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NATIONAL BUREAU OF STANDARDS REPORT

9954

PULL-OUT STRENGTH OF INSERTS EMBEDDED IN REINFORCED CONCRETE SLABS

Progress Report to

The Construction Research Division
Post Office Department

NBS

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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NATIONAL BUREAU OF STANDARDS REPORT

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PULL-OUT STRENGTH OF INSERTS EMBEDDED IN REINFORCED CONCRETE SLABS

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Progress Report
By
Building Research Division
Institute for Applied Technology

For
Construction Research Division
Post Office Department

NBS

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"Pull-Out Strength of Inserts Embedded in Reinforced Concrete Slabs."

(A Progress Report)

1. Introduction

The investigation covered by this progress report is in accordance with a request from the Construction Research Division of the Post Office Department. This request outlined a comprehensive study of the effect of various factors on the load-carrying capacity of some typical inserts commonly used for suspending machinery from concrete ceilings.

Specifically, the scope of this study was presented in Task Order No. 3 for P. O. Project No. 68243, Work Assignment II to Project 68258, and Work Order No. 2 and 3 to P. O. Project 68471. Copies of these documents are presented in the appendix to this report.

The portion of the study presented in this report are as follows:

a. A preliminary investigation aimed at developing suitable testing procedures, apparatus, and test specimens.

b. An investigation of the effect of the positive and negative moments in continuous slabs on the pull-out strength.

c. A broad study of the effect of the type and strength of the concrete on the pull-out strength of the various inserts. Seven lightweight aggregate concretes and four normal weight concretes were studied.

d. A test to determine the pull-out strength of inserts at the intersection of the ribs in a typical waffle slab.

e. Trends indicated by uncompleted work on the effect of dynamic fatigue and high-level sustained loads on the pull-out strength.

2. Inserts

During the preliminary tests 6 types of inserts, designed to be used with 3/4 in threaded rods, were used.

Figure 1 is a photograph of these types. A listing of pertinent data from the manufacturer's catalog is given in Table 1. The inserts listed as 1a and 3a were added after the first few tests indicated that Type 1 and 3 would not satisfy the Post Office Department's requirements.

All the inserts were chosen from a listing supplied by the Post Office Department. After the preliminary tests the number of types were reduced to three (Type 2, 3a, and 4) to satisfy the Post Office Department specification requiring malleable-iron, threaded inserts. Although No. 2 was not malleable-iron, the performance of the insert-material (mild steel) was thought to be equivalent.

3. Test Apparatus, Specimens and Procedure

3.1 Apparatus

Figure 2 illustrates the apparatus used for applying tensile pull-out loads to the inserts embedded in the small slabs. The basic parts were:

1) a steel stand fabricated from 6-in. channels,

2) a center-hole 60 kip hydraulic ram powered with a

remote, hand-operated pump,

3) a center-hole, 60 kip, load cell,

4) an X-Y plotter for recording the output of the load cell, and

5) a 3/4 in., high-strength steel pull-rod.

When testing the continuous slab specimens the same apparatus was used except that the test stand had an effective span of 10-ft. instead of the 42-in. indicated in Figure 2. The test stand was always placed so that its span was in the same direction as the main reinforcement.

During early testing the pull-rod was connected directly into the insert. This method was not satisfactory in the cases where the insert was not perpendicular to the surface of the concrete slab. This happened when the alignment of the insert was disturbed during the casting operation. During later testing a steel "Eye" bold was coupled to the pull-rod with a forged-steel clevis. This method was very satisfactory especially for the misaligned inserts.

For some of the tests the vertical movement of the insert relative to the edge of the concrete slab was measured

by using an LVDT displacement transducer. The LVDT was mounted on the pull-rod and the core rested on a bridge supported at the mid-span edges of the slab. The output of the LVDT was fed to the "X" axis of the "X-Y" plotter used with the load cell. For these tests a continuous plot of the load-vertical movement data was recorded.

The span of the steel test stand was modified twice during the preliminary tests. The first span was 18 1/4 in. The second was 26 1/2 in. The final span was 42-in. as indicated in Figure 2.

3.2 Test Specimens

Except for the waffle slab all test specimens were 4 1/2 in. thick and simulated a portion of a one-way ceiling slab. The tension steel was No. 5 bars placed 6-in. on centers on 3/4 in. bolsters. The temperature steel was No. 3 bars, usually at 12-in. on centers.

All 4 1/2 in. slabs were cast in wood forms. The inserts were nailed to the bottom of the form with 1-in. roofing nails. The slabs were turned over for testing.

For the preliminary tests two different size slabs were used. The first size used had a width of 19-in. and a length of 28 3/4 in. This size is referred to as the 2 x 3 slab in this report. The second size, referred to hereafter as the 4 x 4 slab, had a test surface of 42-in. x 45-in.

For the main part of the investigation 3 types of slabs were used. These were:

1) The 4 x 4 slab (actual dimensions 42-in. x 45-in. x 4 1/2-in. thick). One insert was placed at the center of each slab.

2) The continuous slab specimens (actual dimensions 42-in. x 22-ft. x 4 1/2-in. thick). In addition to the positive moment steel, negative steel (#5 bars at 8-in.) was used over the center 6-ft. of the slab. This steel was placed with 3/4-in. cover from the top surface as cast. Nineteen inserts were placed along the center line of each slab.

3) The waffle slab specimens (overall dimensions 6-ft. x 15-ft. x 12-in). This slab was formed using

10-30 x 30 x 10-in. metal pans. Two-No. 5 bars were placed 3/4 in. from the bottom of each 6-in. rib in the long directions and 2-No. 5 bars were placed on top of these in the other direction. Welded wire fabric (66-1010) was placed over the pans. Inserts were placed at each of the interior intersections of the ribs. Figure 3 illustrates the waffle slab reinforcement.

3.3 Concrete

All concretes were mixed in 8 to 10 cu. yd. commercial transit mixers in about 3 cu. yd. batches. All the normal weight concrete batches were standard ready-mix proportions. This was also true for the lightweight concrete made with the L1 lightweight aggregate.

For the concretes made with L2 through L5 lightweight aggregates the ready-mix contractor supplied the cement and usually the sand. For these concretes the lightweight aggregate was measured and placed in the mixer by NBS personnel. These concretes were proportioned as recommended by the aggregate producer except that water was added until a suitable consistency was attained.

The actual amounts of water in the concretes are not known. This is due to two factors. 1) The water content of the sand was not known. 2) The water measurement gages on many of the mixers were practically unreadable.

Table 2 and 3 presents the aggregate and mix data for the concretes used in the main part of the study and Table 4 presents the strength data. The compressive strengths aimed for were either 3000 or 5000 psi. As can be seen from Table 4 the target was not always attained.

None of the specimens were damp cured. This was done to simulate the conditions which exist on many construction jobs.

3.4 Test Procedure

The testing procedure was rather simple. The tensile pull-out load was applied to the insert at a uniform rate until failure occurred. The maximum load attained during the test was called the pull-out strength. Typical failures are illustrated in Figures 4 and 5.

During the initial tests there were indications that the maximum load was a function of the rate-of-loading. For

that reason a standard loading rate of 2 kips per min. was established. This rate meant that the maximum load was reached in about 6 min. for typical pull-outs.

4. Test Results

4.1 Preliminary Tests

The preliminary tests were to be primarily an investigation directed at the development of test procedures, but the data developed was of some further interest. This was especially true when considering the different types of inserts. A resume of the preliminary test results is presented in Table 5.

4.1.1 Inserts

Type 1 Insert

This insert was designed to be used with a special 5/16 in. thick nut. In the pull-out test the 3/4 in. threaded rod simply sheared the threads off the nut. There was no indication of any failure in the concrete or slab. In further tests with this insert, a sulphur-silica capping

compound was heated and poured into the insert-cavity and around the nut and threaded rod. This procedure increased the capacity of the insert sufficiently to permit pulling the insert out of the concrete.

Type 1a Insert

This insert was similar to Type 1 except that it was designed to be used with the head of a 3/4 in. bolt. Only one test was carried out on this insert. It failed at about the same load and in the same manner as the Type 1 with capping compound.

Type 2 Insert

This insert usually (60% of the time) failed by fracture of the wire loop near the points where it was welded to the ferrule (Figure 4). Even when the loop did not fracture prior to pull-out the wires were highly necked down and near the point of fracture.

Type 3 Insert

This cast iron insert fractured 60% of the time just below the threaded portion (similar to Type 5 in Figure 4).

The load at fracture of the insert varied from 5.6 to 16.4 kips.

Type 3a Insert

This insert was not used in the preliminary tests.

Type 4 Insert

This insert had the greatest capacity in the preliminary tests. Invariably the 2 x 3 test slabs were cracked severely from end to end during the pull out test (Figure 4). The insert did not appear to be damaged by the test.

Type 5 Insert

This cast iron insert fractured 60% of the time just below the threaded portion (Figure 4). The load at fracture of the insert varied from 9.8 to 15.4 kips.

Type 6 Insert

This special, thin-slab insert was included in the program in order to compare its capacity with that of

Type 2. It should be noted from Figure 1 that the only obvious difference between Types 2 and 6 is the direction of the wire loop. The results shown in Table 5 indicate that the capacity of Type 6 is about 50% that of Type 2. The Type 6 Insert did not appear to be damaged by the test.

4.1.2 Concrete Slabs

The concrete specimen used in the batch 1 and 2 tests (Table 5) was the 2 x 3 slab. It can be seen in Figure 4 that the Type 4 Insert test virtually demolished the slab. It was decided that a larger slab should be used so that the severe cracking would not extend to the test stand supports. The 4 x 4 slab was substituted and appeared to be satisfactory. Figure 5 illustrates typical crack patterns in the 4 x 4 slab during the Type 4 Insert tests.

4.1.3 Span of Test Stand

The first test stand had a span of 18 1/4 in. which proved to be insufficient because of the restraint to cracking offered by the stand supports. This span was used for batch 1 tests (Table 5).

The batch 2 tests were run with a test-stand-span of 26 1/2 in., the maximum possible with the 2 x 3 slab. Here again the span proved to be insufficient.

Finally the span of the test stand was extended to 42 in., the maximum possible with the 4 x 4 slab.

4.1.4 Discussion of Results

<u>Inserts</u> Because of a Post Office Department specification requiring malleable iron inserts suitable for 3/4 in. threaded bars the inserts to be used in further tests were limited to Types 2, 3a and 4. Type 6 was eliminated because of its special application and its low capacity relative to the others. Type 1 was eliminated because its capacity was limited by the nut supplied with the insert.

<u>Concrete Slabs</u> The 4 x 4 ft. slab appeared to be satisfactory for individual insert tests when used with the 42 in. test stand.

4.2 Continuous Slab Tests

4.2.1 Continuous Slab Specimens

These slabs were designed as one-way slabs to be continuous over three supports spaced at 10 ft. on centers. The reinforcement was as described in section 3.2.2. Four continuous slabs were cast from concretes designated as S-1, 2, 3 and 4 in Tables 3 and 4. In addition, four companion 4 x 4 slabs, with single inserts were cast with the S-2, 3 and 4 continuous slabs.

