NATIONAL BUREAU OF STANDARDS REPORT

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EFFECT OF AGE DIFFERENCE OF ELEMENTS AND LONG TERM STORAGE ON THE FLEXURAL BEHAVIOR OF SPLIT BEAMS

by

J. O. Bryson and L. F. Skoda

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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Effect of Age Difference of Elements and Long Term Storage on the Flexural Behavior of Split Beams

by

J. O. Bryson and L. F. Skoda

ABSTRACT

Two split beams were constructed with a one month delay between prestressing the tensile element and casting-on the compressive element to explore the effect of the difference in ages of the two halves of the beams on their long term behavior. After casting, one beam was aged for 1 1/2 years and the second beam was aged for 1 year. At the end of the storage periods the maximum strains developed from elastic, plastic, and shrinkage deformations were about 2100 micro in./in. for the first beam and 1600 micro in./in. for the second beam.

In the load tests the beams showed no effect from the delayed casting and long storage period when compared with similar beams that were cast and tested without delay.

INTRODUCTION

In the study of the flexural behavior of split beams[1/] conducted at NBS, two principal variables were introduced to investigate the effect of abrupt changes of strains in the composite member at the interface on the crack pattern and resistance to bending moment of the beams. The variables were: The location of the interface between the prestressed and non-prestressed portions with respect to the midplane of the composite beam and the magnitude of the prestress at the interface. The effects of creep and shrinkage of the concrete were minimized by continuous moist curing. The time from casting to testing was also held to a minimum with the use of Type III cement. The concrete developed the prescribed strength for prestressing in 3 to 5 days and for testing in 4 to 6 days. The time between the prestressing of the tensile element and the placing of the concrete for the compressive element ranged from 1 to 3 days. Therefore, the overall time from casting to testing ranged from 10 to 14 days.

The effect of differential shrinkage was, for all practical purposes, eliminated in the earlier tests. However, in actual construction practice differential shrinkage stresses might occur quite often. This would result from a time delay between the casting and prestressing of the tensile element and the casting-on of the compressive element.

To explore the effect of a difference in age of the two halves of split beams on their long-term behavior, two beams were cast with a 1 month delay between prestressing the tensile element and the casting-on of the compressive element. These beams were stored indoors simply supported

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[1/] Flexural Behavior of Prestressed Split-Beam Composite Concrete Sections, by J. O. Bryson, L. F. Skoda, and D. Watstein, Journal of the Prestressed Concrete Institute, Vol. 10, No. 3, June 1965.

on a 9 ft span to age for 1 year in one case and 1 year and 5 months in the other case, after which the beams were tested to failure in flexure. The ages are reckoned from the time that the tensile elements were prestressed.

TEST SPECIMENS

The test specimens included the two split beams, 3-by 4-by 16-in. free shrinkage prisms, and 6-by 12-in. cylinders. The split beams were 4-by 12-in. in cross-section and 10 ft in length. The depth of the tensile element and the compressive element were each 6-in., therefore, the interface of the two elements coincided with the midplane of the composite unit. The beams were post-tensioned and the tendons were unbonded. A single steel bar fixed in a parabolic profile served as the prestressing tendon. The tendons were located in the cross-section so that the calculated prestress in the top fiber of the tensile element at midspan was zero. The force in the tendon was calculated to produce a prestress of 2250 psi in compression at the bottom fiber of the tensile element. This prestress includes the effect of the weight of the beam on a 9 ft simply supported span. In short, these beams were identical, in all respects, to the "A" beams[2/] in the first series of tests.

A group of 6-by 12-in. control cylinders were cast from each batch of concrete for each beam. The 3-by 4-by 16-in. shrinkage specimens were cast from the concretes of the first beam only. There were three prisms cast with the tensile element and three with the compressive element.

INSTRUMENTATION

Gage lines for a 10-in. Whittemore strain gage were established on each side of the beams and the shrinkage prisms parallel to the longitudinal axis. The gage lines were established at the time of casting with gage plug inserts fastened to the inside of the forms. There were four gage lines on each side of the split beams and one gage line on each side

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[2/] ibid

of the shrinkage prisms. The gage lines on the split beams were located at midspan approximately 1-in. from the top and bottom surfaces and 1-in. above and below the interface. The gage lines on the shrinkage prisms were centrally located on the sides.

The use of Whittemore strain gage instrumentation allowed observation of the strains in the concrete during the early stages of curing and served to reveal the nature of the stress block developed over the cross-sections. Initial readings on all gage lines were made one day after casting each element of the split beam and the shrinkage specimens.

The tensioning force in the tendon was measured with a steel dynamometer attached to the tendon at the end of the beam opposite to the jacking end.

