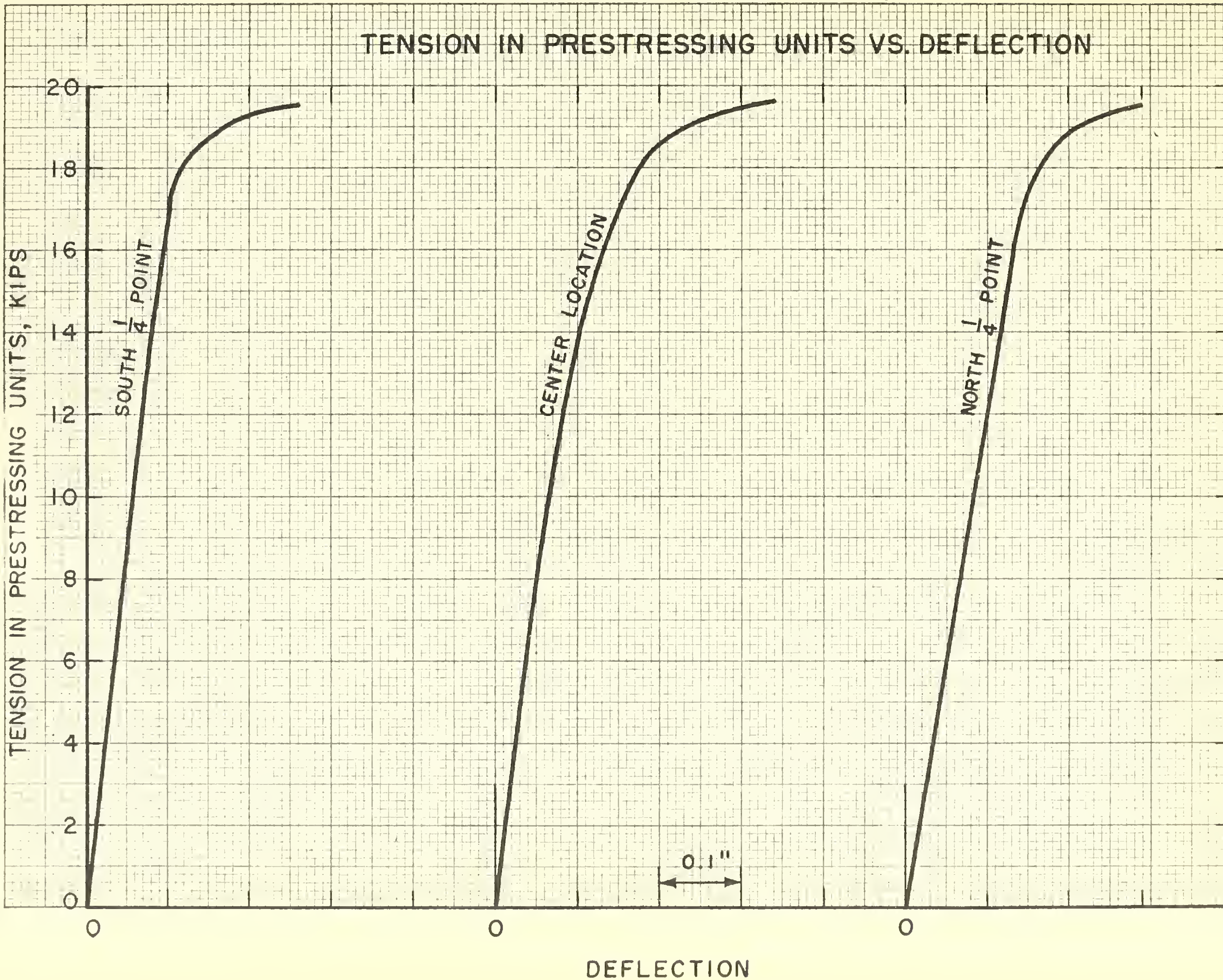

FIG. 13

PRESTRESSED SLAB NO. 3

APPLIED LOAD VS. TENSION IN PRESTRESSING UNITS

