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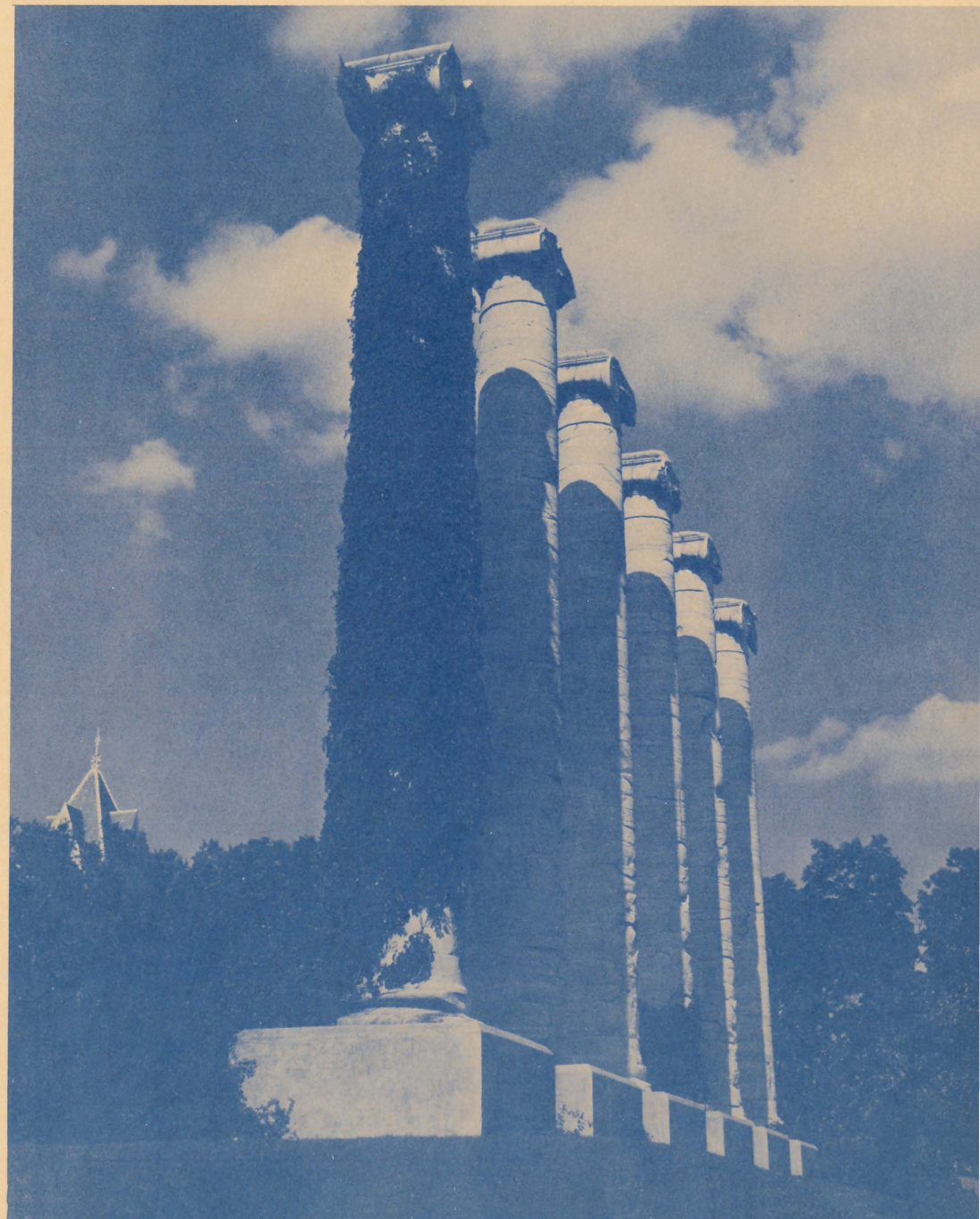
Push-Out Tests of Stud and Channel Shear Connectors In Normal-Weight and Lightweight Concrete Slabs

by

Lawrence N. Dallam



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I. INTRODUCTION

1.1 General

It has been shown by previous investigators that a composite concrete-steel beam is stiffer, stronger and usually more economical than the non-composite concrete slab on steel beam.(1) The composite behavior of the beam is accomplished by interconnecting the concrete slab and steel beam in such a way as to prevent relative movement between the slab and steel beam. Mechanical devices called shear connectors can be welded to the flange of the steel beam to prevent or limit this relative movement. The types of shear connectors most generally employed to date have been studs (headed type or L type), standard channel sections, and spirals.

Recommendations for the design of composite concrete-steel flexural members are given in the current AISC and AASHO Specifications. Both specifications cover the use of stone aggregates in the concrete slab but do not cover the use of lightweight aggregates in the slab. This exclusion is due to a lack of test data for lightweight concretes. The specifications in general are based on push-out tests and some full-scale tests. The push-out test is a direct shear test which is described in Art. 2.1.