Bonded wire electrical resistance strain gages were used to measure longitudinal concrete strains in the beam during load tests. These gages were mounted on the specimens with a quick setting adhesive immediately before testing. The gages were located on both sides of the beam at midspan and were spaced along the depth of the beam to show the distribution of strains over the cross-section.

The deflection of the beams at midspan were measured with respect to the platen of the testing machine with 0.001-in. dial indicators.

MEASUREMENTS AND TEST PROCEDURE

Whittemore measurements on the split beams and the shrinkage prisms and readings of the prestress dynamometer were made at intervals of about 1 mounth over the storage period. At the end of the storage period, the beams were tested in flexure simply supported with the load applied at the third (1/3) points. The test procedure was the same as for the split beams of the first series referred to earlier.

RESULTS AND DISCUSSION

The two beams were designated AC-1 and AC-2. The initial prestress in both beams tapered from a maximum of 2250 psi in the bottom fiber of the tensile element to zero at the top fiber of this element. The compressive element was cast-on stress free.

The results of measurements made over the storage period and during the load test are presented in Table 1. Figures 1 through 4 show the variation of strains developed over the storage period. The strains at the bottom and top gage lines of beam AC-1 are presented in Figs. 1 and 2, respectively, and those at the bottom and top gage lines of beam AC-2 are presented in Figs. 3 and 4, respectively. The measurements from shrinkage specimens cast with beam AC-1 were used to estimate the plastic strains in the beam. The curves in Fig. 1 show the total strains, elastic strain, shrinkage and plastic strains occuring at the bottom gage line for beam AC-1. The total strain for the top gage line and the corresponding shrinkage strain were nearly the same as can be seen from the curves in Fig. 2. Also, it is noted that the elastic strain computed from the loss in prestress is very small and therefore it is assumed that no plastic strains occurred at this level in the beam. Shrinkage specimens were not cast with beam AC-2, therefore, only the total strain and elastic strain curves are shown.

At the end of the storage period, the total strain measured at the bottom gage line was approximately 2100 μ in./in. for beam AC-1 and approximately 1600 μ in./in. for beam AC-2. This difference in the total strain is significant and is not due to the difference in the lengths of the storage periods since the strains in both beams tended to level off after about 200 days of storage. The difference in the strains is apparently caused by the difference in the concretes. It is noted that at the end of the storage periods (time of test) the concrete strengths for the top and bottom elements was 4710 psi and 4940 psi for beam AC-1, and 5640 psi and 5380 psi for beam AC-2, respectively.

In the load tests, the ultimate loads for the beams were 24,150 lb for beam AC-1, and 24,850 lb for beam AC-2. Both beams failed by flexural compression. These results show favorable agreement with those for split beams and reference beams of the first series where the ultimate loads for all beams ranged from 22,200 lb to 25,800 lb.

The load-deflection relationship for the beams are shown by the curves in Fig. 5. For comparison, curves of the load-deflection relationship for a reference beam (R1-1) and a similarly constructed split beam (A-2) from the first series of tests are shown in Fig. 6. The values of deflection at the applied load of 12,000 lb for these beams are 0.14 in., 0.10 in., 0.12 in., and 0.12 in. for beams AC-1, AC-2, R1-1, and A-2, respectively. These values of deflection are presented for comparison since they correspond to the value of applied load computed for zero stress at the bottom fiber of the beams.

The crack patterns for both beams are shown in Fig. 7. These beams developed several more cracks than did the beams tested in the first series. However, the patterns are essentially the same. As was the case in the earlier beams, the first crack developed at midspan and was shortly followed by additional cracks symmetrically located about the midspan. The crack patterns also indicate that complete composite action was carried out through the load tests.

CONCLUSIONS

The one month delay between prestressing the tensile element and casting-on the compressive element and the long storage period for the two split beams, had no measurable effect on the flexural characteristics of these beams. The two beams when tested after more than a year of storage, showed essentially the same response to load, ultimate load properties, and crack patterns as the split beams in the first series of tests that were protected from drying shrinkage and tested shortly after casting.

Table 1. Measured and Observed Properties of Beams

BEAM	Observed strain in bottom gage[1] at prestress	Maximum observed strain[2] at end of storage period		Loss of prestress at end of storage period	Concrete strength at time of load test, top/bottom	Deflection at, 12,000 lb applied load	Ultimate load	Type failure
		Bottom gage	Top gage[3]					
	µ in./in.	µ in./in.	µ in./in.	%	psi	in.	lb	
AC-1	544	2100	650	27.3	4710/4940	0.14	24,150	Flexural compression
AC-2	505	1600	450	21.4	5740/5380	0.10	24,850	Flexural compression

[1] These were Whittemore strain gage lines located 1 1/8 in. above the bottom surface of the beams.

[2] The maximum strain includes elastic, plastic, and shrinkage deformations.