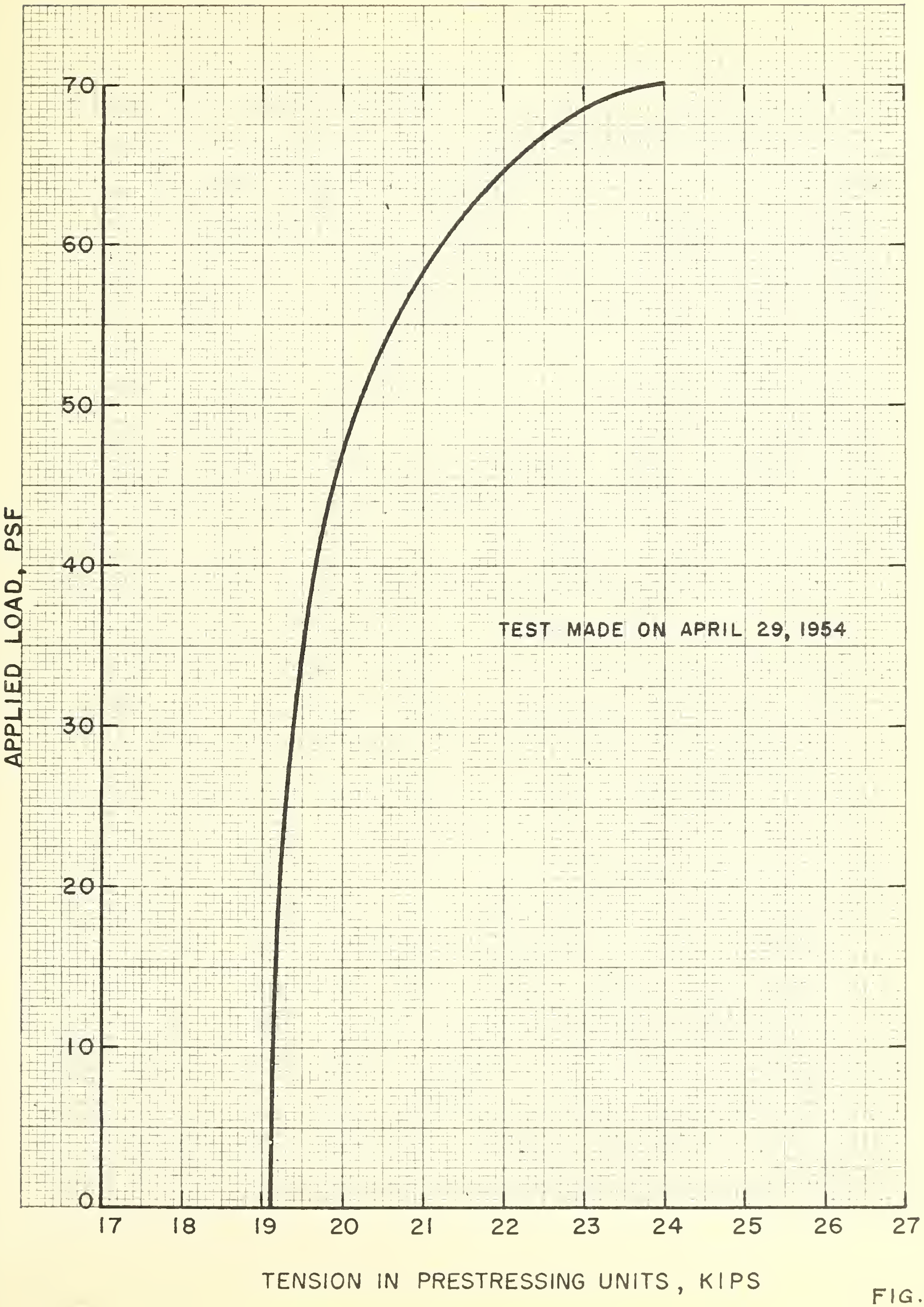

FIG. 14

PRESTRESSED SLAB NO. 3
APPLIED LOAD VS. DEFLECTION

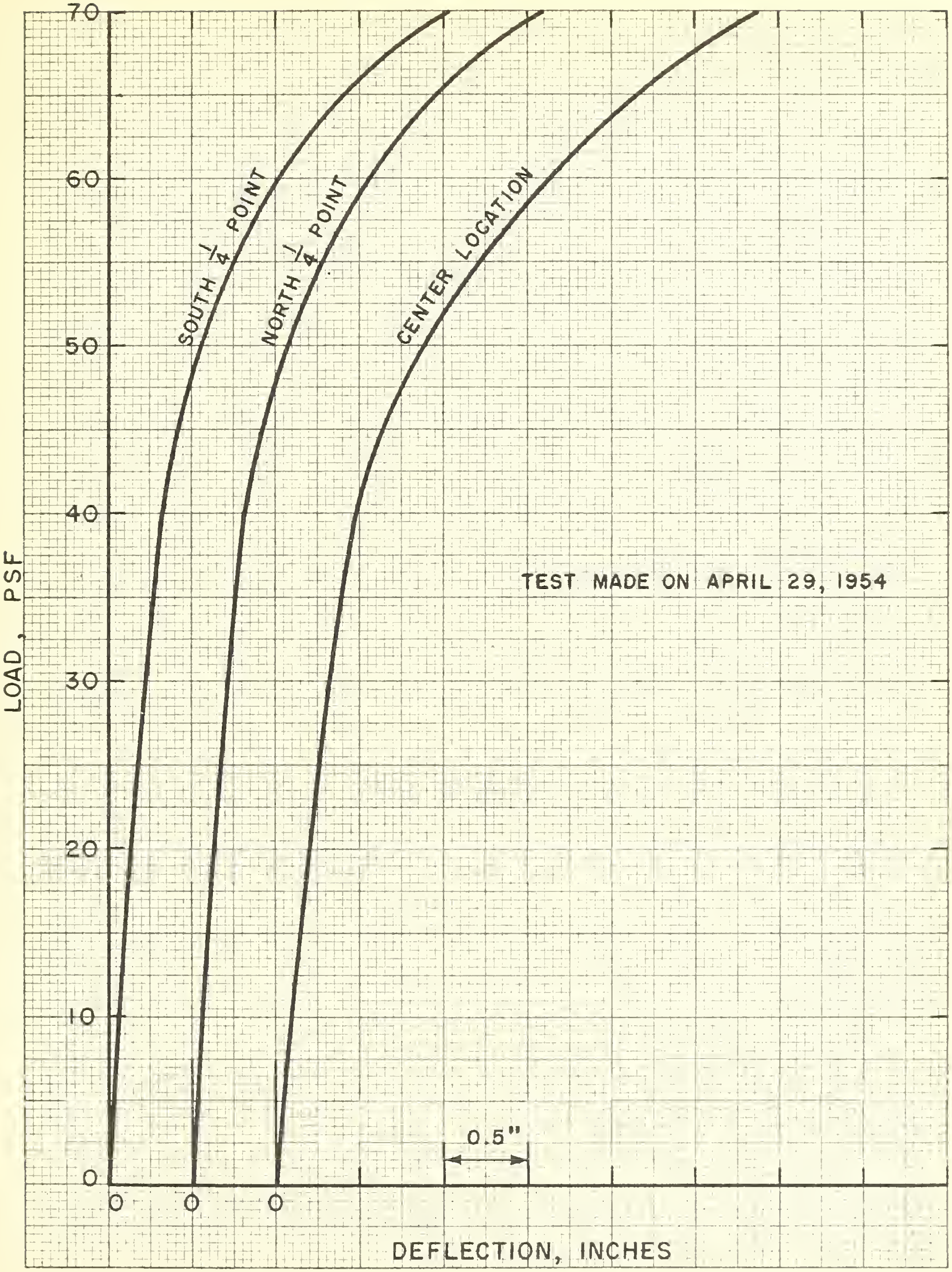

FIG. 15