1.2 Object and Scope of Tests

A testing program was initiated to study the behavior and efficiency of shear connectors in composite structures, and to determine the relationship between lightweight and normal-weight concretes in composite design. This phase of the investigation was to include a series of push-out tests using both normal-weight and lightweight concretes in the slab with studs and channels as shear connectors. The results were to be compared with those reported by other investigators.

(1) Numerals in parentheses refer to corresponding references in the bibliography.

Twenty-four push-out specimens were tested with static loading. The variables studied were stud diameter or channel length and type of concrete.

1.3 Acknowledgements

The testing program presented in this report was conducted at the Civil Engineering Laboratory under the supervision of the Engineering Experiment Station of the University of Missouri in cooperation with the State Highway Commission of Missouri and the Bureau of Public Roads of the U. S. Department of Commerce. This report covers the testing program for the period between September 13, 1962, through June 30, 1963.

The program was performed with the guidance of an advisory committee consisting of the following personnel:

Representing the U. S. Bureau of Public Roads:

R. C. Gibson, Regional Bridge Engineer

Mitchell Smith, District Bridge Engineer

Representing the State Highway Commission of Missouri:

D. B. Jenkins, Chief Engineer, Division of Bridges

R. R. Cox, Senior Bridge Engineer

Representing the University of Missouri:

Adrian Pauw, Professor of Civil Engineering

L. N. Dallam, Assistant Professor of Civil Engineering

General direction of the investigation was provided by Adrian Pauw. All work performed on the project was under the supervision of L. N. Dallam. Messrs. M. H. Proctor and R. Shaw were graduate students working on the project. Messrs. R. Thornton and D. Morton were the project technicians and their assistance is gratefully acknowledged. The studs were furnished by Nelson Stud Welding of Lorain, Ohio. The report was typed by Frances Gordon Williamson and Barbara O'Dell Herder.

II. DESCRIPTION OF SPECIMENS AND APPARATUS

2.1 Description of Specimens

Two types of push-out specimens were used and are shown in detail in Figure 1. The type A specimen consisted of a steel 8WF48-beam section 39 inches long, and two concrete slabs 30 x 24 x 6 inches; while the type B specimen consisted of a steel 8WF48-beam section 20 inches long, and two concrete slabs 20 x 24 x 6 inches. The type A specimen was similar to the specimen used by Dr. I. M. Viest in his significant series of push-out tests.[2] In each type of specimen the concrete slabs were connected to the steel beam either by two studs or one channel per slab.

The studs were all nominally four inches in height with a diameter of 1/2, 5/8, 3/4 or 7/8 inches. The channel connectors were either four or six inch lengths of 4-in. x 5.4-lb. rolled steel standard channel sections. The dimensions of the studs and channels are listed in Table 1.

In all specimens an attempt was made to destroy the natural bond between the flanges of the steel beam section and the concrete slabs by applying a layer of grease to the flanges of the WF beam.

The slabs were reinforced as shown in Figure 1. The reinforcing bars were used to simulate the reinforcing in an actual bridge slab. The #5 bars were also used to prevent premature tensile failure of the slabs during the testing of the larger diameter studs and channels.

Standard 6 x 12 inch control cylinders were cast with each mix and were tested at approximately the same age as the corresponding push-out specimen.

2.2 Materials

The concrete for the slabs was comprised of either a normal-weight or lightweight aggregate and a standard brand of Type I Portland Cement. The mix proportions of the constituents of the normal-weight concretes were

1:2.4:3.61 by weight with a cement-water ratio of about 2.56 and a cement factor of 5.8 sacks per cubic yard. The maximum size of stone aggregate was 3/4 inches. This mix conformed with the Class B-1 mix required by the State of Missouri for bridge construction. The lightweight concrete had Haydite as an aggregate and mix proportions of 1:2.65 by weight, a cement factor of 7.0 sacks per cubic yard and sufficient mixing water for a 1-1/2 inch slump. The Haydite aggregate used was the "BX" blend of fine and coarse expanded shales. The concretes were either mixed in the University laboratory or obtained from a local ready-mix plant.

A check on the manufacturer's minimum specifications for the properties of the steel in the studs was made on a random sample of four studs. These properties were determined from tests of coupons machined from the studs. With the exception of one coupon, which was machined from a previously untested stud, studs from tested push-out specimens were used. The coupons were approximately 3.75 inches long, shouldered, and circular in cross-section, with a straight section of about two inches. The properties measured are given in Table 2 and include the apparent yield stress, ultimate tensile stress and per cent reduction in area. The 7/8-inch stud coupons tested slightly below the minimum ultimate tensile stress of 60,000 psi specified by the manufacturer. The apparent yield stress and ductility were acceptable for all coupons.

2.3 Preparation of Specimens

The studs were welded to the flanges of the steel beam by the Nelweld method. The channels were connected to the steel beam flange by a 3/16-inch continuous weld along the front and back of the channel. After welding the connectors in place, the flanges of the steel beam were covered with a layer of grease.