[3] The top gage lines were located 1 in. down from the top surface of the beams.

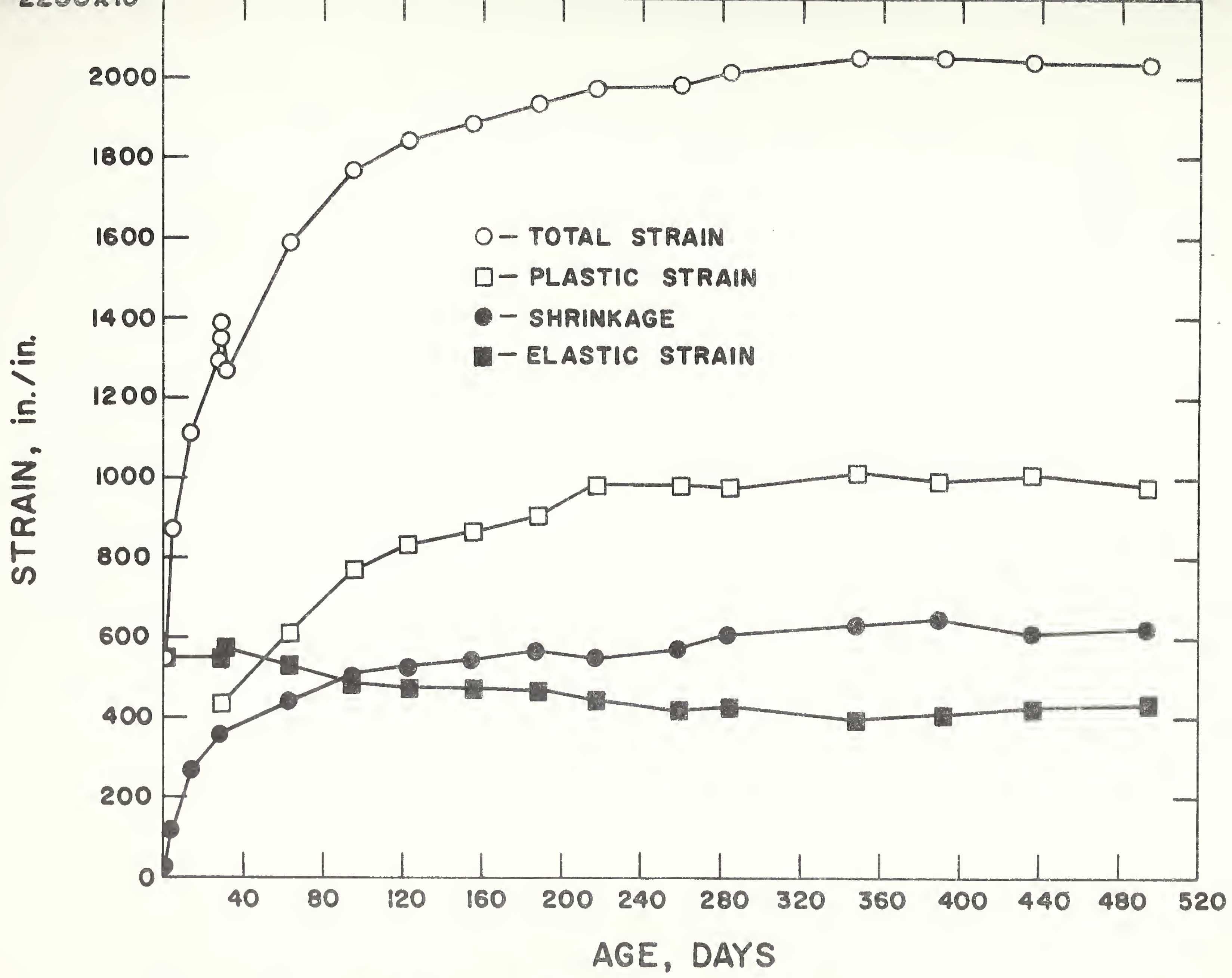

FIG. 1. STRAINS AT BOTTOM GAGE LINE ON BEAM AC-1.