The continuous slabs were 42 in. wide x 22 ft. long x 4 1/2 in. thick. Nineteen inserts were cast in each slab at about 12 in. on centers. The slabs were cast as is normal with the inserts nailed to the bottom of the form. The slabs were turned over for testing.

4.2.2 Test Procedure

Figure 6 illustrates a typical slab ready for test. Air pressure applied to two plastic air bags, placed between the slab and the floor, was used to provide the force necessary to simulate uniform service loads. Three steel cross-members, placed across the slab at 10 ft. centers and bolted to the tie-down floor, provided the reactions to the loads.

The air pressure in the bags was adjusted to that required for the simulated service loads. The simulated live load on slab S-1 was 150 psf while the load on S-2, 3 and 4 was 90 psf.

Figure 7 is a close-up showing the method of applying the pull-out load to the inserts. The LVDT and bridge used in measuring the vertical movement of the insert is also shown.

The S-1 slab was considered a trial specimen to be used for refinement of the test procedure and 4 x 4 control specimens were not cast for it. For each of the others, the four 4 x 4 control specimens were tested at the same time as the continuous slabs.

4.2.3 Test Results

The pull out test results for the four slabs are given in Figures 8, 9, 10, and 11. It is obvious from these plots that there is a definite relationship between the insert locations and the pull out strengths, especially at locations close to the reactions.

It should be noted that not all the inserts were tested. Generally, every other insert was pulled out first and then the balance were pulled out. However, many times the first pull out cracked the slab in such a manner that the neighboring inserts might have been effected. When this happened the neighboring inserts were not pulled.

The pull-out strengths for the inserts in slabs S-2, 3 and 4 are plotted in Figure 12 in a non-dimensional form. These strengths are expressed as their ratio to the pull-out strengths of the inserts in the companion 4 x 4 control slabs and are plotted against their distance from the nearest support (reaction).

The curve drawn on Figure 12 is an average computed from 5 sets of the plotted points.

4.2.4 Discussion of Results

These data indicate that for comparable continuous slabs the average pull out capacity of the inserts more than 3 feet from a support would be 75% of the capacity determined on the 4 x 4 slabs. However, some may be as low as 60%.

Conversely, inserts placed close to a support would have higher strengths than indicated by the 4 x 4 slab tests. However, as nearly all inserts in an actual slab would be at least 3 feet from a supporting member there doesn't appear to be any advantage in allowing more than one design load.

An analysis indicates that the moments from the simulated live load had no significant effect on the pull-out strengths. The moment from the concentrated pull-out load far over shadows that from the live load.

4.3 The 4 x 4 Slab Tests

This series of tests, using the 4 x 4 slab specimen, was designed to provide data suitable for evaluating the effect of the following variables on the pull-out strength.

a) Type of insert

b) Strength of concrete

c) Type of concrete

The concrete-slab test-specimen was described in Section 3.2. From each batch of concrete 12 - 4 x 4

slabs and at least 9 - 6 x 12 in. control cylinders were cast. Each group of 12 slabs was subdivided into 3 sets of 4 each. Each set of 4 slabs had one type of insert. The inserts were placed at the center of the slabs.

The reinforcement was spaced symmetrically about the center lines so that the center pair of main bars were each 3 in. from the center and the center pair of temperature bars were each 6 in. from the center.

The test procedure was described in Section 3.4.

4.3.1 Results

Table 6 presents the pull-out strength data for the 4 x 4 slab tests. Each pull-out strength shown is the average of the tests from a set of four slabs. This data is presented as a bar-graph in Figure 13.

a) Effect of Type of Insert

Insert Type 2, 3a, and 4 were included (see Figure 1 and Table 1) in this series of tests. From Table 6 it is apparent that the Type 4 Insert has slightly greater pull out strength than Type 3a or Type 2. The average of all

the tests in Table 6 indicate that the pull-out strength of 3a is 92% of Type 4 and Type 2 is 87% of Type 4.

The differences between the strengths of the three inserts appear to be a function of the type of concrete. For the normal-weight concrete (indicated by "H" in concrete symbol) the average strength of Type 3 is 98% of Type 4 while for the lightweight concretes (indicated by "L" in concrete symbol) this ratio is 89%.

The situation changes when comparing the Type 2 insert to the Type 4. In this case the ratios for the normal-weight and lightweight concretes are both 87%.

The Type 2 insert (Figure 1) is made so that a reinforcing bar can be passed through the wire loop resulting in a possible increase in its pull out strength. However, in 50 of 66 tests made on this insert the wire in the loop fractured. This would indicate that a bar within the loop could not increase the strength. Further analysis of the lower strength, lightweight concrete data indicates that in lightweight concretes with strengths of 3000 psi or less there might be a slight advantage. No tests were made with bars in the loop.

One Type 2 insert was tested in a hydraulic testing machine to determine the tensile strength of the wire (diameter 0.26 in.) in the loop. A 1.5 in. round, steel bar 12 in. long inserted through the loop of the insert, was used to hold the insert in the upper head of the machine. A 24 in. piece of 3/4 in. threaded bar, screwed into the insert, was gripped by the lower head. The ultimate load was 6880 lb. Both sides of the wire loop necked down considerably with one side fracturing. This failure was typical of those in the pull-out tests.

b) Effect of Strength of Concrete

The effect of compressive-strength differences on the pull-out strength for the normal-weight concretes is not obvious from the data available. Two factors tend to obscure the relationship. 1) The rather limited range in strengths, and 2) The rather wide scatter in the pull-out strength data.

Pull-out strength data from 4 different lightweight concretes made with the L-1 aggregate are plotted in Figure 14. For two of these concretes data is available only for the Type 4 Insert. Therefore only Type 4 pull-out strength data for Concretes L-1 and L-1A, batch 3 of the

preliminary tests, and a concrete for fatigue tests (unreported as yet) were used in plotting Figure 14. The straight line drawn through the data on this figure indicates that the pull-out strength for the Type 4 insert would be about 3.4 times the compressive strength.

The data from the two concretes made with the L-2 aggregate (L-2 & L-2a, in Table 6) indicate that a similar relationship probably holds, but no estimate was made.

For the lightweight concretes it appears that there is a relationship connecting pull-out strength with compressive and/or splitting strength when individual aggregates are considered. However, when considering all the lightweight concretes the relationship is obscure and no general statement can be made with the data available.

c) Effect of Type of Concrete

It is apparent from the data in Table 6 that the pull-out strengths are less in lightweight than in the normal-weight concretes. The strengths of the 4 normal-weight and of the 7 lightweight concretes were averaged. These averages indicate that the pull-out strength of the

inserts in the lightweight concretes would be about 80% of that in the normal weight. The average compressive strength of all the normal weight concretes was only 3670 psi while the average for all the lightweights was 4000 psi.

Furthermore there appears to be some differences in pull-out strength which can be attributed to differences in aggregate. For instance note the differences in pull-out strength between the specimens made with the L-1 aggregate (L-1 and L-1A) and with the L-2 aggregate (L-2 and L-2A).

4.3.2 Discussion of Results

The test results indicate that:

a) There are measurable differences in the pull-out strengths of the various inserts and that the differences vary with the type of concrete.

b) There appears to be a relationship between the compressive strength of lightweight concretes made with a particular aggregate and the pull-out strength. And there is probably a series of relationships between the compressive strength and pull-out strength for all concretes, but it is not apparent from the data available.

c) Inserts in lightweight concretes will have lower pull-out strengths than when in normal weight concrete.

4.4 Waffle Slab Test

For this test four Type 3 Inserts were cast in the concrete at the four interior intersections of the 6 in. ribs (Figure 3). The intent was to determine if the pull-out strength was effected by the relatively thin section of concrete around the insert. It should be noted that standard practice requires the placing of two reinforcement bars in both directions at the bottom of the ribs. This

practice, which was followed for this test, results in the insert being positioned so that bars are close to the insert on four sides.

Only one slab (designated as W-1), with four Type 3 Inserts, was tested. Figure 15 is a photograph of this slab after testing. The crack pattern (accentuated by felt pen) is easily visible showing how the cracks tended to extend along a line just below the reinforcement. The average pull-out strength was 15.5 kips. The pull-out test was made using the 42 in. test stand placed on the transverse ribs.

The results indicate that the pull-out strength of Type 3 Inserts in similar waffle slabs will be as good or better than that in a 4 1/2 in. flat slab. There is no doubt that the inserts were restrained by the reinforcement as evidenced by the crack patterns in the ribs.

4.5 Trends from Uncompleted Tests

4.5.1 Sustained Load Tests

These tests are to be used to determine the maximum pull-out load which can be carried by an insert for an

indefinitely long period of time. (See Work Order No. 3 to Project 68471 in appendix.) These loads were to be determined using the 4 x 4 slabs made with two different concretes.

The tests are underway, but significant data have not been developed. The trends indicate that the long-term pull-out strength will be of the order of 90% of the short-term strength.

4.5.2 Dynamic Fatigue Tests

These tests will be used to determine the dynamic (cyclic) fatigue characteristics of an inserts in the 4 x 4 slabs made with 2 different concretes. (See Work Order No. 2 to Project 68471 in appendix).

The work has been completed on the lightweight concrete, but not on the normal-weight (stone) concrete.

The lightweight concrete (F-2) was the standard, 6 bag, semi-light-weight mix used previously. The compressive strength at the time of the fatigue test was 3450 psi. The splitting strength was 370 psi.

The results show that for this concrete using the Type 4 Insert the limiting value of the pull-out strength under cyclic fatigue (10 cps) is about 60% of the short-term static strength.

In these tests 2 specimens loaded to 62% of the static strength had not failed after 1.9×10^6 cycles. However, 3 specimens loaded to 66% failed after an average of 2.4×10^5 cycles.

5.0 Summary and Conclusions

The following conclusions are valid only for conditions simulated by the test procedures and concretes mentioned above. In general the conclusions are based on results for the 4 x 4 slabs.

5.1 Inserts

Eight different inserts were used in these tests, but because only three types were used in most of the tests conclusions are given only for these three (Types 2, 3a and 4).

1. The average pull-out strengths for the inserts in normal weight concrete with an average compressive strength of 3670 psi are: Type 2 - 12.7 kips, Type 3a - 14.3 kips and Type 4 - 14.6 kips.

2. The average pull-out strengths in a lightweight concrete (5 different aggregates) with an average compressive strength of 4000 psi are: Type 2 - 10.4 kips, Type 3a - 10.6 kips and Type 4 - 11.9 kips.

5.2 Strength of Concrete

1. No estimate can be made at this time regarding the general effect of the compressive, or splitting strength, of normal-weight concrete or lightweight concretes on the pull-out strength.

2. For the lightweight concrete made with one lightweight aggregate (L-1) an estimate can be made. The pull-out strength of the Type 4 insert in this concrete is about 3.4 times the compressive strength.

3. It seems likely that there is a relationship between the pull-out and compressive strength for

other concretes although there appears to be significant factors other than strength.

5.3 Type of Concrete

1. On the average, the pull-out strength of the inserts when embedded in a lightweight concrete was 80% of the strength when in a normal weight concrete.

2. There appears to be differences in pull-out strengths which can be attributed to differences in the lightweight aggregates used in the concretes.