The slabs were cast on edge as shown in Figure 2 in order to have concrete from the same batch in each slab. The concrete was carefully vibrated to eliminate air voids around the shear connectors. The concrete slabs were cured in the laboratory with wet burlap and a polyethylene covering until ready for testing. All specimens were at least 28 days old at the time of test. The actual age can be determined from the data given in the Appendix. The 6 x 12 inch control cylinders were cured under the same conditions as the push-out specimens.

2.4 Loading Apparatus and Instrumentation

The specimens were tested in a 300,000 lb. capacity Riehle hydraulic testing machine. The load was applied to the end of the steel beam section through a spherical block and a steel distributing plate. Strips of lead were inserted between the WF beam and the steel plate to improve the load distribution.

Slip between the slabs and the steel beam section, and total load applied were measured for each specimen. The slip was measured with four 0.0001-inch dial indicators mounted at the locations shown in Figure 1. Each dial was rigidly attached to the appropriate steel beam flange with the dial stem bearing on a bracket glued to the concrete slab. The dials and brackets were placed directly opposite the shear connectors. The testing arrangement is shown in Figure 3.

III. TESTS AND RESULTS

3.1 Test Procedure

The load was applied in increments of varying magnitude at a speed of .05 inches per minute. In general, the load was released several times before failure occurred. The load was usually released and reapplied in at least three steps, the magnitude of the steps depending upon the level the load had reached before release. Figure 4 illustrates the loading increments in a typical test.

Values of load and slip were observed after each increment of loading. The load was kept constant during the reading of the dials which were allowed to stabilize before readings were taken. However, the slip dials would not stabilize at loads near failure. Failure of the specimen was determined during the test when the specimen would not take additional load. The load was then released and the slabs removed to observe the condition of the connectors and the concrete.

3.2 Presentation of Test Data

The compressive strength of the concrete in the slabs was determined from companion clyinders tested in accordance with the ASTM standard C39-49. The results are given in Table 3.

A summary of the properties of all push-out specimens tested is given in Table 4. The actual test data taken during each test are presented in the Appendix. A plot of the data from a typical push-out test is shown in Figure 4. The presentation of the test data in this form is cumbersome and confusing. To better represent the behavior of the connector in the push-out test, curves of load per connector versus average slip and residual

slip are presented beginning with Figure 5. The curves with average slip as the abscissa are the envelopes of the actual load-slip curves of which Figure 4 is a typical example. Each load vs. average slip curve is approximately the same as the curve which would have been obtained if the specimen had been loaded continuously to failure rather than the loading-unloading sequence used. The load vs. residual slip curves are a plot of the slip (measured after the load was removed) versus the highest load reached before removal.

The value of slip plotted as the abscissa was the average of all four dials and the value of force per connector was obtained by dividing the total applied force by the number of connectors in the specimen. While the load carried by each individual stud could not be obtained directly, the differences in slip recorded by the four dials were very small, indicating an equal distribution of the total load to each connector.

3.3 Discussion of Test Results

A summary of the pertinent push-out test results is given in Tables 5 and 6. Only those specimens that performed satisfactorily are included in these tables. Specimens no. 4, 6, 7, 8 and 9 (see Table 4) did not attain their expected ultimate strengths due to improper welding of the studs. The studs were attached by the Nelweld method using a machine of insufficient capacity to weld a 3/4-inch diameter stud. Due to the resulting improper fusion between the weld and the parent metal the welds failed during the push-out test. A plot of the load vs. residual slip curves of these specimens (Figure 7) indicates that the "useful capacity" of the studs was attained. However, their behavior under repeated load is questionable and would probably exhibit a weld failure below the critical load or useful capacity of the studs.

The first group of specimens (4,6,7,8,9,18) rested on a plywood base in the testing machine. After repeated use of the forms, the wood warped and caused eccentricity in specimens no. 9 and 18 when placed on the plywood base. This eccentricity resulted in a failure load below the expected capacity of the specimens. The eccentricity was eliminated in subsequent tests by capping the specimens with a high strength gypsum plaster (Hydrastone).

Specimens no. 15 and 16 did not reach their expected capacity due to a concrete failure in the region of the studs and therefore were not included in Table 5. A possible explanation for the premature failure of the concrete is that the mixes were very dry and several air voids were noticed upon removal of the slabs. This type of failure is not typical for push-out specimens with 5/8-inch diameter stud connectors as reported by other investigators and demonstrated by specimens no. 13, 14 and 15. Typical failures of the studs and concrete are shown in Figures 13, 14 and 15. The stud failure is one of shear in the stud just above the top of the weld. The concrete failure is probably a bearing or crushing of the concrete which initiates in the region of the connector and results in a splitting of the slab. There were no flexural tensile failures in the slabs (as reported by some investigators) because #5 reinforcing bars were placed in the outer face of each slab in the direction of the applied load (Figure 1). Therefore, the test results in Tables 5 and 6 are a good indication of the behavior of the connectors for the particular concretes used.