PRESTRESSED SLAB NO. 3

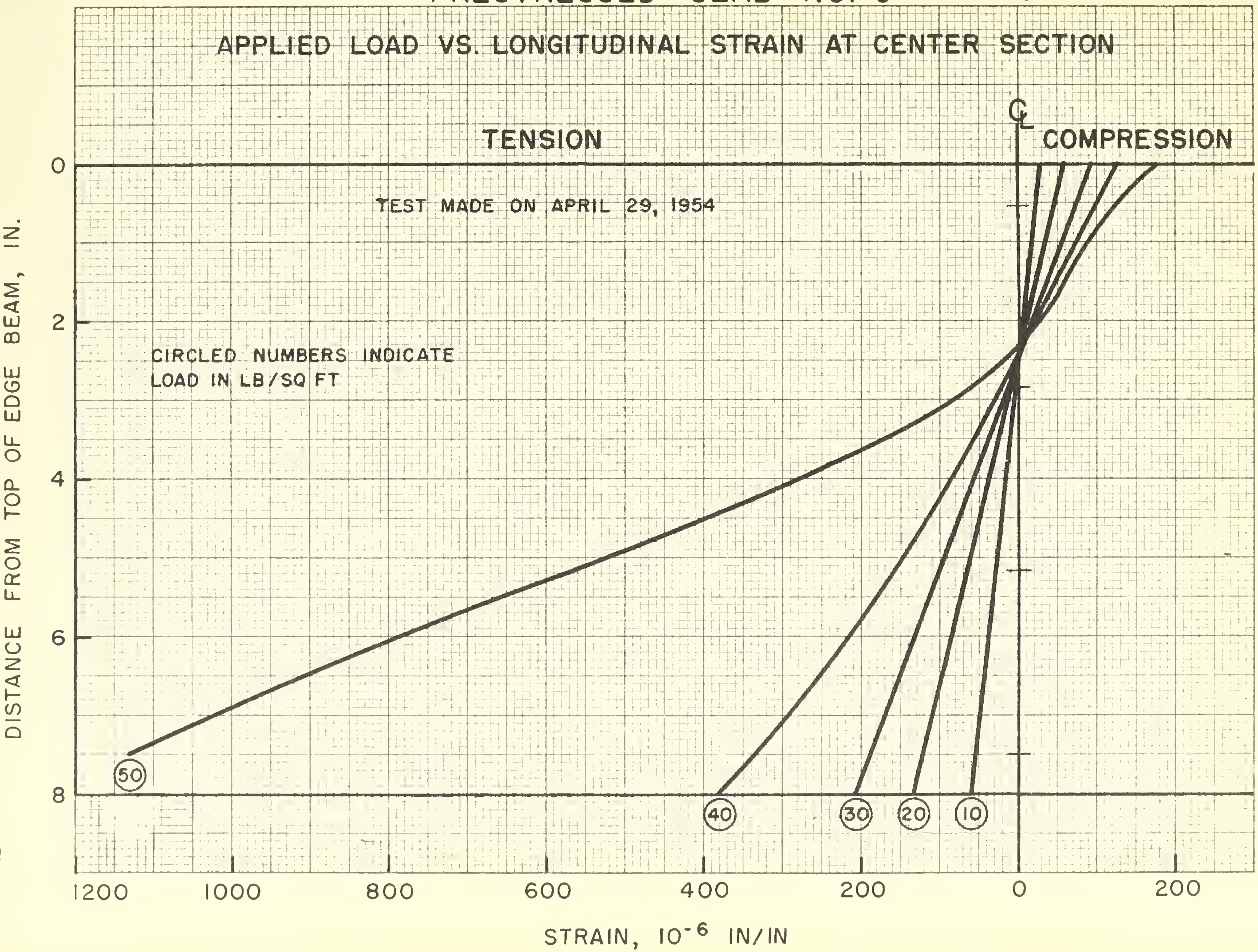

FIG. 16

PRESTRESSED SLAB NO. 3

APPLIED LOAD VS. TENSION IN PRESTRESSING UNITS