5.4 Position of Insert

1. When the inserts in a 4 1/2 in. one-way slab are 3 ft. or more from an end support in the direction of the main reinforcement the pull-out strength is about 75% of that determined on the 4 x 4 slabs.

5.5 Waffle Slab Ribs

1. The pull-out strength of the insert when placed at the intersection of the 6 in. ribs in a waffle

slab is probably equivalent or better than that determined in 4 1/2 in. thick, flat slab.

5.6 Sustained and Fatigue Loads (Tentative)

1. The sustained load pull-out strength is of the order of 90% of the static, short-term strength.

2. The pull-out strength under cyclic fatigue loading is considerably lower than the static short-term strength. The fatigue strength for Type 4 inserts in a lightweight concrete was between 62 and 66% of the short-term strength for about 2 million cycles.

5.7 Design Loads for Inserts

The two most critical factors in determining design loads for these inserts in slabs, such as were used in this investigation, are the position of the inserts relative to their supports, and the presence of cyclic fatigue loads on the inserts. If it is assumed that all inserts are at least 3 ft. from the closest support and that the loads carried by the inserts are cyclic by nature

then the maximum load capacity of an insert would be a combination of the two reduction factors (75% and 60% of the static test on the 4 x 4 slab). No tests were made to determine if these factors are additive as could be assumed.

5.8 Research Required

The results presented above have raised a number of questions. These are:

1. What part does the position of the reinforcement relative to the insert have on the pull-out strength? The results presented above were for specimens made by laboratory technicians who placed the bars according to the specs. The tolerances for the placement in the field are rather large.

2. How do we combine the individual reductions in capacity indicated for fatigue loading and for the span effect?

3. If the concrete strength is increased above the 3000 to 4000 psi range is it permissible to allow an increase in the pull-out strength for the inserts?

4. What effect does angular loads and/or angular displacement of the insert have on the pull-out strengths? It would be practically impossible to insure that these inserts would be embedded perfectly in the field. Even in the laboratory some problems were encountered. In addition, under service conditions, there is often a component of the load which is not vertical.

TABLE 1 Manufacturer's Catalog Data

Insert No.	Source	Catalog Name	Type of Metal	Ultimate Strength, in Concrete	Working Load
1 1/	Hohmann & Bernard	Universal - All size nut	Mall. Iron		3,000
1a 2/	Richmond	Malleable adjustable	Mall. Iron	7650	3,020
2	Superior	Threaded insert	Steel	10,000	—
3	Hohmann & Bernard	Threaded Insert	Gray Cast Iron	12,500	3,100
3a 3/	Hohmann & Bernard	Threaded Insert	Malleable Iron	15,300	3,800
4	Richmond	Rocket	Malleable Iron	11,900	3,020
5	Richmond	Kohler	Gray Cast Iron	12,400	3,020
6	Richmond	Thin Slab Ferrule	Steel	—	—

1/ Type 1 insert came with a special 5/16" thick nut tapped for 3/4" thread.

2/ Similar to type 1 except made for head of standard 3/4" bolt.

3/ Same as type 3 except for metal.

TABLE 2 Aggregate Description 1/

Concrete	Type of Concrete	Type of Aggregate		Source of Aggregate	
		Coarse	Fines	Coarse	Fines
H-1 & H-1A	Normal Weight	Crushed Stone	Natural Sand	Md.	Md.
S-1, 2, 3, & 4	Normal Weight	Crushed Stone	Natural Sand	Md.	Md.
W-1	Normal Weight	Crushed Stone	Natural Sand	Md.	Md.
H-2 & H-2A	Normal Weight	Gravel	Natural Sand	Md.	Md.
L-1 & L-1A	Semi-Lt. Wt.	Crushed Exp. Shale	Natural Sand	Va.	Md.
L-2 & L-2A	Semi-Lt. Wt.	Crushed Exp. Shale	Natural Sand	Ga.	Md.
L-3	Semi-Lt. Wt.	Coated Exp. Shale	Natural Sand	Ill.	Md.
L-4	Lightweight	Coated Exp. Shale	Expanded Shale	Calif.	Calif.
L-5	Semi-Lt. Wt.	Crushed Exp. Shale	Natural Sand	Texas	Md.

1/ The lightweight aggregates were made from either shale, clay or slate, but since the raw materials ~~was~~ were not identified they are all called expanded shale. The lightweight aggregates were furnished through the courtesy of the Expanded Shale, Clay and Slate Institute of Washington, D.C.

TABLE 3 Concrete Mixes

Concrete	Type of Concrete	Nominal Cement Content	Nominal 28-Day Strength	Slump	Fresh Unit Weight
		Sacks/Yd	psi	in	pcf
H-1	Crushed Stone	5	2500	___	___
H-2	Gravel	5	2500	4"	___
H-1A	Crushed Stone	6	3000	5"	___
H-2A	Gravel	6	3000	5"	___
L-1	Semi-Lt. Wt.	6	3000	6.5	117
L-2	Semi-Lt. Wt	5.75	3000	1.75	114
L-3	Semi-Lt. Wt.	5.5	3000	1.0	115.
L-4	Lightweight	5.25	3000	1.5	96.
L-5	Semi-Lt. Wt.	5.5	3000	2.0	120
L-1A	Semi-Lt. Wt.	8	5000	2.5	119
L-2A	Semi-Lt. Wt.	7	5000	3	117
S-1	Crushed Stone	4	2000	7	___
S-2	Crushed Stone	5	2500	6	___
S-3	Crushed Stone	5	2500	6 1/2	___
S-4	Crushed Stone	5	2500	5	___
W-1	Crushed Stone	5	2500	5	___

TABLE 4 Concrete Strengths 1/

Concrete	Target Compressive Strength	Measured Compressive Strength (f^1_{ci})	Measured Splitting Strength (T)	Age At Test
	Psi	Psi	Psi	Days
H-1	3000	3480	—	7
H-2	3000	3150	380	7
H-1A	5000	3950	—	27
H-2A	5000	4110	450	19
L-1	3000	2640	270	35
L-2	3000	3040	350	8
L-3	3000	5420	400	17
L-4	3000	3300	280	5
L-5	3000	3370	330	8
L-1A	5000	5050	370	19
L-2A	5000	5200	480	20
S-1	3000	2640	—	18
S-2	3000	3830	—	21
S-3	3000	3940	—	15
S-4	3000	3110	—	12
W-1	3000	3330	420	7

1/ At the time of pull out test.

TABLE 5 Preliminary Test Results

Insert No.	Batch 1 1/ No. of Tests	Batch 1 1/ Average Pull Out Strength	Batch 2 2/ No. of Tests	Batch 2 2/ Average Pull Out Strength	Batch 3 3/ No. of Tests	Batch 3 3/ Average Pull Out Strength	Typical Failure
		Psi		Psi		Psi	
1	3	10.5	1	11.1	—	—	See text. Sect. 4.1
1A	—	—	1	12.0	—	—	Insert pu out.
2	3	12.4	2	10.5	—	—	60% of inser fractured
3	3	14.1	2	10.2	—	—	60% inser fractured
4	3	17.0	8	14.4	3	5.3	Insert pu out with concrete
5	3	12.8	2	11.7	—	—	60% of inser fractured
6	3	7.0	2	5.8	—	—	Insert pu out with crete con

1/ Crushed stone concrete, compressive strength about 5500 psi.

2/ Crushed stone concrete, compressive strength about 5000 psi.

3/ Semi-lightweight concrete, compressive strength about 1500 psi only 3 test were run on batch 3 because of the poor quality concrete.

TABLE 6 Test Results for 4 x 4 Slabs

Concrete	Compressive Strength [1/]	Pull Out Strength Insert No. 2	Insert No. 3a	Insert No. 4
	Psi	Kips	Kips	Kips
H-1	3480	10.0	12.0	12.0
H-2	3150	12.5	14.6	15.8
H-1A	3950	14.9	17.4	16.2
H-2A	4110	13.5	13.1	14.5
Avg. Normal Wt.	3670	12.7	14.3	14.6
L-1	2640	10.2	11.5	11.6
L-2	3040	8.0	8.9	9.9
L-3	5420	10.9	10.3	11.5
L-4	3300	7.2	7.3	9.3
L-5	3370	9.2	10.6	11.5
L-1A	5050	15.3	14.1	15.8
L-2A	5200	11.8	11.5	13.4
Avg. Lt. Wt.	4000	10.4	10.6	11.9

1/ At the time of the pull out test

2/ Each value is average of the tests on each set of 4 slabs.