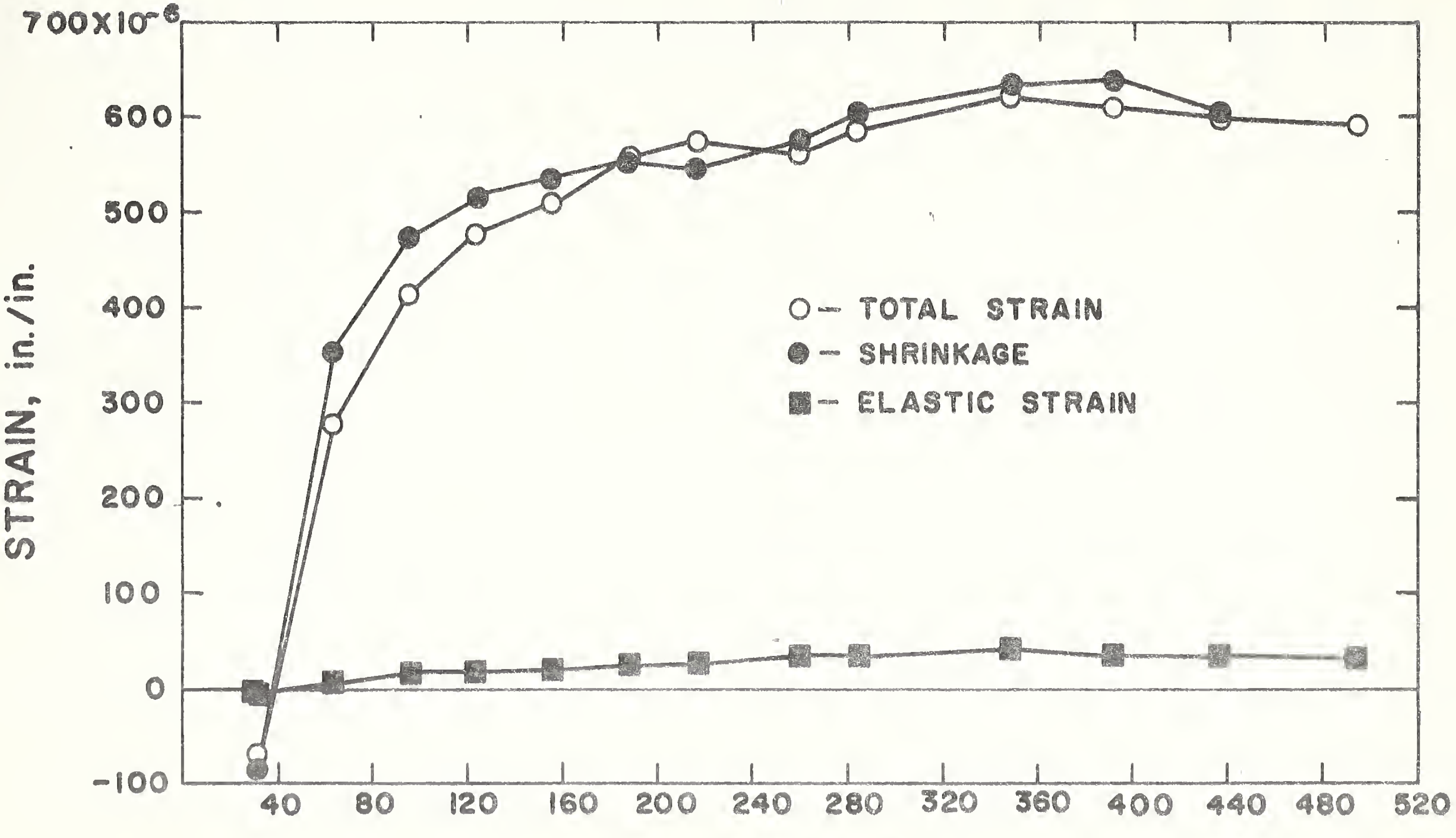

FIG. 2. STAINS AT TOP GAGE LINE ON BEAM AC-1.