In Tables 5 and 6 there is a critical load, Q_{cr}, listed for each specimen. These values were determined, in general, from the load vs. residual slip curves of the respective specimens (see Figures 5 through 13). The critical load is taken as the force per connector at the point on the load-

slip curve where there is a marked increase in slip with little increase in load. This load vs. residual slip curve usually shows a more definite break in the curve than the load vs. average slip curve. Therefore, the critical loads were determined from the load vs. residual slip curves where possible.

Due to an error in loading, a complete load vs. residual slip curve could not be plotted for specimens no. 2 and 5 and the critical loads were determined from the respective load vs. average slip curves.

IV. COMPARISONS

4.1 Comparison of Stud Tests With Published Data

The results of the stud tests are compared in Table 7 with the results of similar stud tests reported by other investigators. Only those tests that used headed studs four inches in height with comparable diameters are included in Table 7. All tests had the same number of studs (four) connecting the slabs to the steel beam section in the push-out specimens.

The values of critical load and ultimate load compare reasonably well with the values reported by the other investigators although, in general, the magnitudes are somewhat smaller. In the working range (average slips up to about .02 inches) the loads transferred by one stud compare very well in most instances for both concretes used in the Missouri tests.

The push-out specimens used by the other investigators differed in some respects with the type used in this investigation. These differences were mainly in the dimensions, reinforcing, and curing of the slabs. Viest[2] used a 7-inch slab reinforced with a single layer of wire mesh consisting of #10 wires spaced 4 inches in each direction. His slabs were cast separately and horizontally (to simulate actual conditions) and cured in a moist room for six days. Thurlimann[3] used 6-inch slabs cast in the upright position used for testing and were reinforced with two layers of #4 bars running each way. The manner of concrete curing was not reported. Chinn[4] employed a 6-inch slab cast in the same manner as Viest but cured with wet burlap and polyethylene sheets. The slab reinforcing consisted of a "reinforcing cage" of #3 and #5 bars.

The variations in the load-slip characteristics of the tests reported in Table 7 could in part be due to the design differences of the respective

push-out specimens. However, it is felt that the differences in the type and quality of the concrete is more significant in explaining the variations in the behavior of the connectors.

4.2 Comparison of Channel Tests With Published Data

The results of the channel tests are compared with the published results of other investigators in Table 8. Only results from push-out tests using 4-in. x 5.4-lb. standard channel connectors in four and six-inch lengths are included.

The values of ultimate load per channel for the Missouri tests are as much as 30 per cent less than those reported by the University of Illinois. For comparable concrete strengths the channels embedded in the Missouri aggregates transferred less load at slips below .02 inches. However, the critical loads, Q_{cr}, as determined from the load-residual slip curves, are very close to the Q_{yp} values of the Illinois tests. Q_{yp} is the yield load of the channel which was found to be the same as the Q_{cr} determined from the same test.[5]

4.3 Comparison of Connectors With Current Specifications

The results of the push-out tests of this investigation are compared in Table 9 with the corresponding recommendations of the 1961 AASHO and 1961 AISC Specifications. The stud connectors exhibited useful capacities smaller than those allowed by both the AASHO and AISC except for the 3/4 studs with normal concrete. The channel connectors exceeded the recommended values except for specimen N4BC6 which was less than four per cent smaller than the AASHO value. The applicable equation for the useful capacity of studs according to the 1961 AASHO Specification is:

$$Q_{uc} = 330\ d^2 \sqrt{f'_c}\ \text{in pounds per stud.}^{(6)}$$

This equation states that the useful capacity of a stud is a function of the square of its diameter and the square root of the compressive strength of the concrete.

The differences between the Missouri tests and the AASHO equation for the useful capacity of studs can be accounted for in the term involving the strength of the concrete. The mixes used in this investigation were designed to give a minimum compressive strength of 4000 psi. All specimens with normal-weight concrete had the same mix proportions, as did all specimens with lightweight concrete. There was some variation in mixing water which was more pronounced in the lightweight concretes than in the normal-weight concretes. The resulting cylinder strengths varied from 4140 to 6280 psi for the normal-weight concretes and 3965 to 6580 psi for the lightweight concretes. Although the cylinder strengths varied greatly between specimens (and within some specimens) the performance of the studs embedded in the concrete did not behave accordingly. For example, in Table 5 specimen no. 3 had 6110 psi concrete and specimen no. 2 had 5140 psi concrete, but specimen no. 2 attained a higher critical and ultimate load and exhibited less slip for loads through the working range of the studs than did specimen no. 3 whose concrete strength was almost 1000 psi greater.

Since the mixes were designed to yield a minimum compressive strength of 4000 psi, the useful capacities were computed from the AASHO formulas based on this value and placed in parentheses in Table 9. The test values compare very favorably with these values. It is noticed that these values are the recommended ones in the Missouri State Highway Specifications (listed in Table 9).

V. SUMMARY AND CONCLUSIONS

5.1 Summary

Twenty-four push-out specimens were tested and the results compared with published findings of other investigators. The concrete in the specimens consisted of aggregates native to the State of Missouri. The aggregates were either a blend of Haydite (BX Haydite) or sand and 3/4-inch stone. The mix proportions conformed to the standards of the State of Missouri for highway bridge construction.