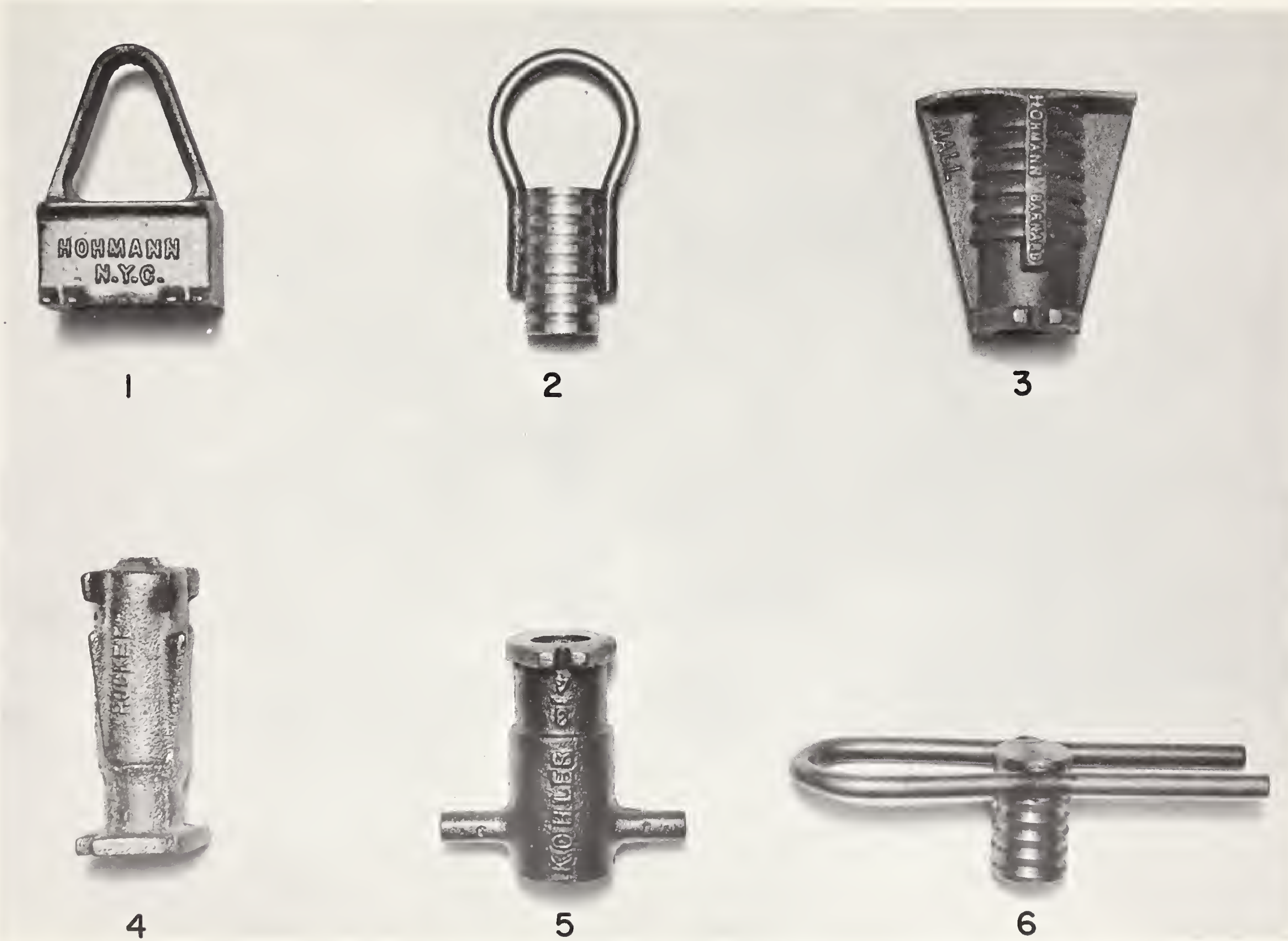

Figure 1, Inserts and Identification Numbers

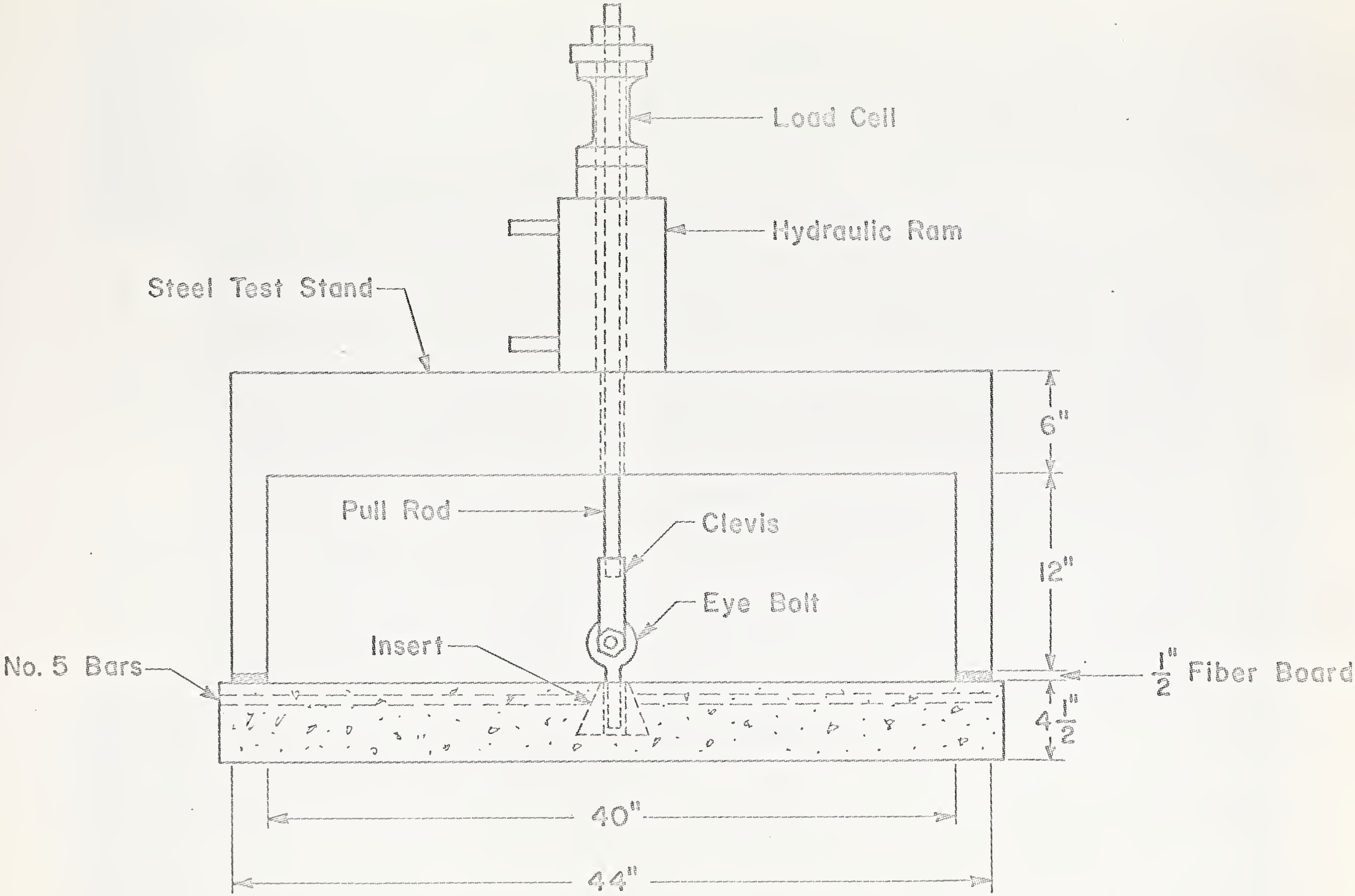

Figure 2 Pull-Out Test Apparatus

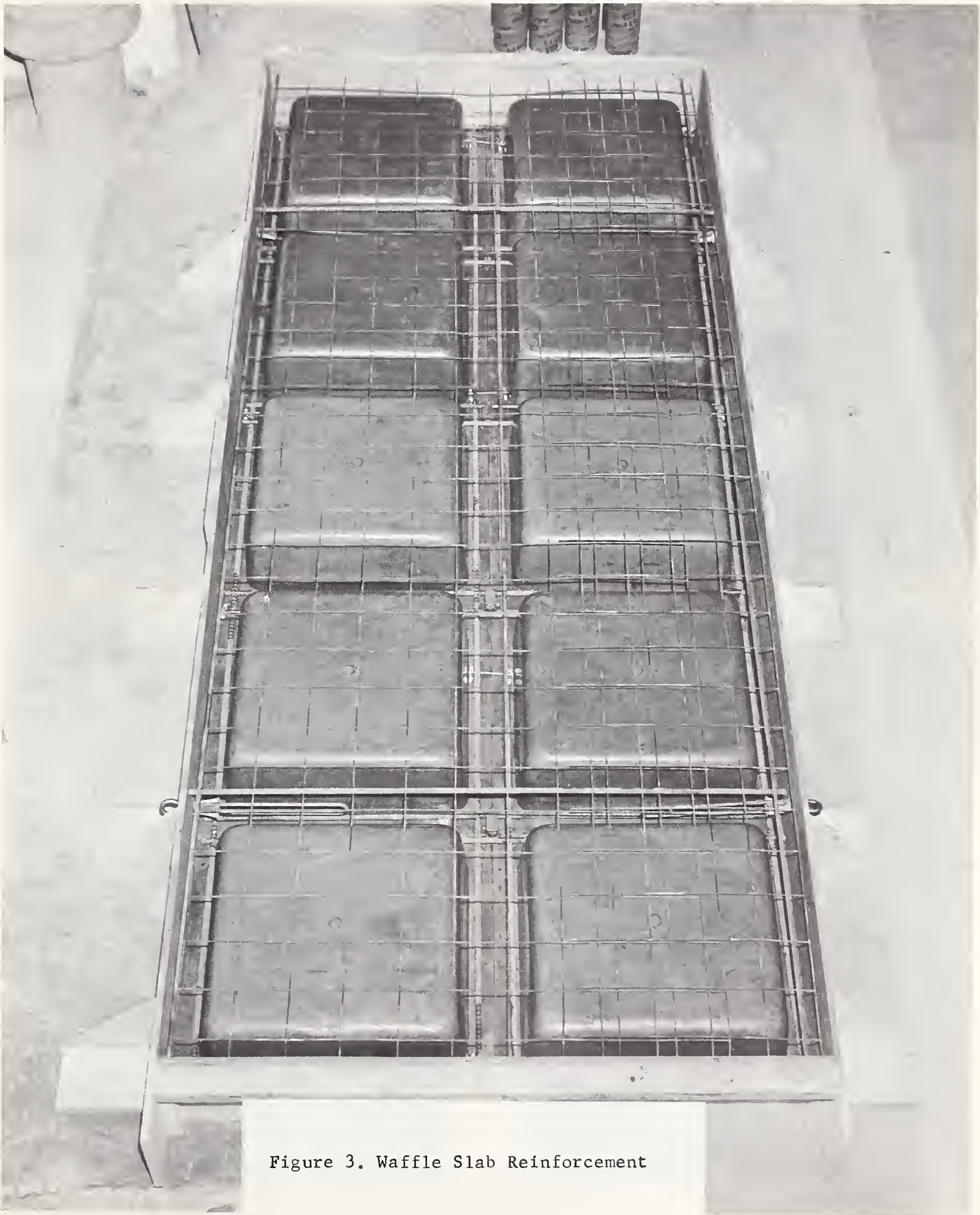

Figure 3. Waffle Slab Reinforcement

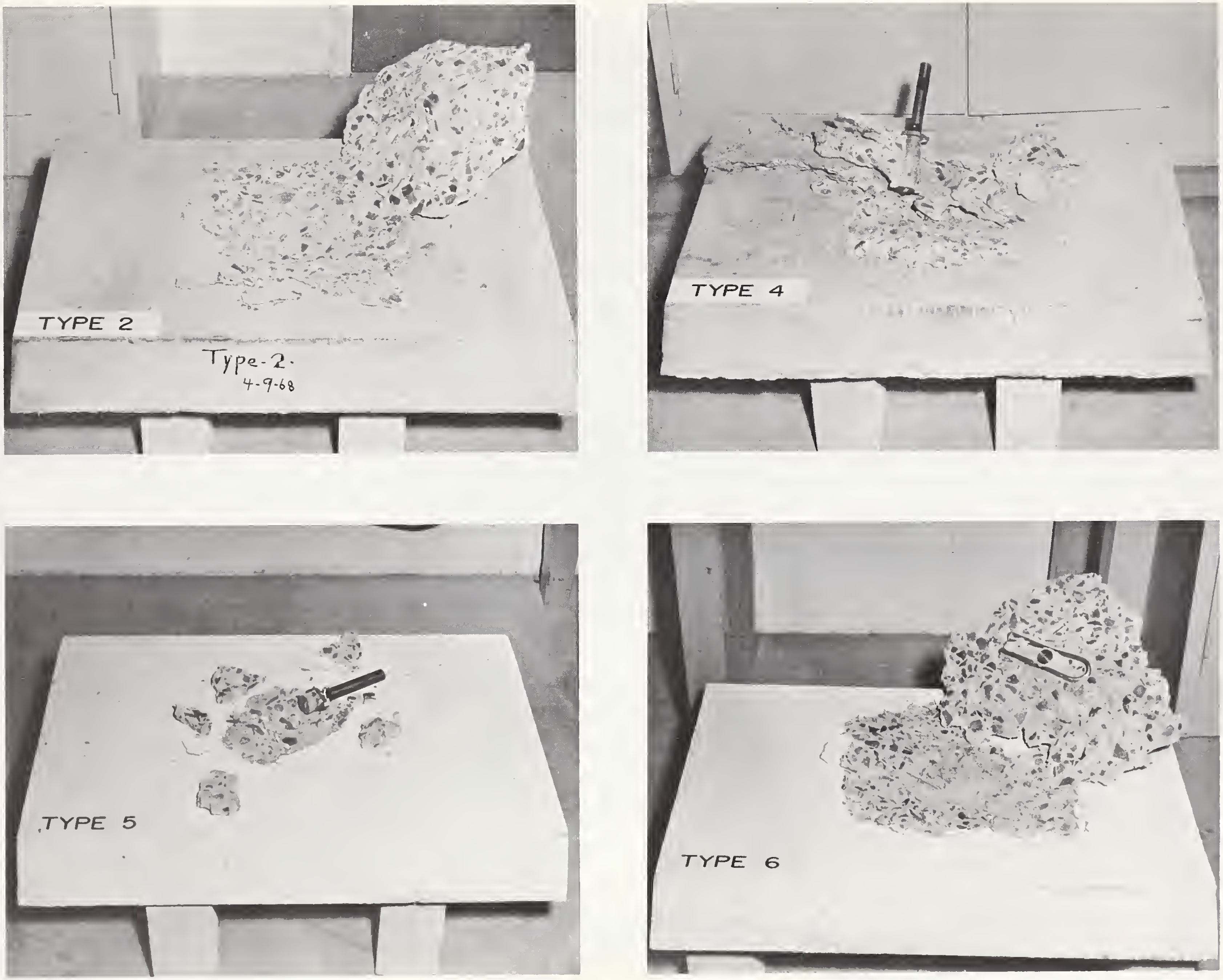