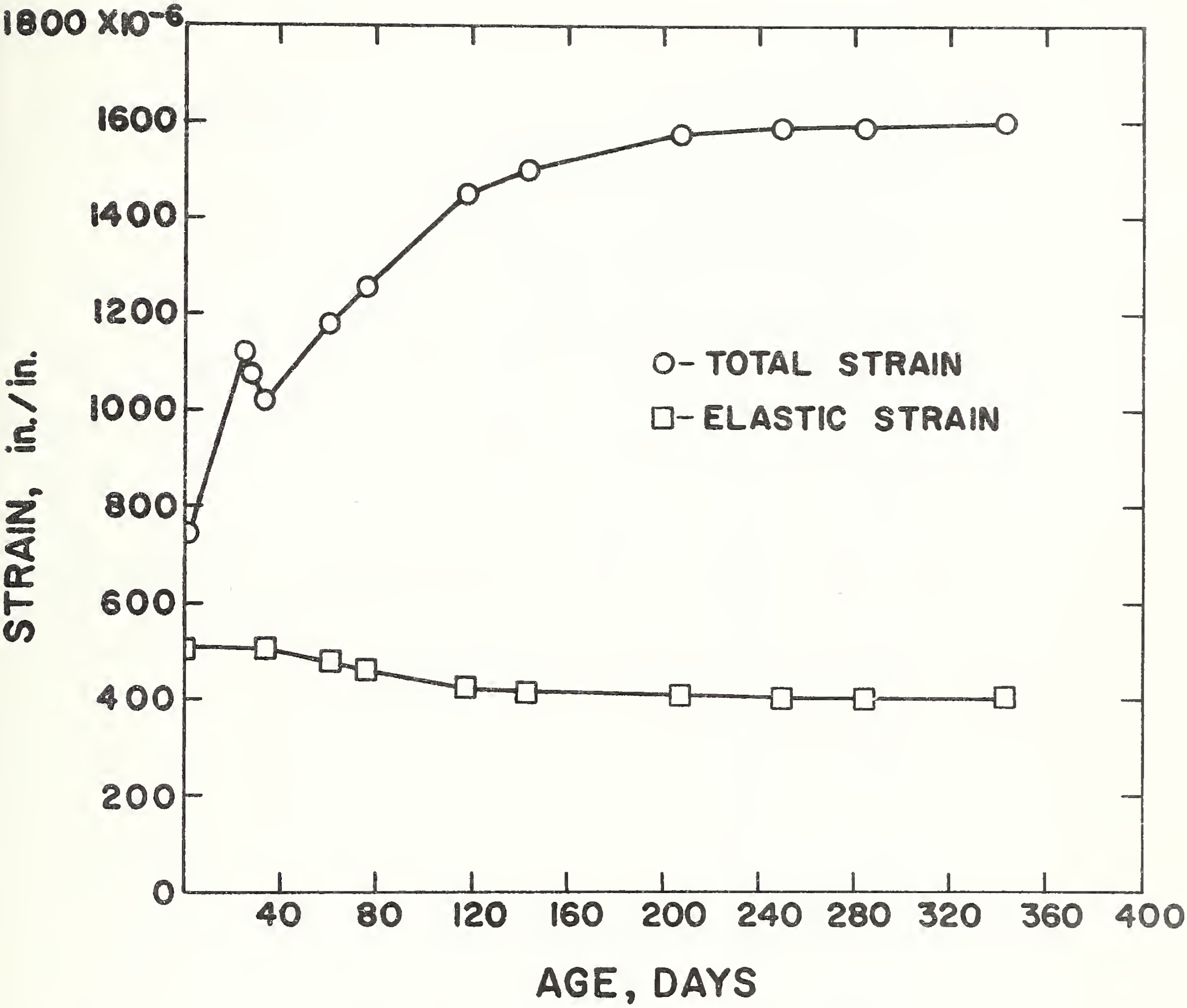

FIG. 3. STAINS AT BOTTOM GAGE LINE ON BEAM AC-2.