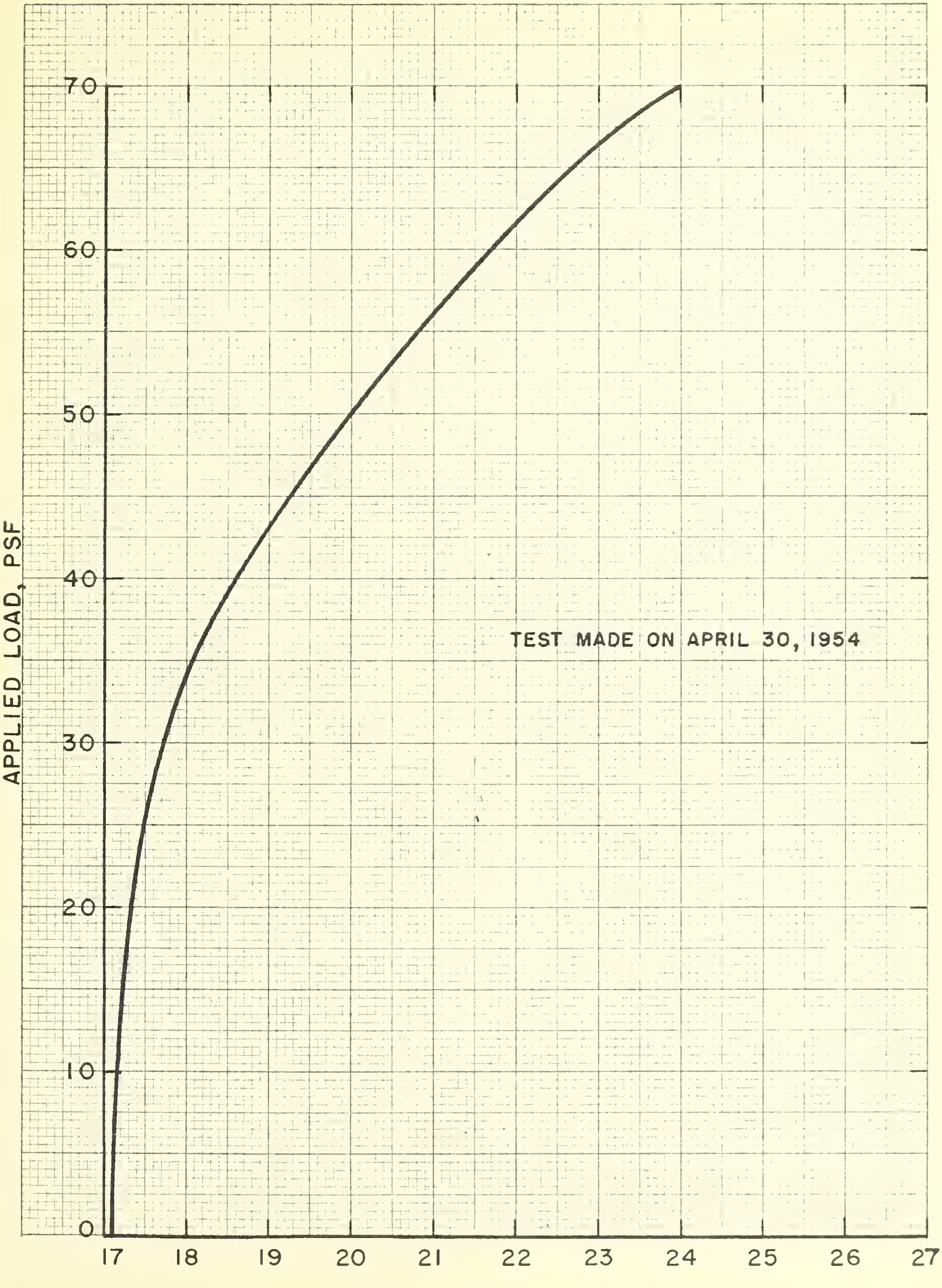

FIG. 17

PRESTRESSED SLAB NO. 3
APPLIED LOAD VS. DEFLECTION

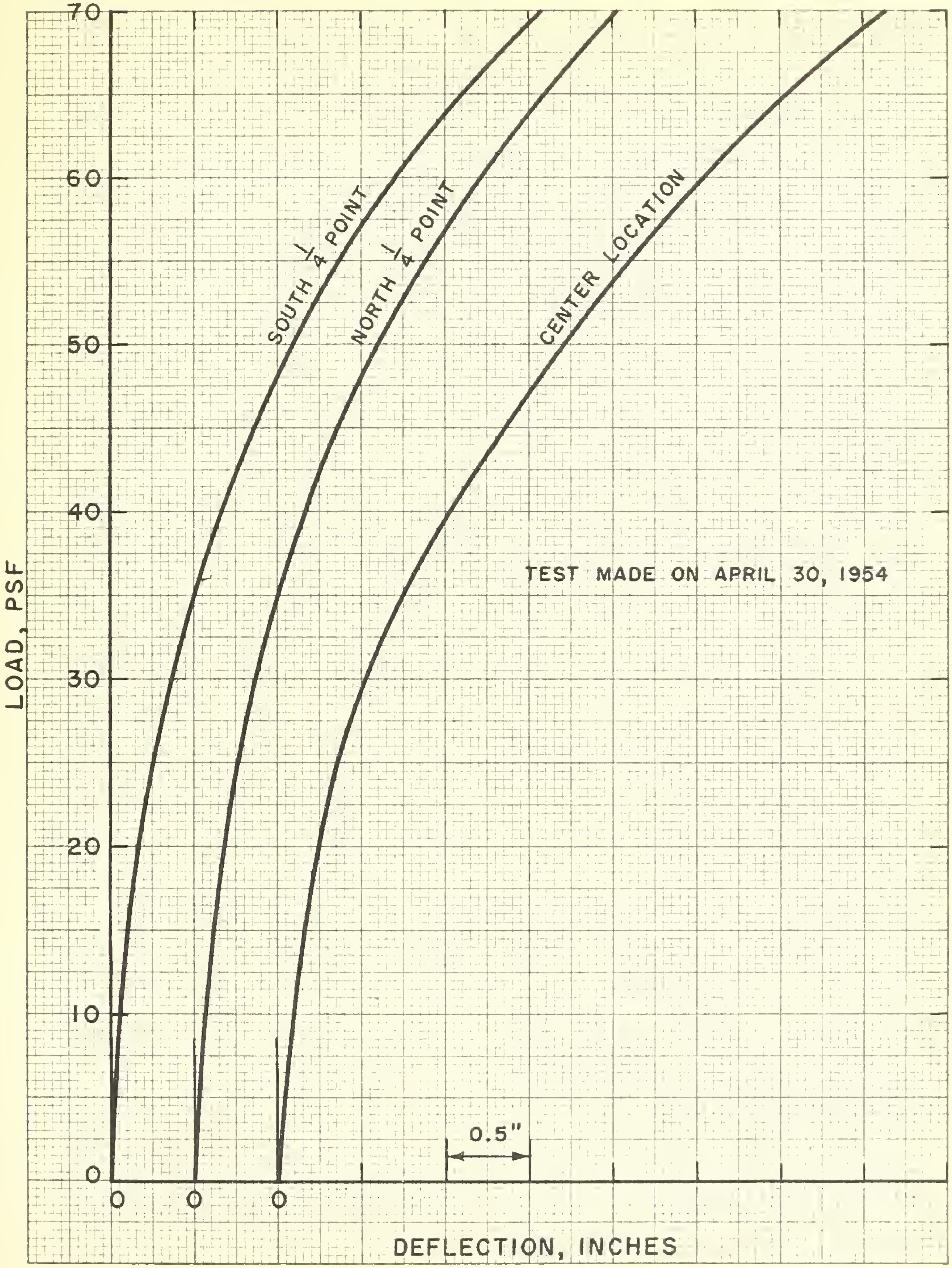