Figure 4. Typical Failures in
2-ft. x 3-ft. Slabs

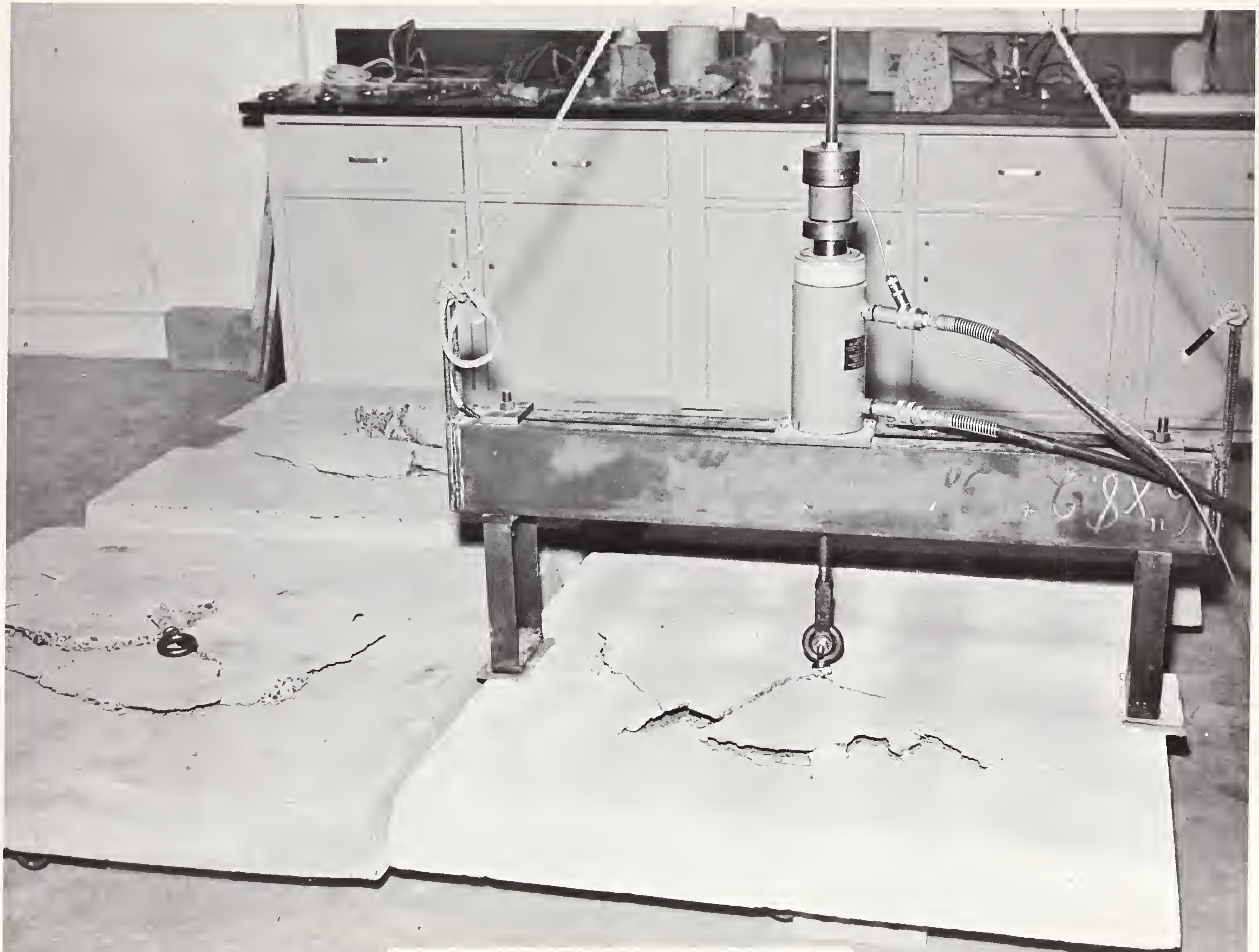

Figure 5. Test Setup and Failure in 4-ft. x 4-ft. Slabs

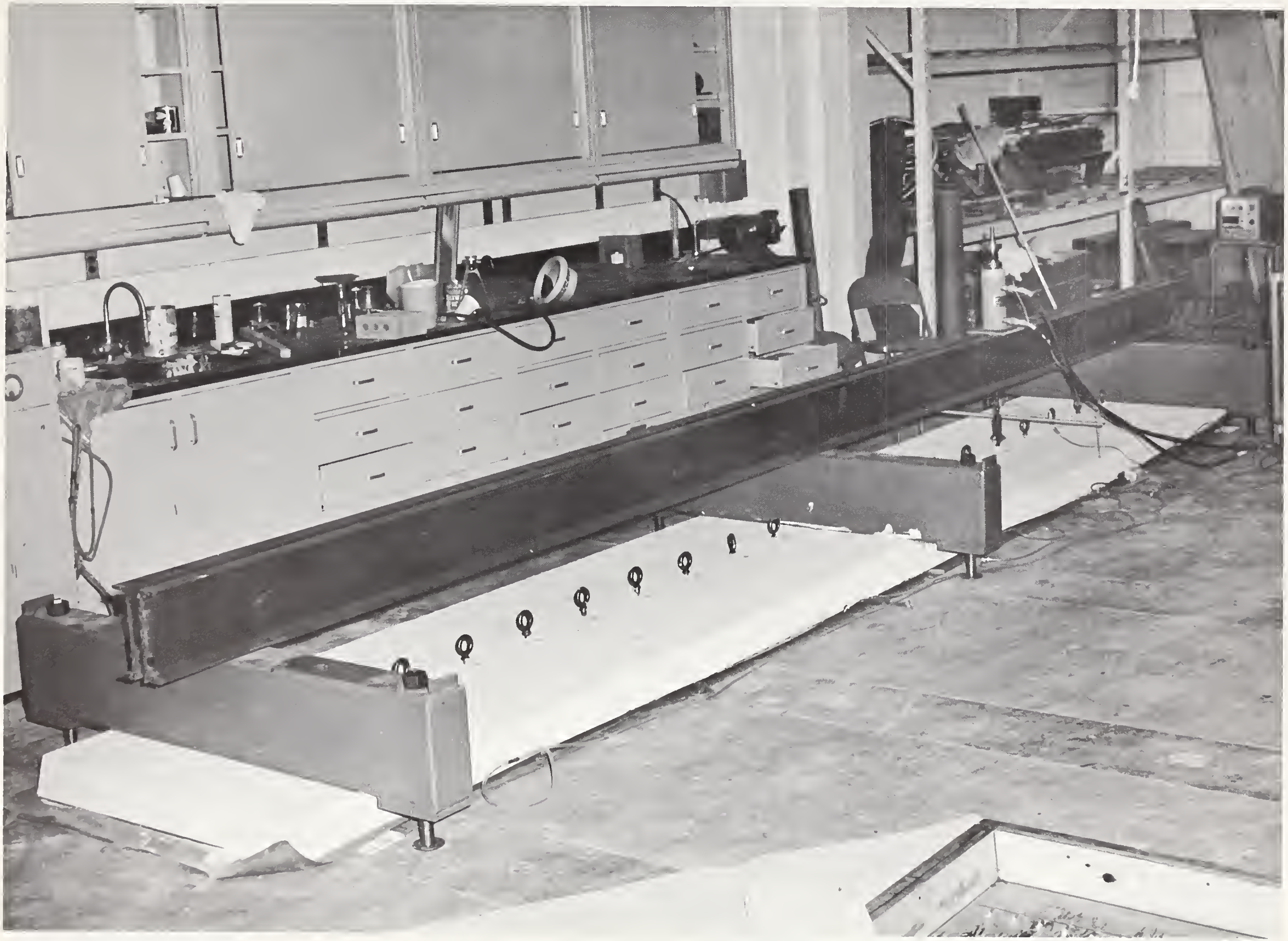

Figure 6. Test Setup for 4-ft. x 22-ft.
Continuous Slab

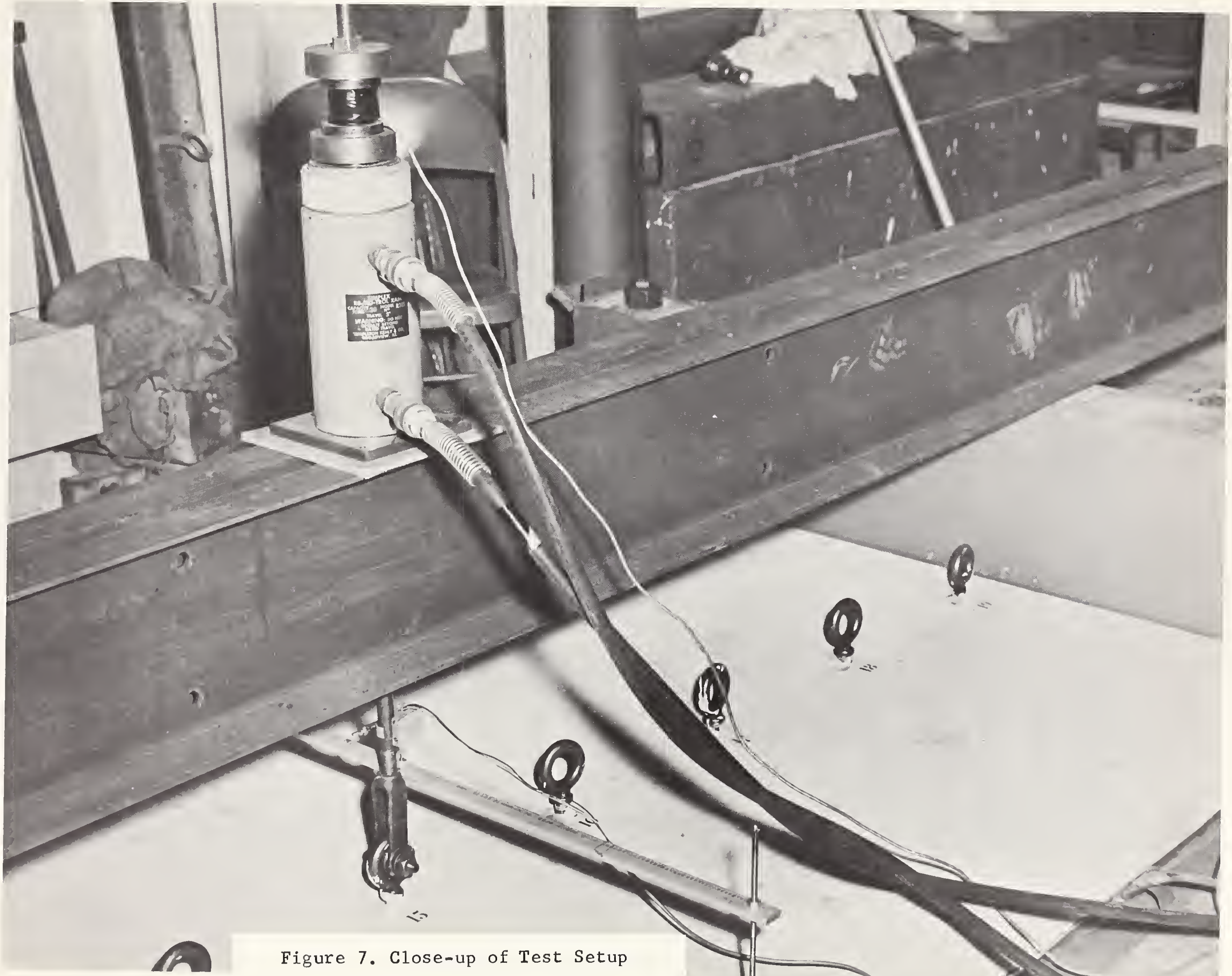