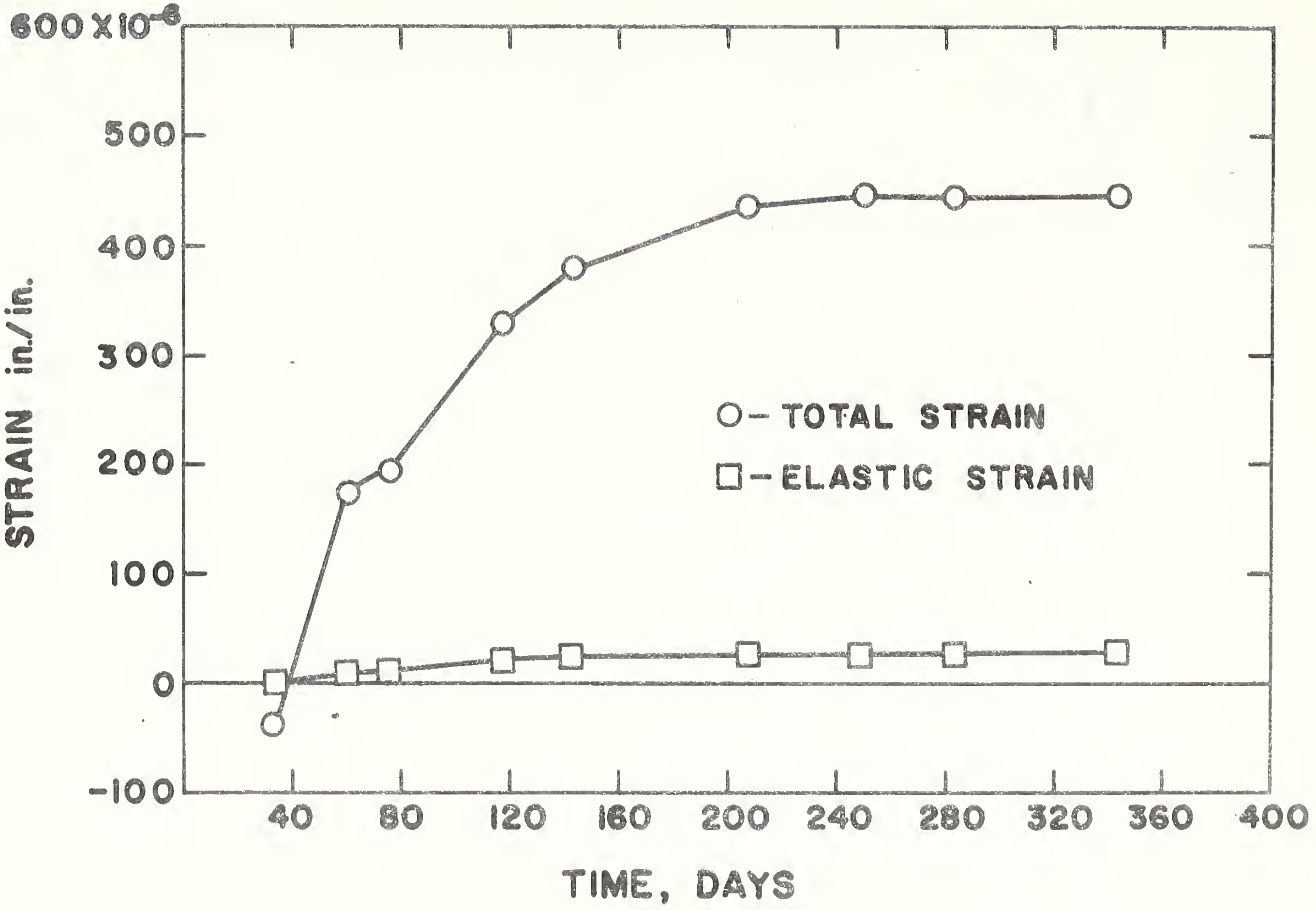

FIG. 4. STAINS AT TOP GAGE LINE ON BEAM AC - 2.