Both standard channel sections and headed studs were used as shear connectors in the push-out specimens. At least two specimens were cast with lightweight concrete slabs and one with normal-weight concrete slabs, for each stud diameter studied (1/2, 5/8, 3/4, 7/8). Standard 4-in. x 5.4-lb. channel sections either four or six inches in length were tested as shear connectors. One specimen of normal-weight and one specimen of lightweight concrete were cast for each length of channel tested.

5.2 Conclusions

From the test results of this investigation, the following conclusions are made:

(1) Stud and channel shear connectors embedded in lightweight concrete slabs have about the same useful capacities as those in normal-weight concrete slabs.

(2) The test results confirm the present Missouri State Highway Specifications for Composite Design and these specifications could be revised to permit the use of lightweight concretes in the slab.

In support of the above conclusions two full-scale composite beams of 20-foot spans with 1/2-inch studs as connectors and lightweight concrete in

the slabs were tested and reported in a Masters thesis.[6] This study showed that the load-slip characteristics of a stud in the full-scale beam were approximately the same as those of the stud in the companion push-out test in the working range of the beam. This indicates that the push-out type of test can forecast the behavior of a shear connector in an actual composite beam within the useful capacity of the connector.

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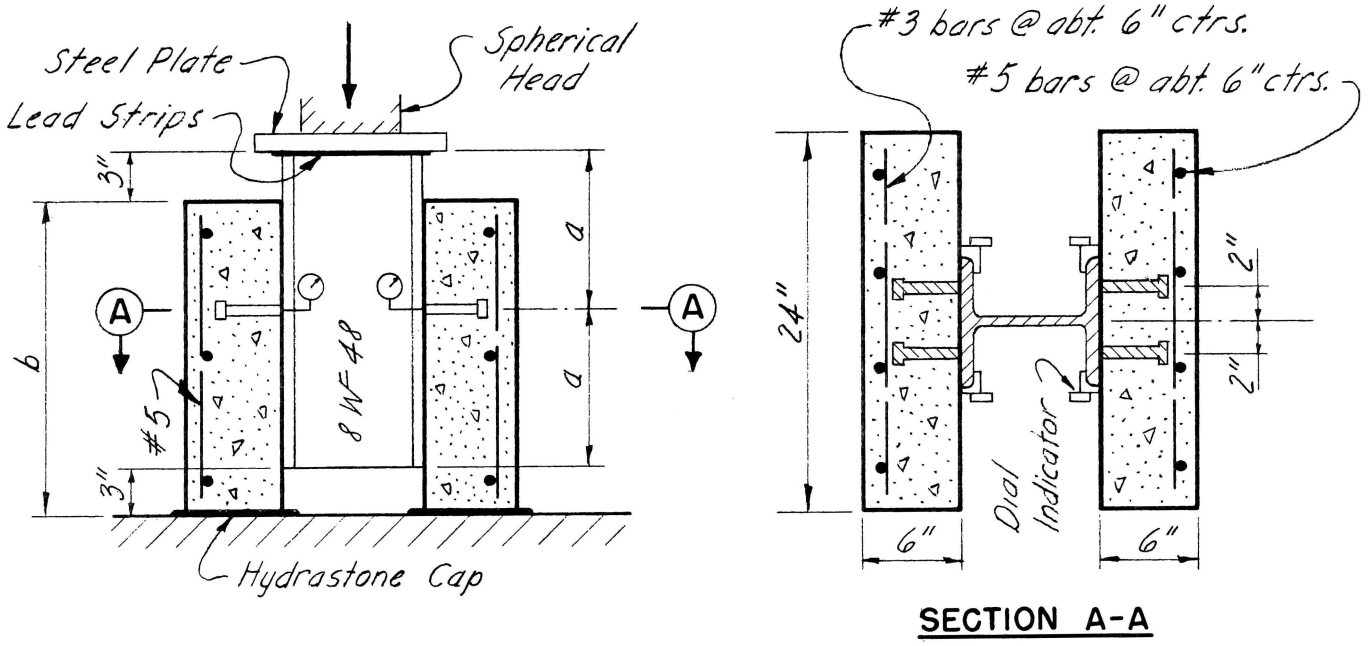
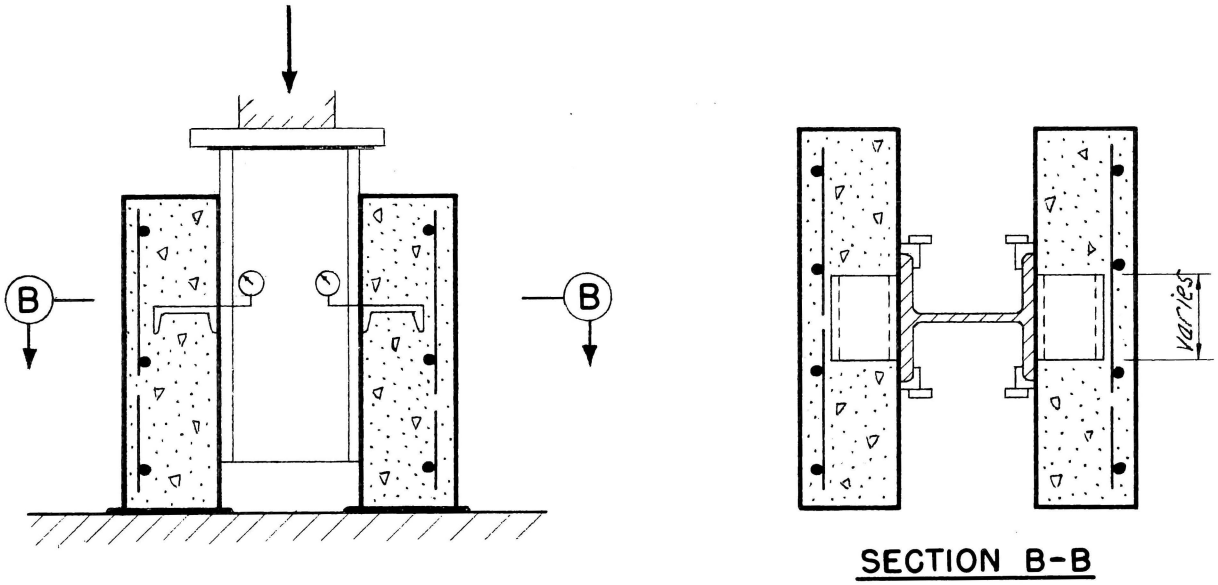