Figure 7. Close-up of Test Setup
for Continuous Slab

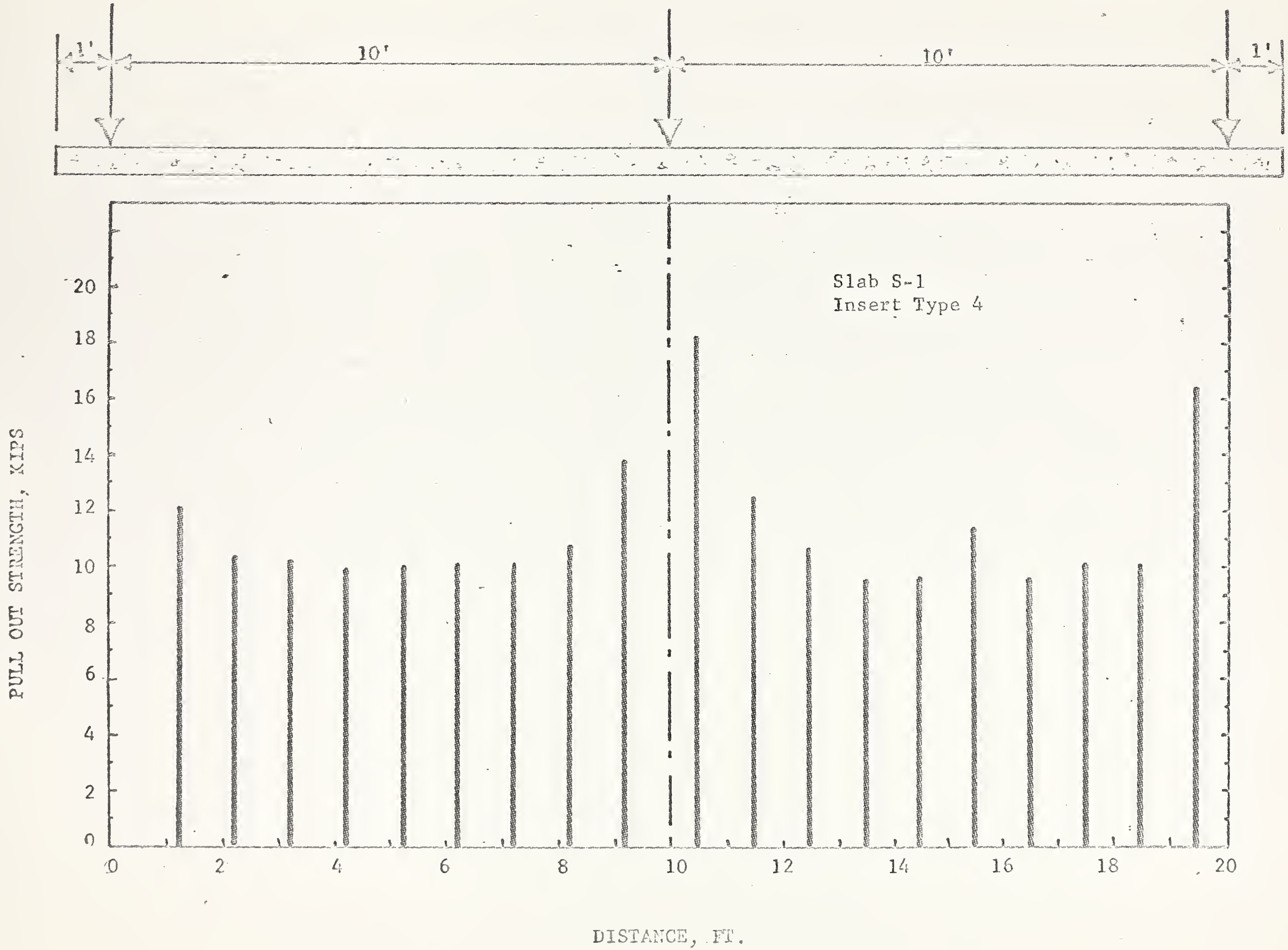

Figure 8 Pull-out Strengths of Individual Inserts in Slab S-1

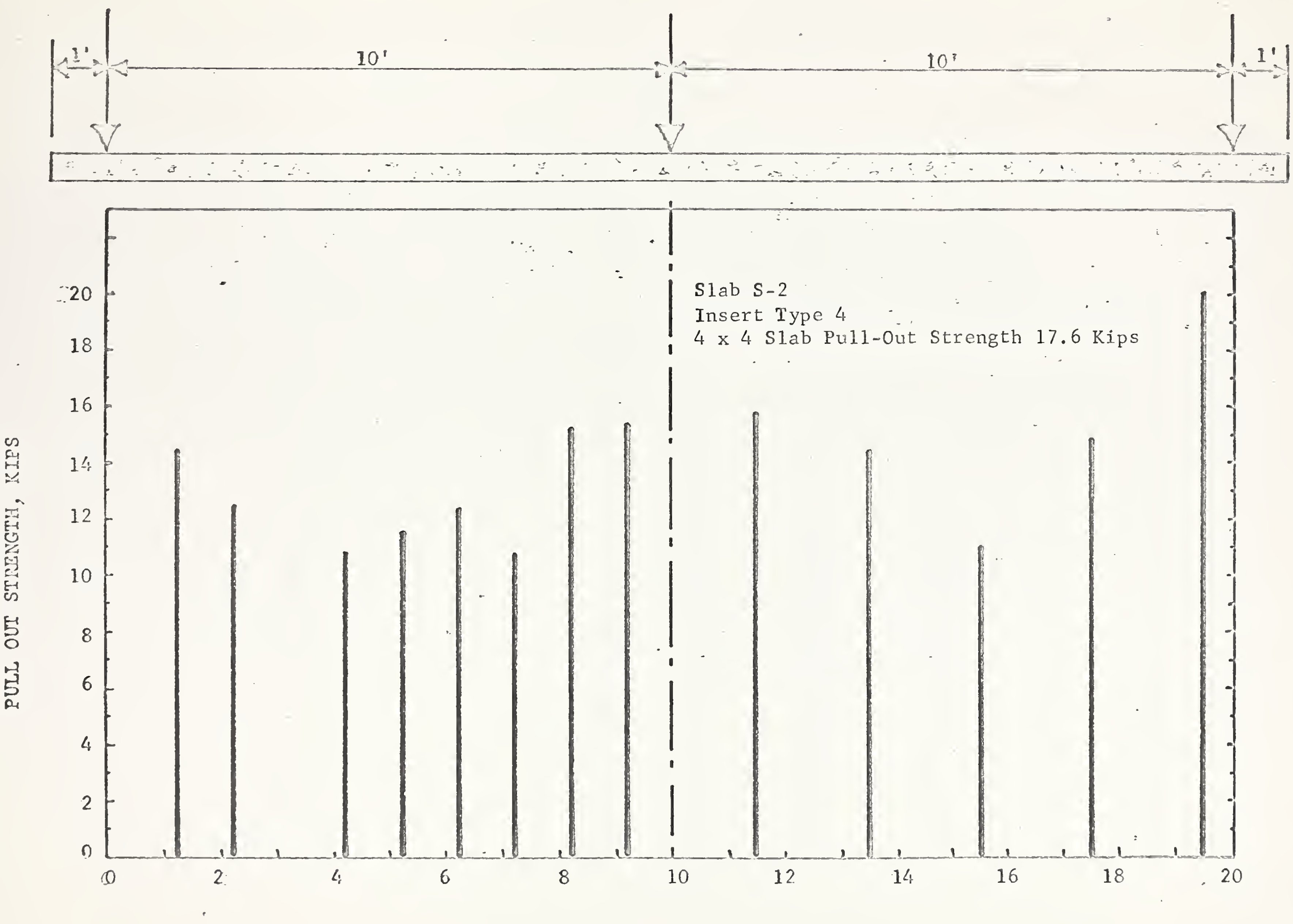

Figure 9 Pull-Out Strengths Of Individual Inserts In Slab S-2

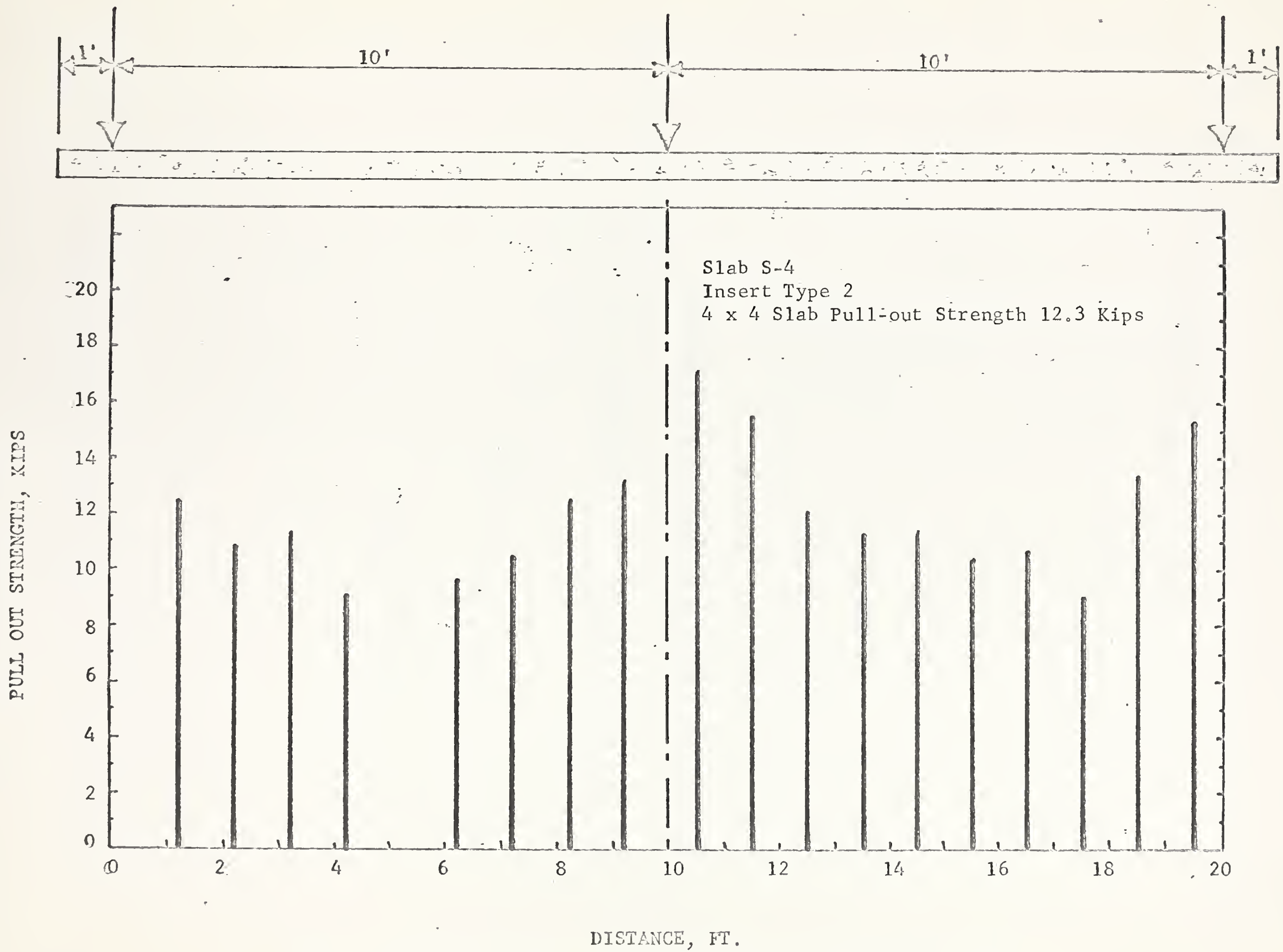