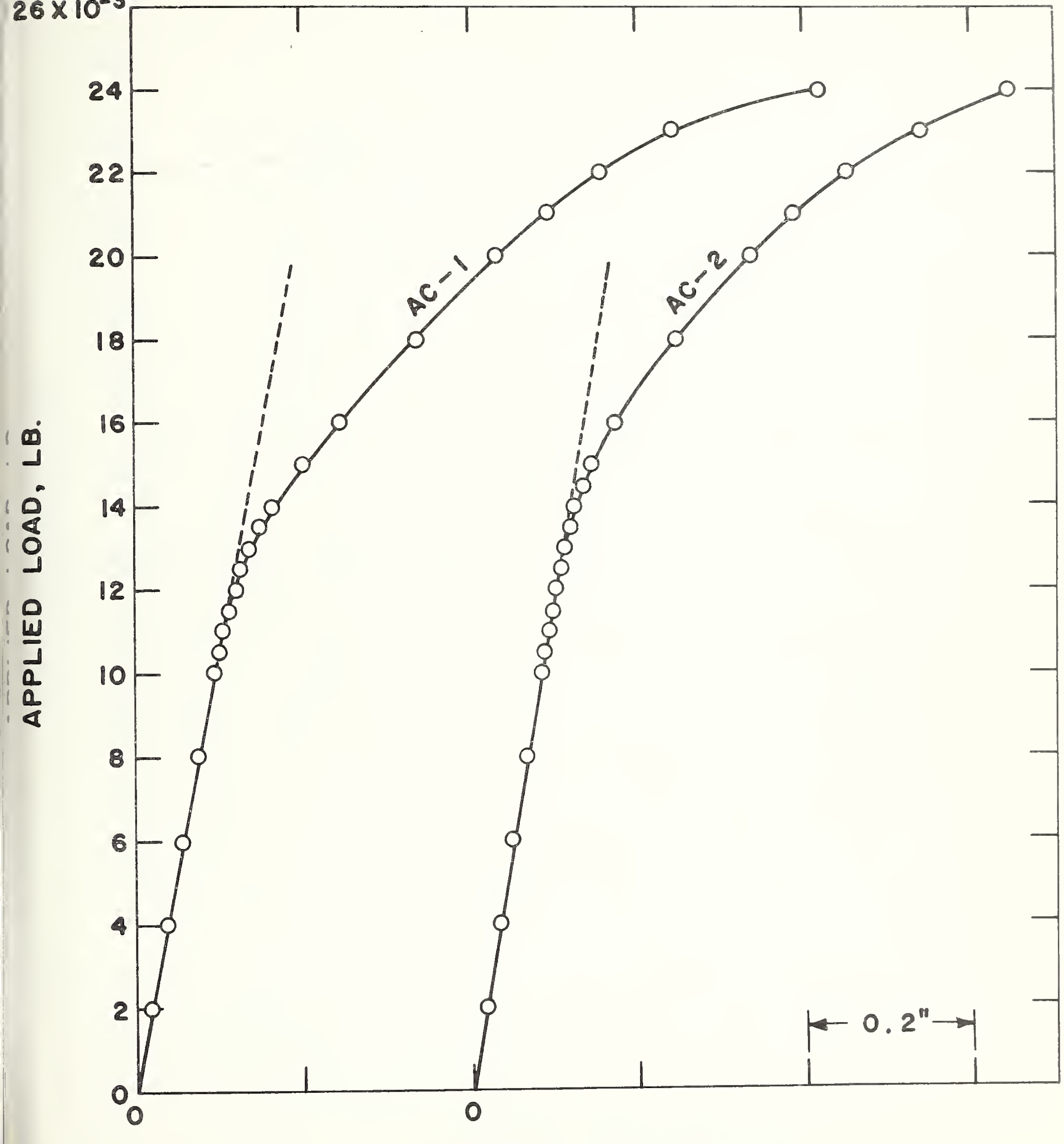

FIG. 5. LOAD-DEFLECTION RELATIONSHIP FOR BEAMS AC-1 AND AC-2.

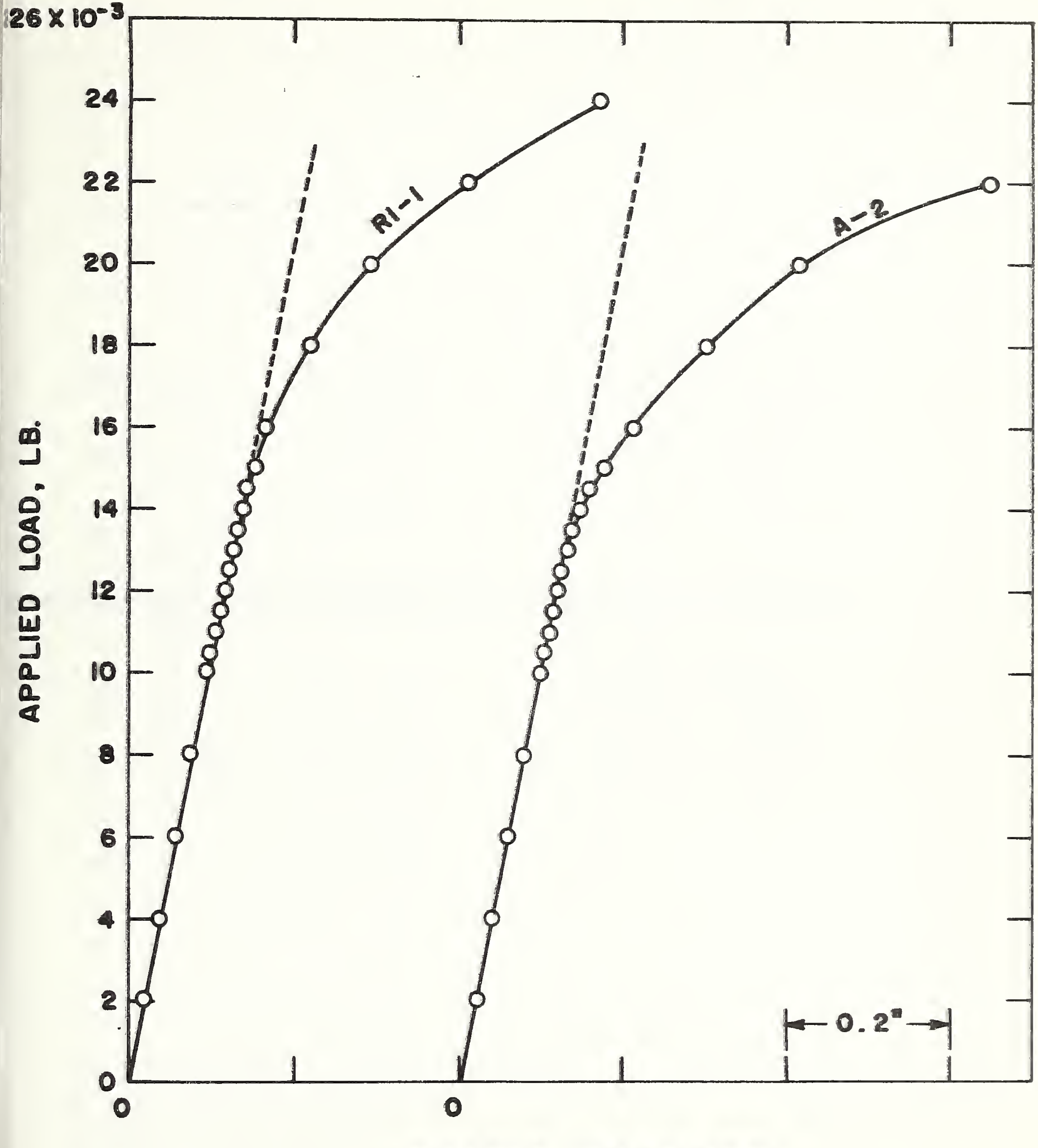

FIG. 6. LOAD-DEFLECTION RELATIONSHIP FOR BEAMS R1-1 AND A-2 FROM PREVIOUS TEST.