FIG. 18

PRESTRESSED SLAB NO. 3

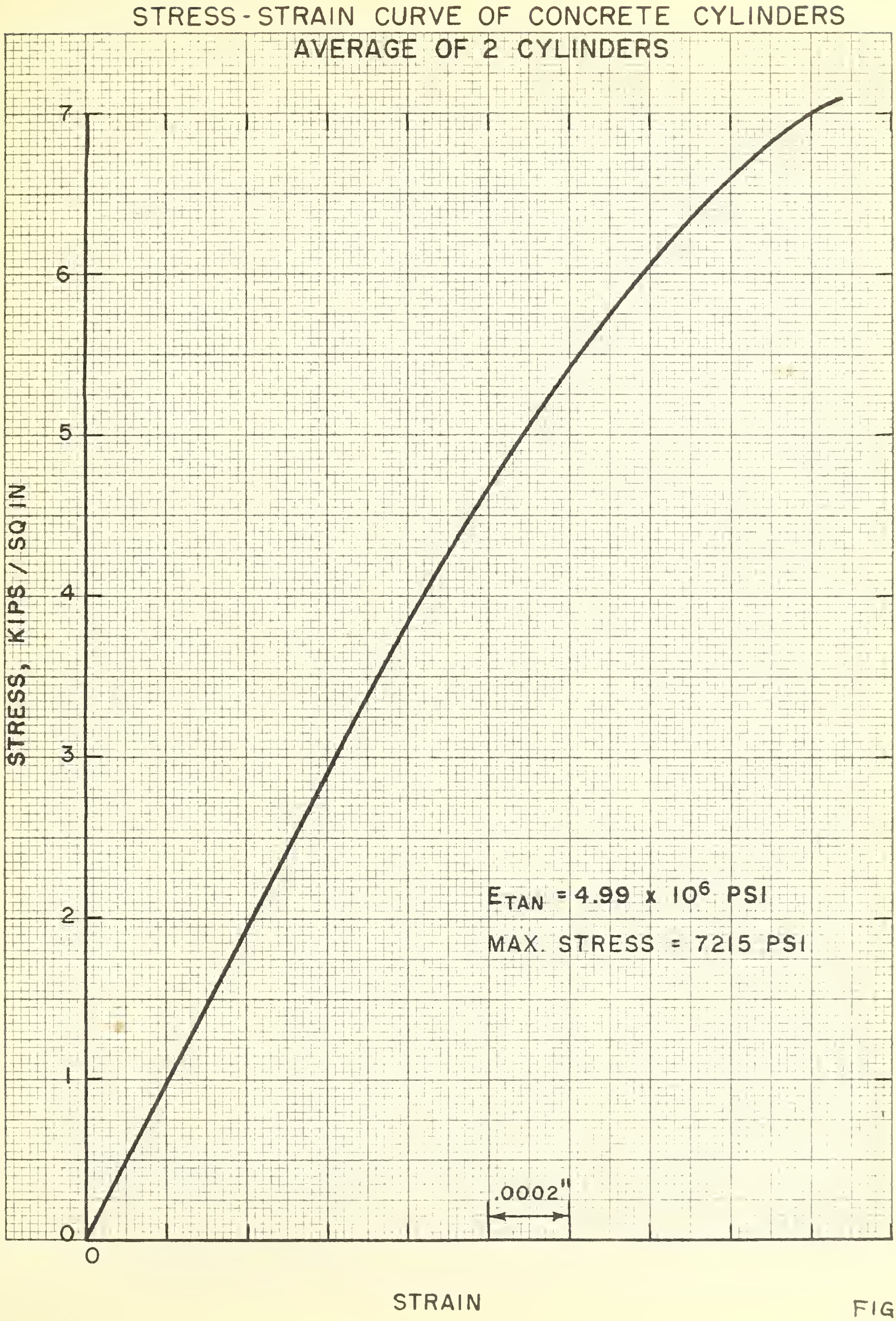

FIG. 19

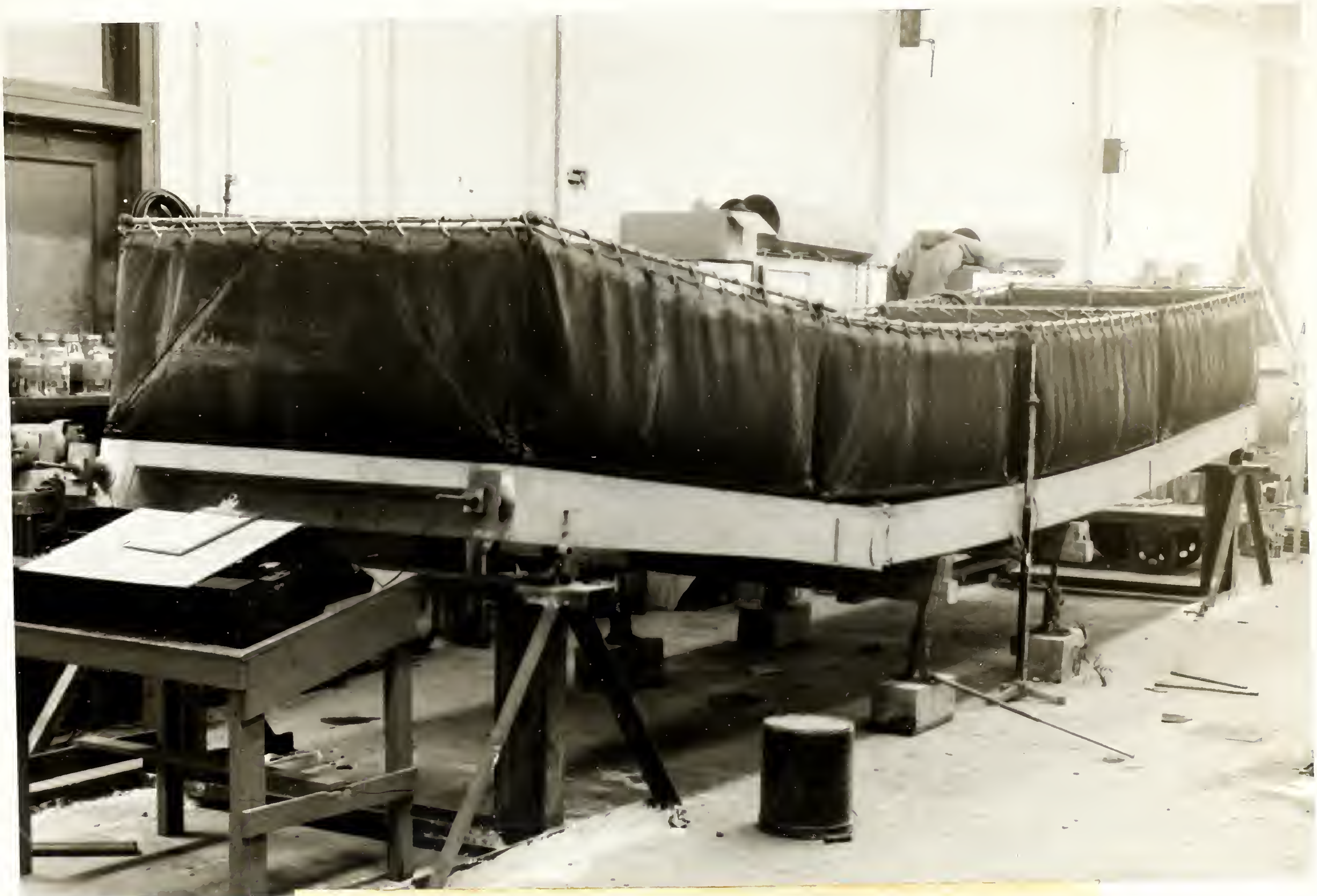