SECTION A-A

STUDS



SECTION B-B

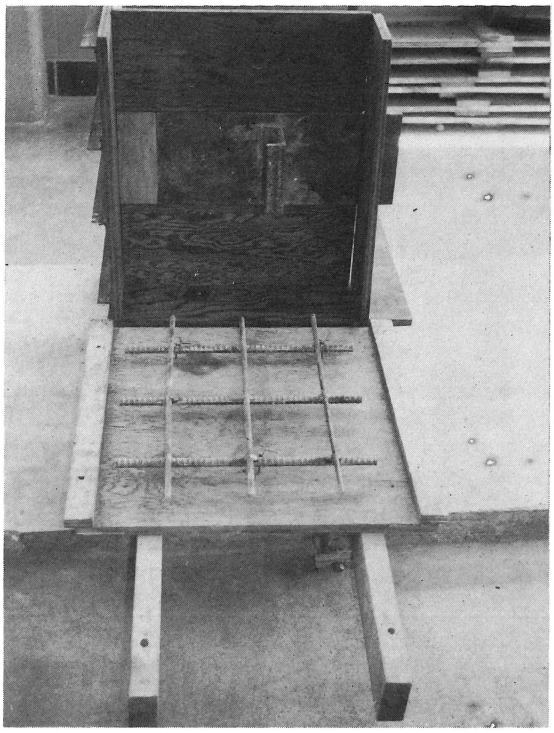
CHANNELS

(Same as Studs Except as Noted)

Type A Specimens - $a = 19\frac{1}{2}$" ; $b = 30$"

Type B Specimens - $a = 10$" ; $b = 20$"

Figure 1 - Details of Push-out Specimens.



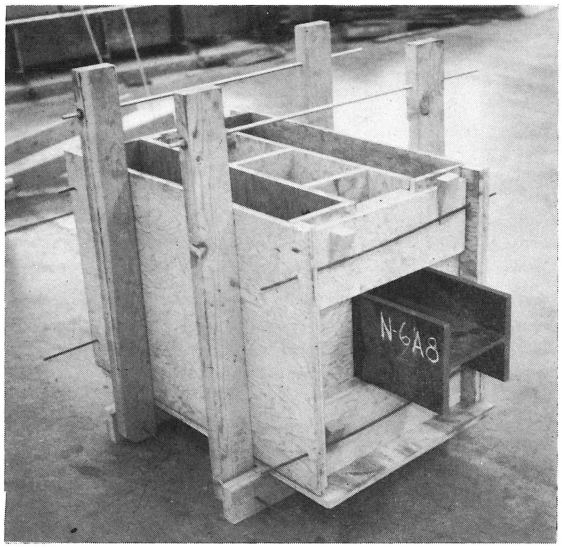
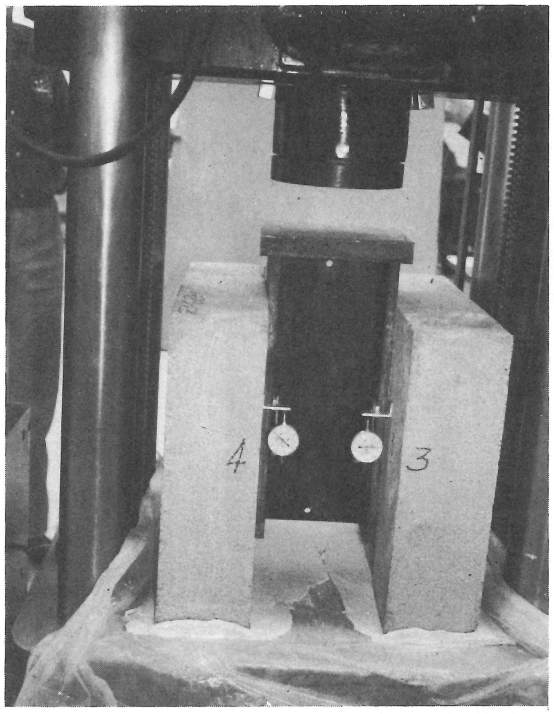