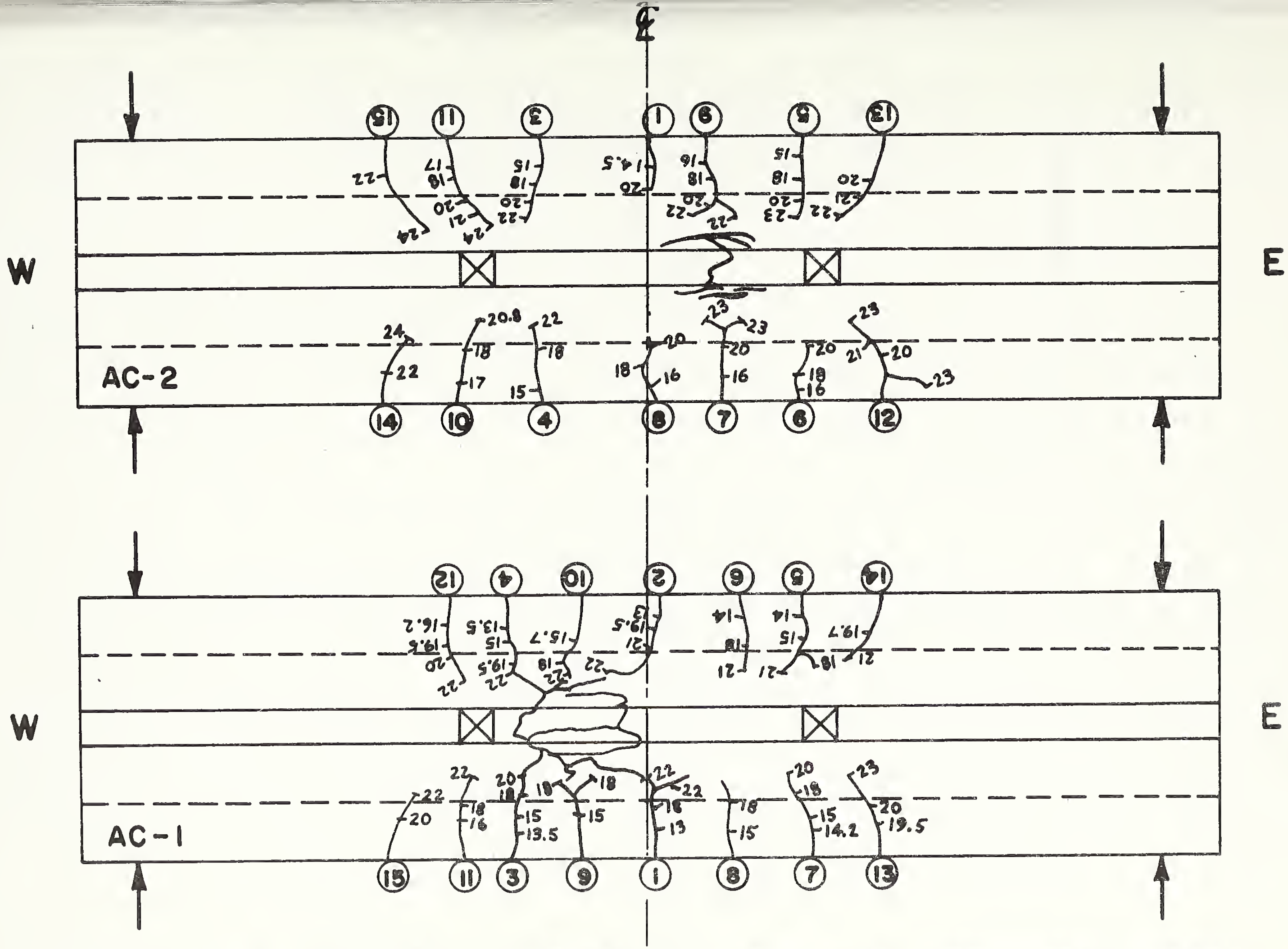

FIG. 7. CRACK PATTERNS OF BEAMS AC-1 AND AC-2. ENCIRCLED NUMBERS INDICATE ORDER OF OCCURENCE OF CRACKS. THE OTHER NUMBERS GIVE THE LOAD AS THE CRACKS EXTENDED UPWARD.


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