Fig. 20 - Overall view showing failure at 80 psf.

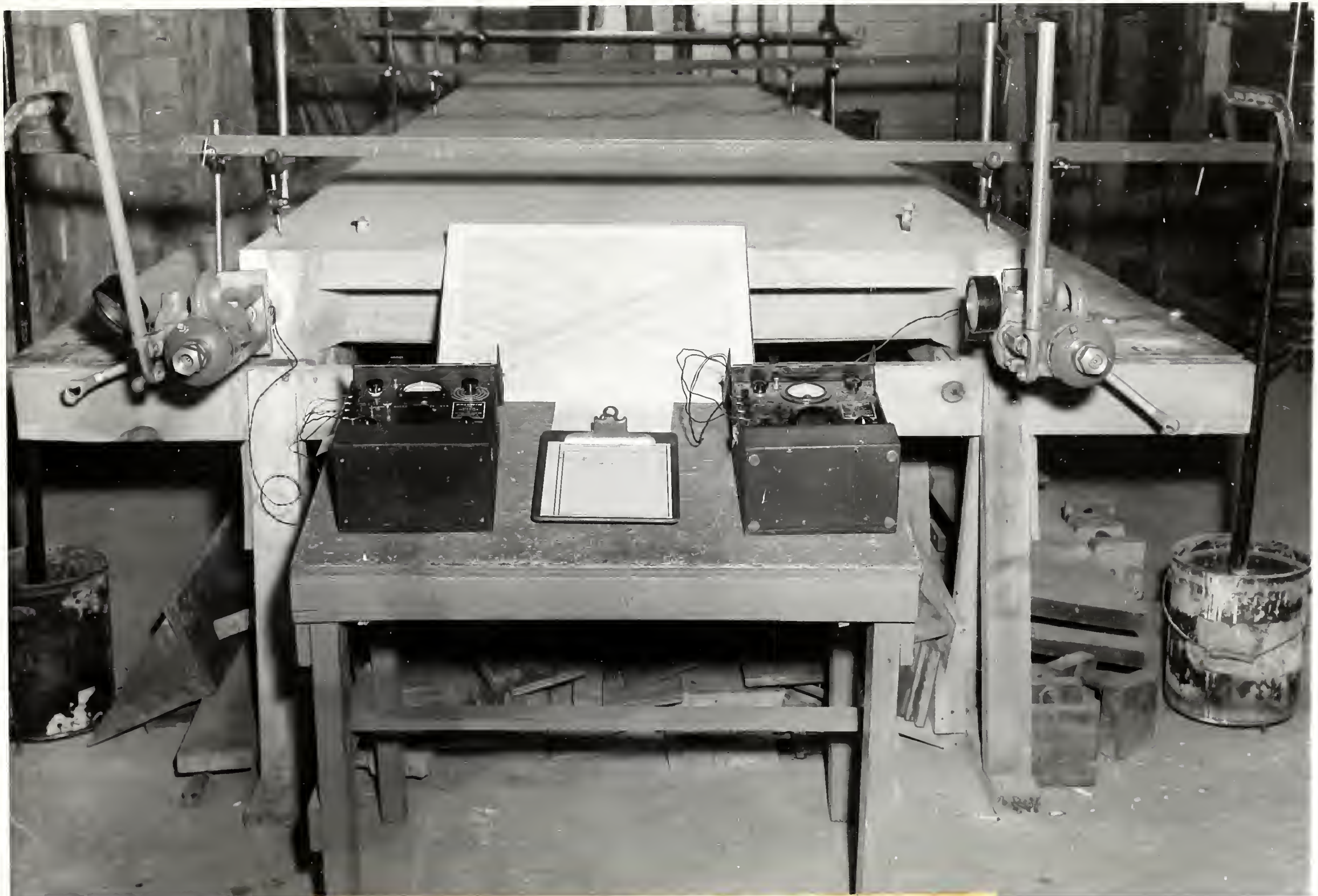

Fig. 4 - Arrangement for prestressing.