Figure 2 - Forming Details of Specimens.



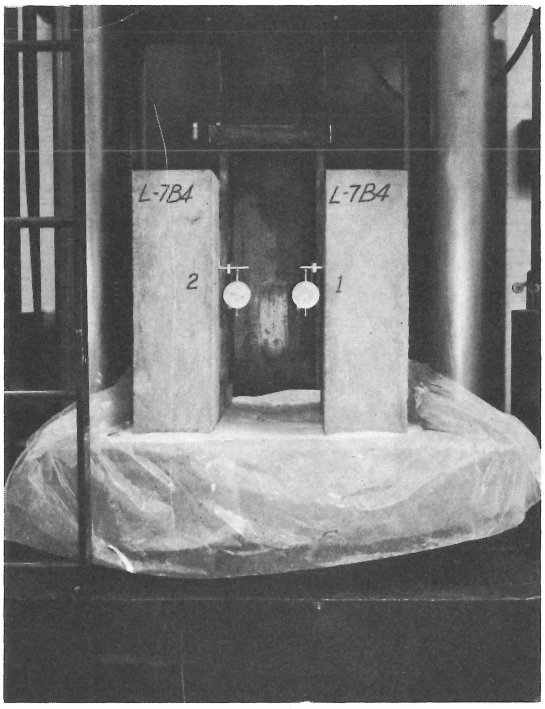


Figure 3 - Specimens Ready for Testing.