Figure 10 Pull-Out Strengths Of Individual Inserts In Slab S-3

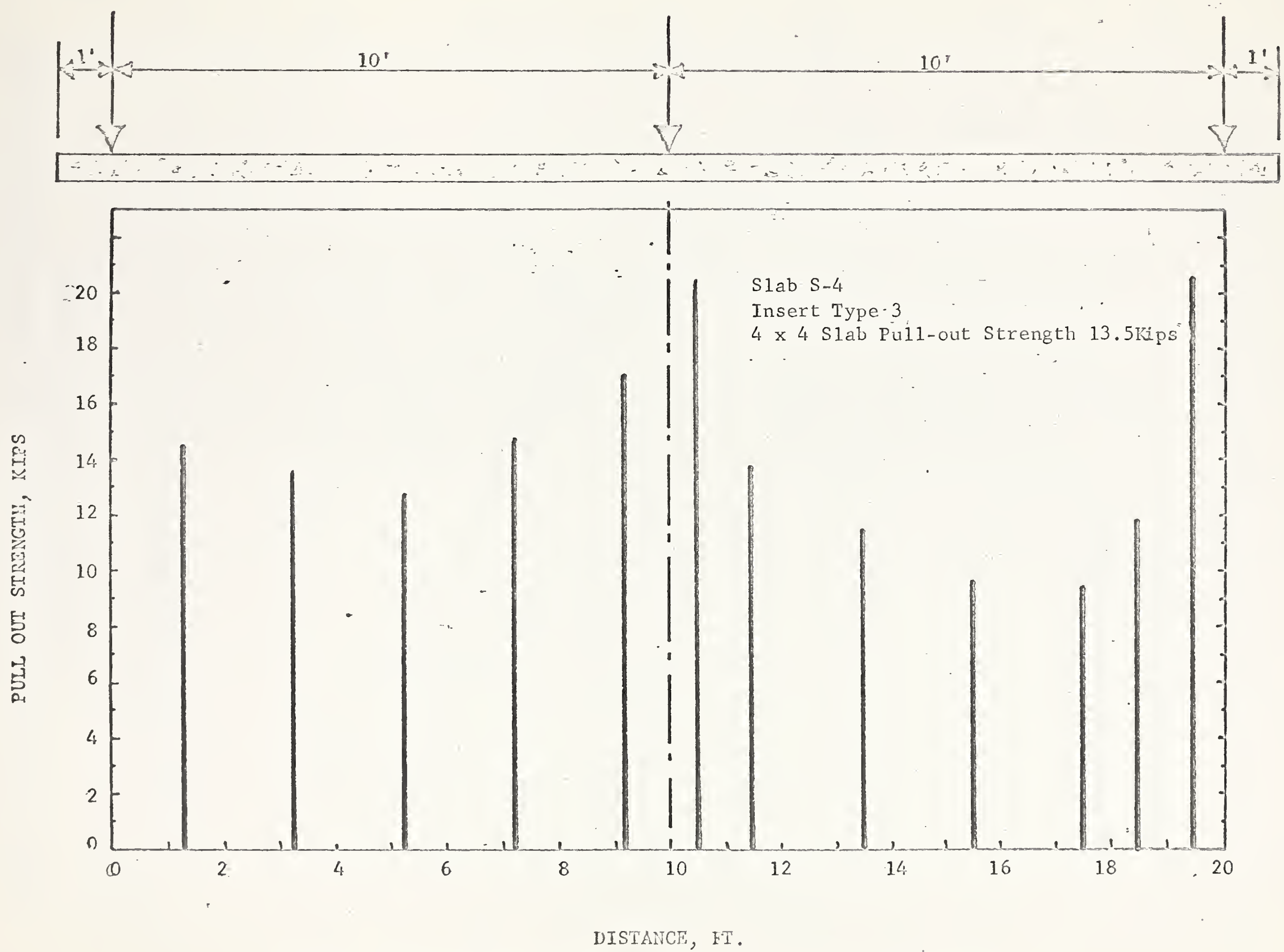

Figure 11 Pull-Out Strengths of Individual Inserts In Slab S-4

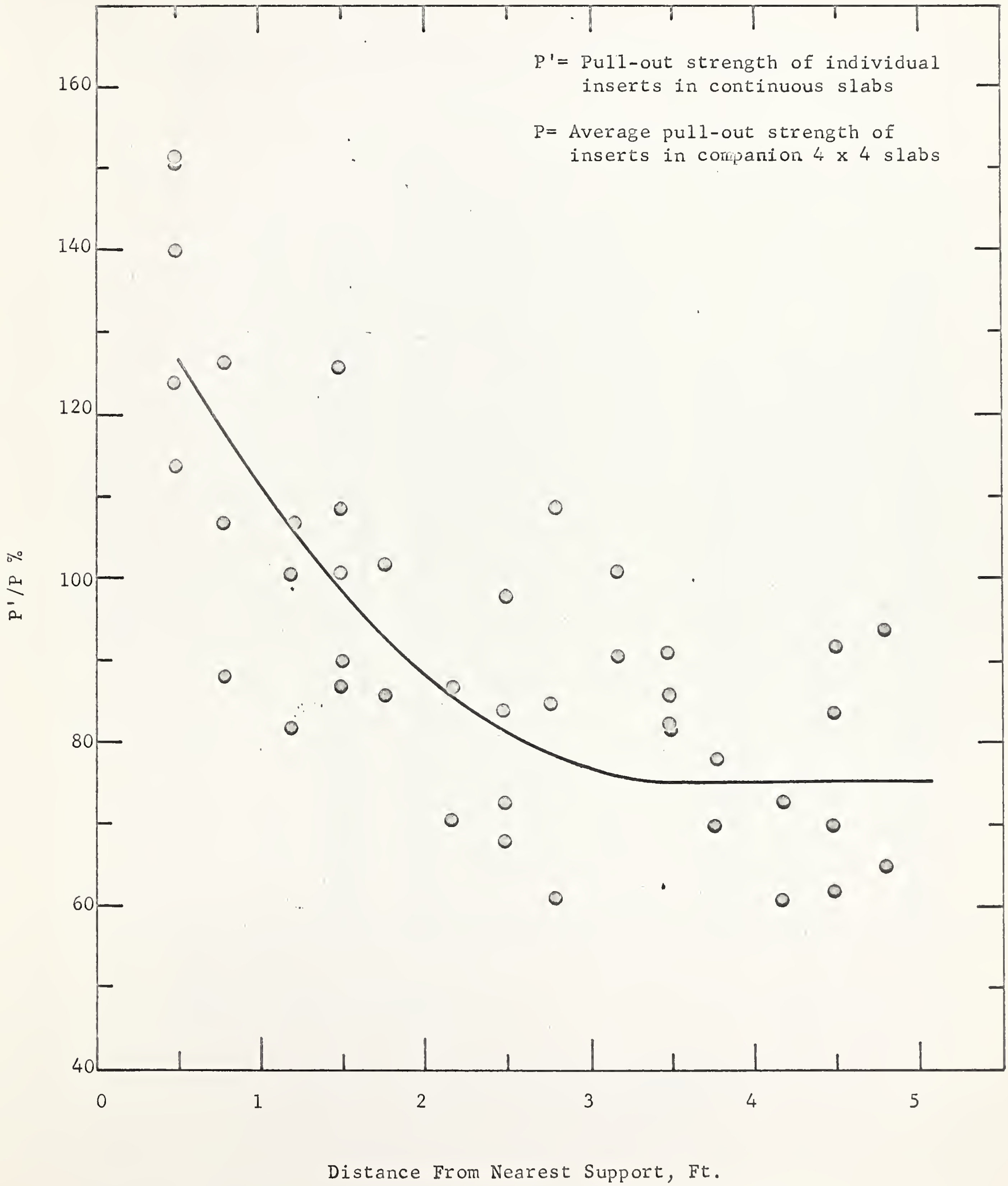

Figure 12 Continuous slab pullout strength data for slabs No. 2, 3, and 4.