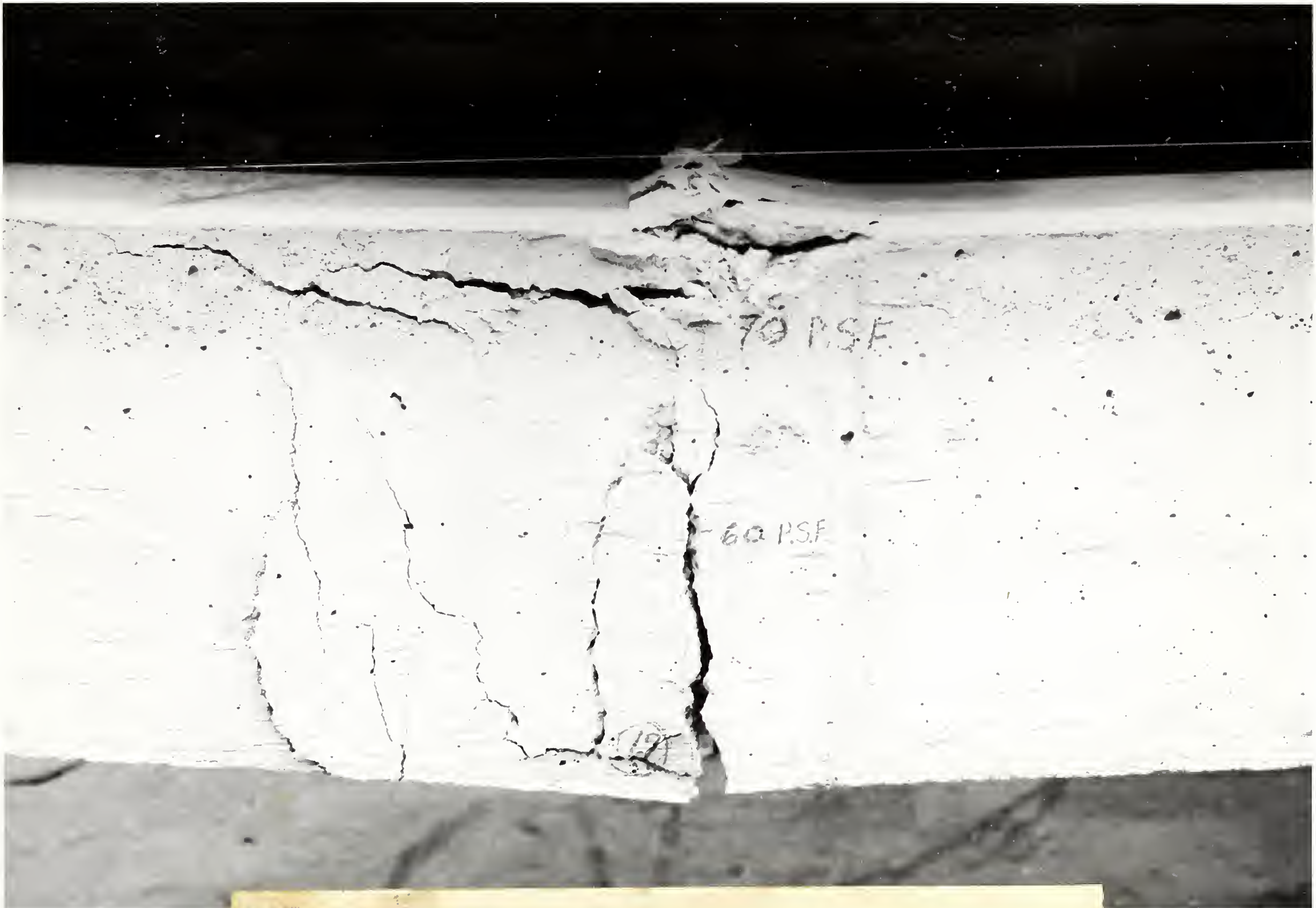

Fig. 21 - View of crack in east edge beam at failure. (Load = 80 psf).

Fig. 22 - View of crack in east edge beam after removal of load.