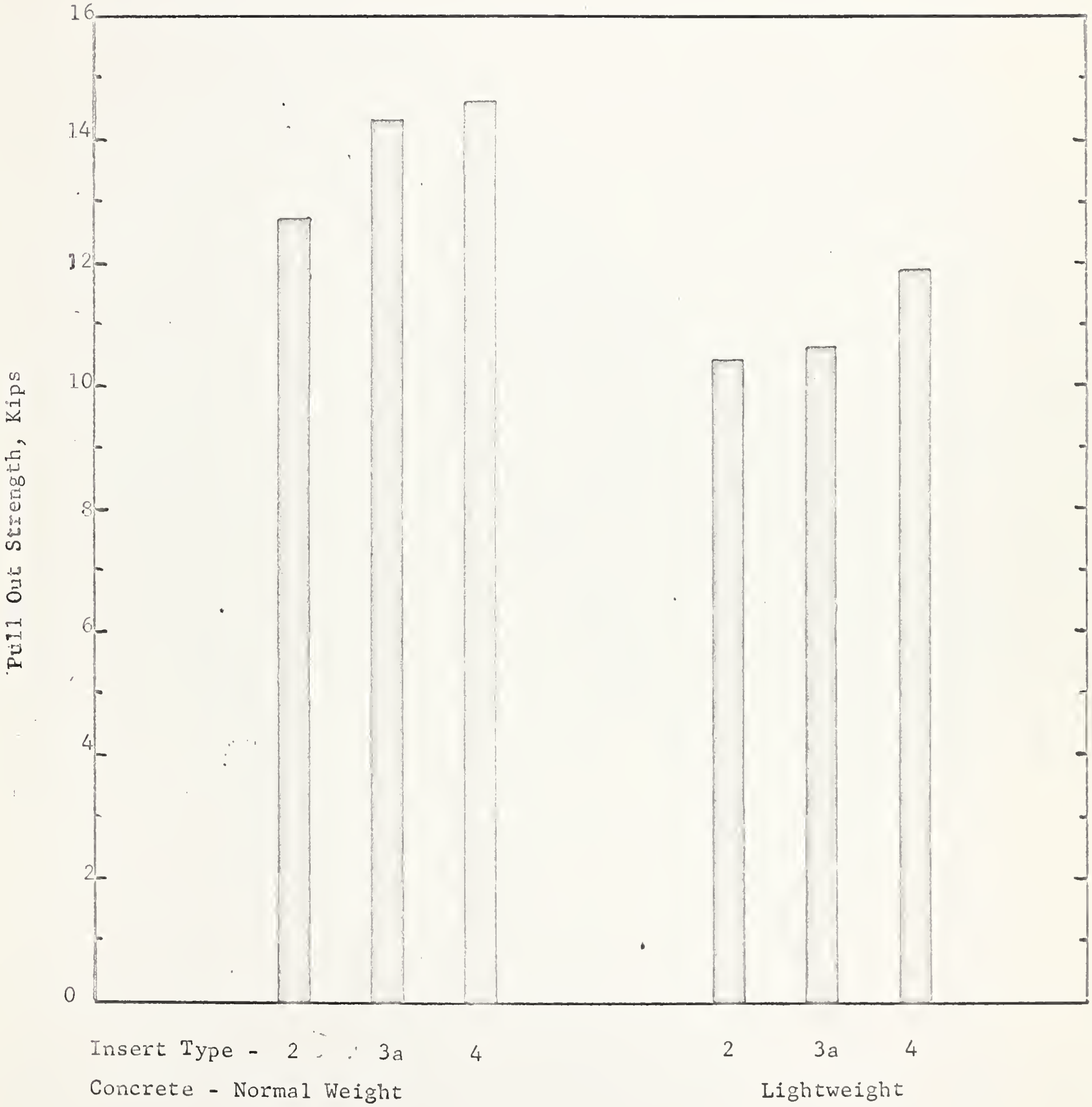

Figure 13 Average Pull-Out Strengths For Inserts in the 4 x 4 Slabs

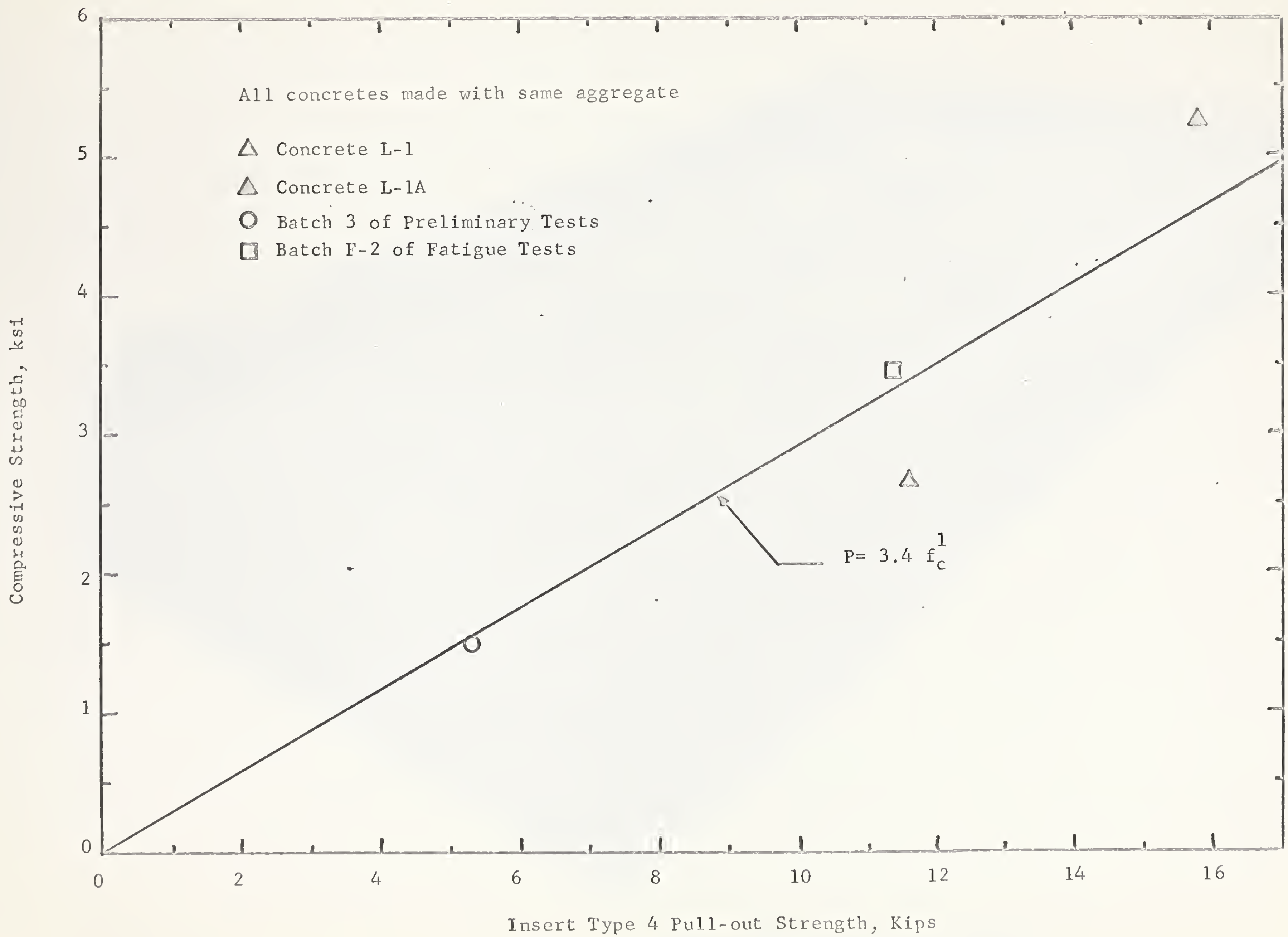

Figure 14-Compressive Strength Vs Pull-Out Strength for Insert Type 4 in Lightweight Concrete

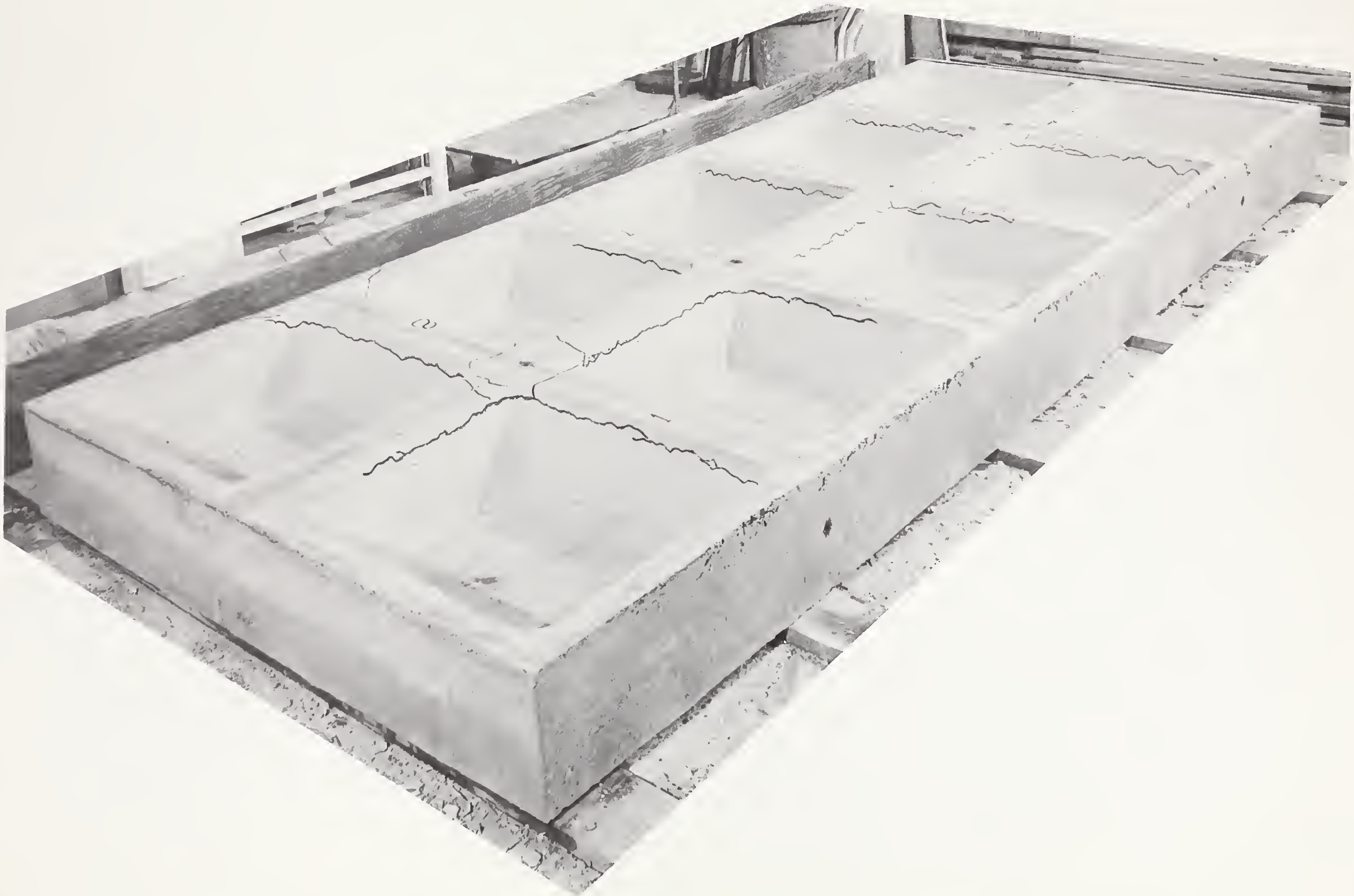

Figure 85 Waffle Slab after Testing