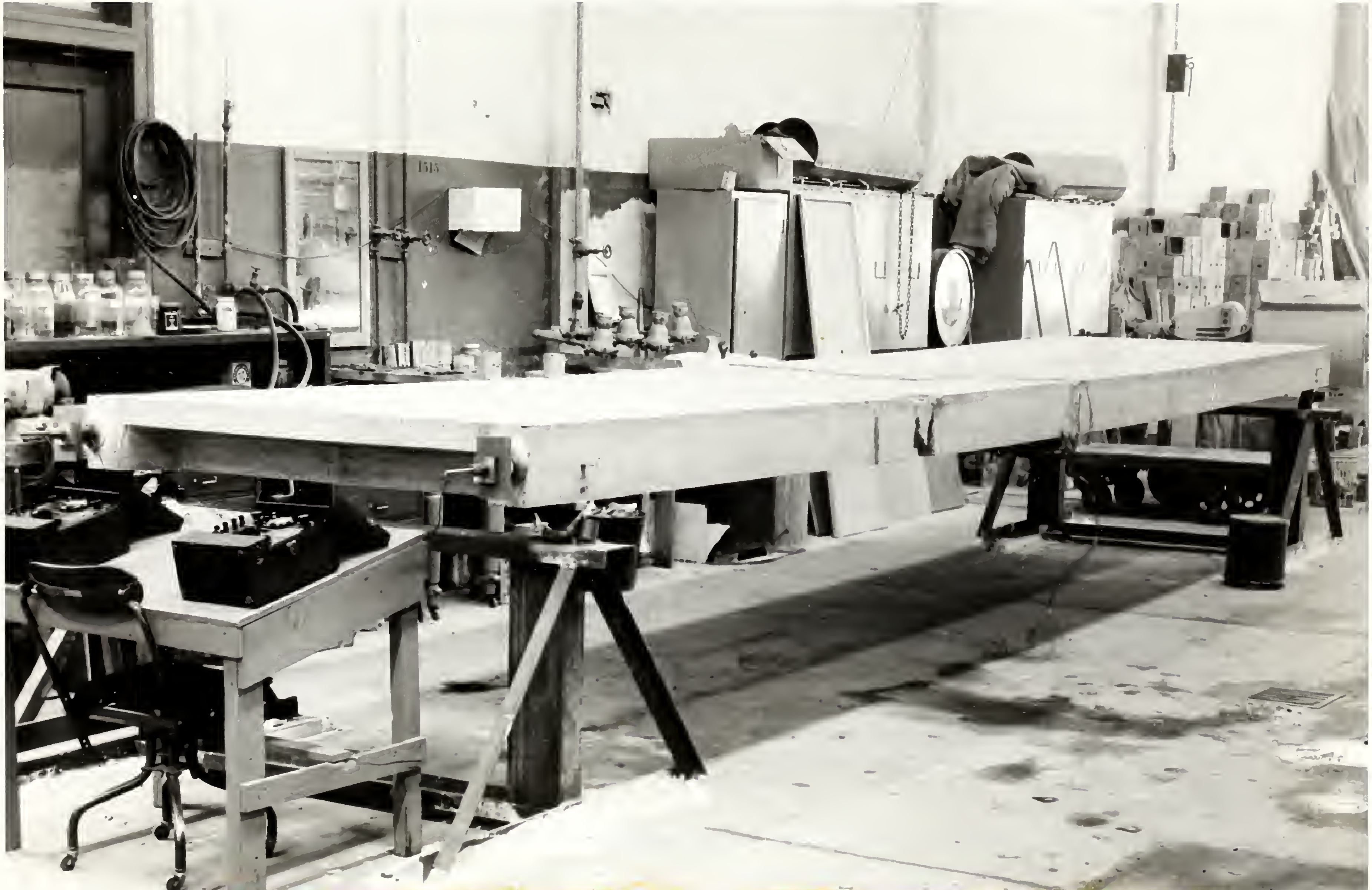

Fig. 23 - Overall view of specimen showing recovery after removal of load.

CRACK PATTERN

APRIL 30, 1954

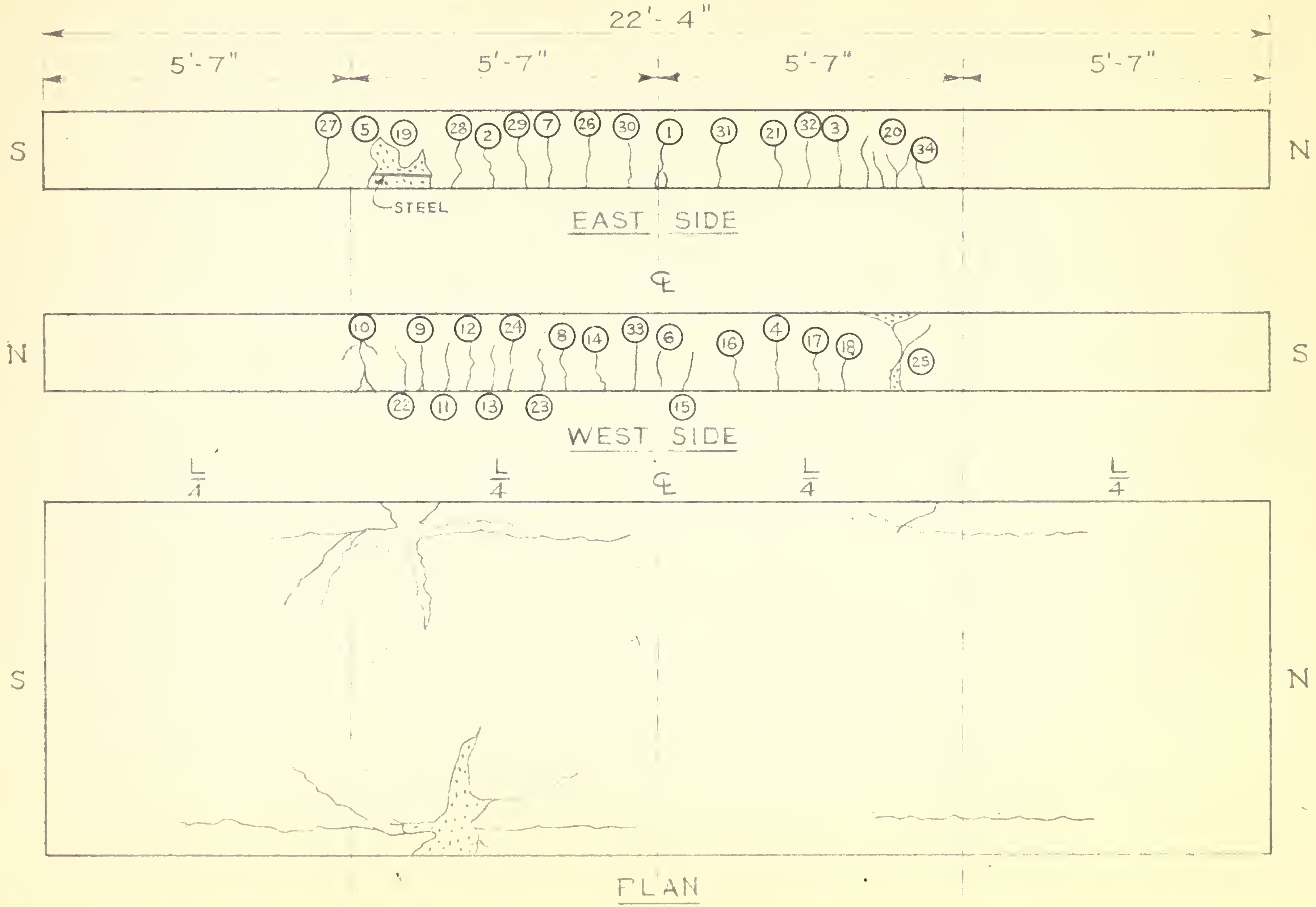

FIG. 24

THE NATIONAL BUREAU OF STANDARDS

Functions and Activities

The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to Government Agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. A major portion of the Bureau's work is performed for other Government Agencies, particularly the Department of Defense and the Atomic Energy Commission. The scope of activities is suggested by the listing of divisions and sections on the inside of the front cover.

Reports and Publications

The results of the Bureau's work take the form of either actual equipment and devices or published papers and reports. Reports are issued to the sponsoring agency of a particular project or program. Published papers appear either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau itself publishes three monthly periodicals, available from the Government Printing Office: The Journal of Research, which presents complete papers reporting technical investigations; the Technical News Bulletin, which presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions, which provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: The Applied Mathematics Series, Circulars, Handbooks, Building Materials and Structures Reports, and Miscellaneous Publications.

Information on the Bureau's publications can be found in NBS Circular 460, Publications of the National Bureau of Standards ($1.00). Information on calibration services and fees can be found in NBS Circular 483, Testing by the National Bureau of Standards (25 cents). Both are available from the Government Printing Office. Inquiries regarding the Bureau's reports and publications should be addressed to the Office of Scientific Publications, National Bureau of Standards, Washington 25, D. C.

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