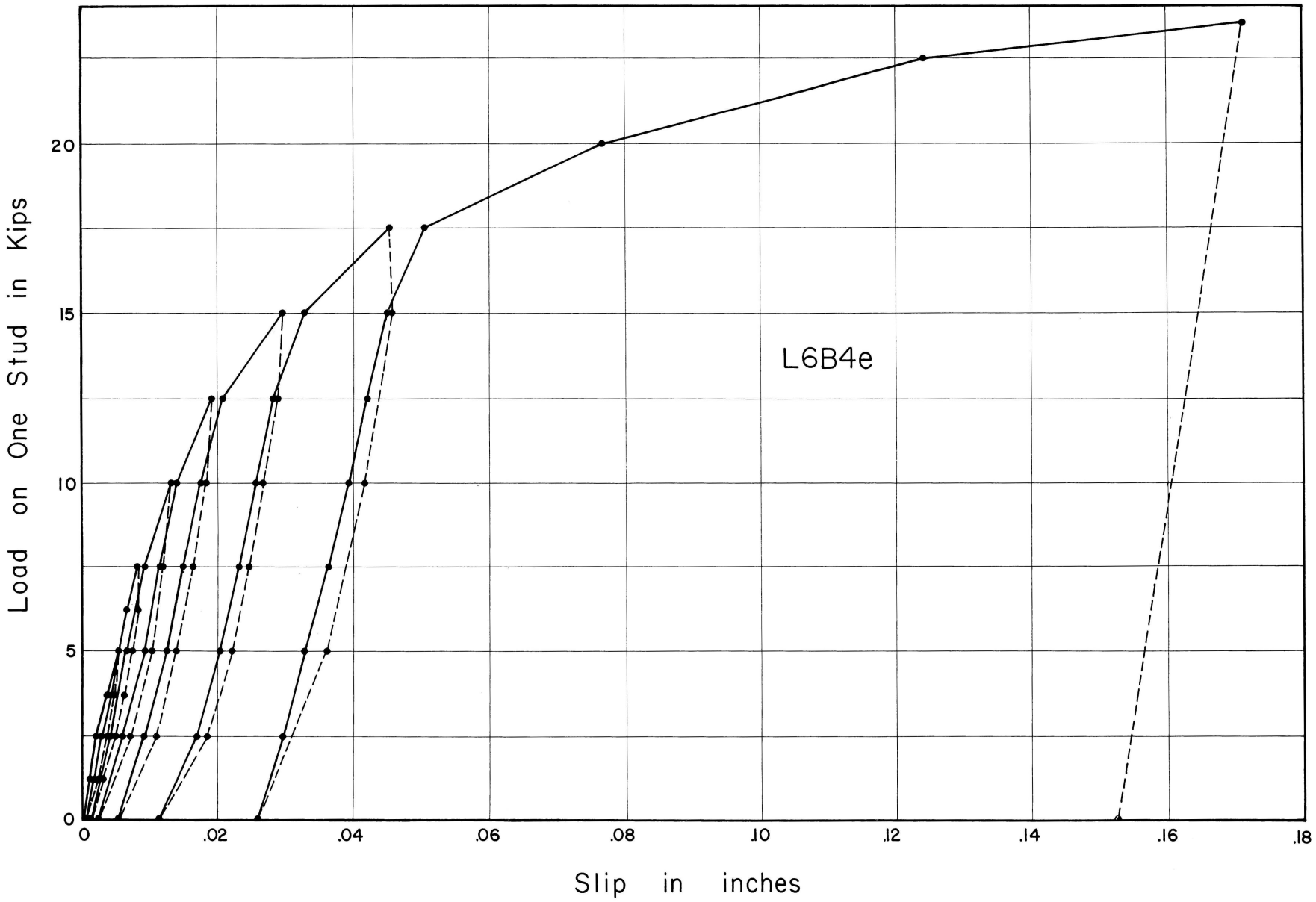


Figure 4 - Typical Load-Slip Curve

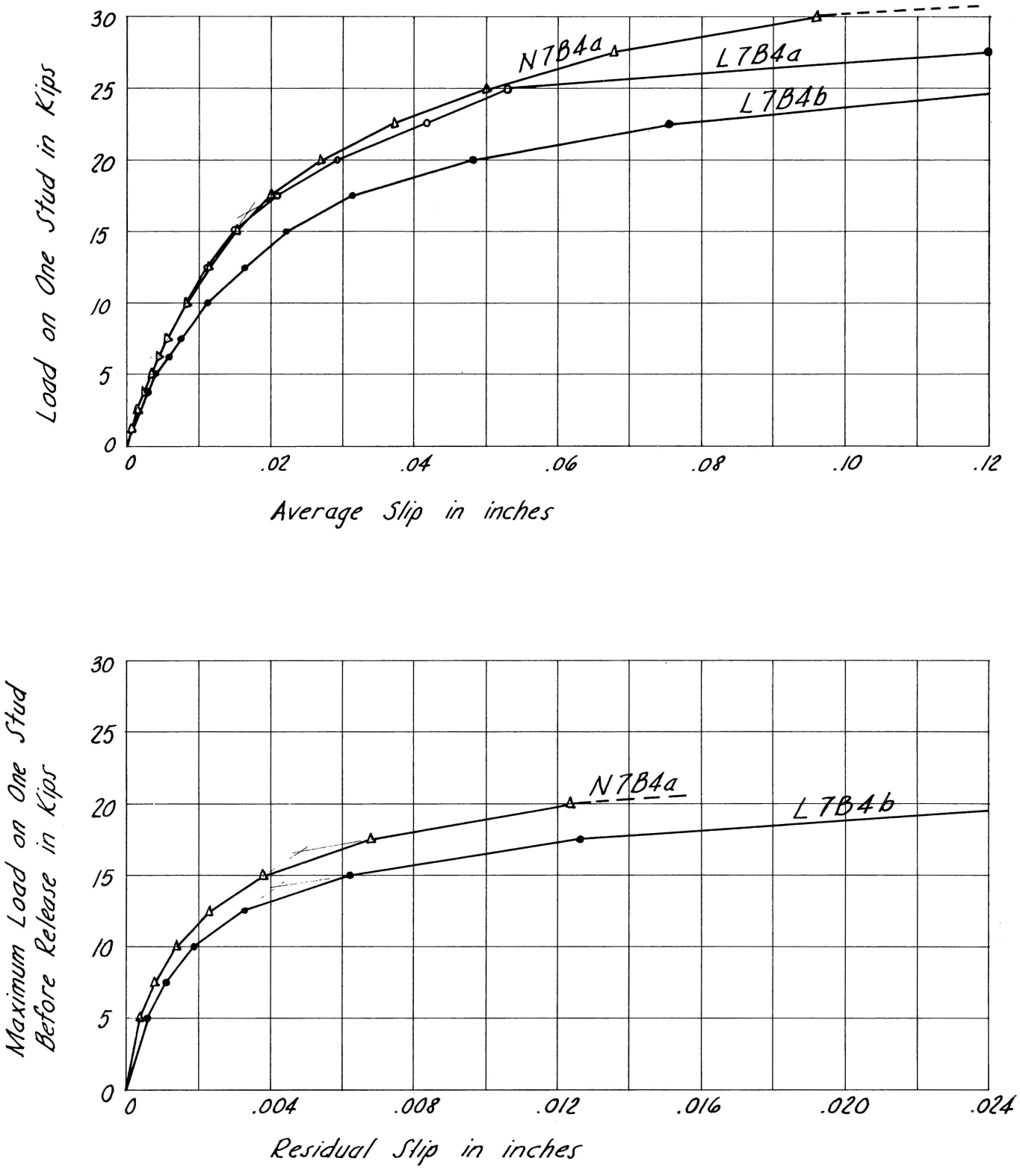
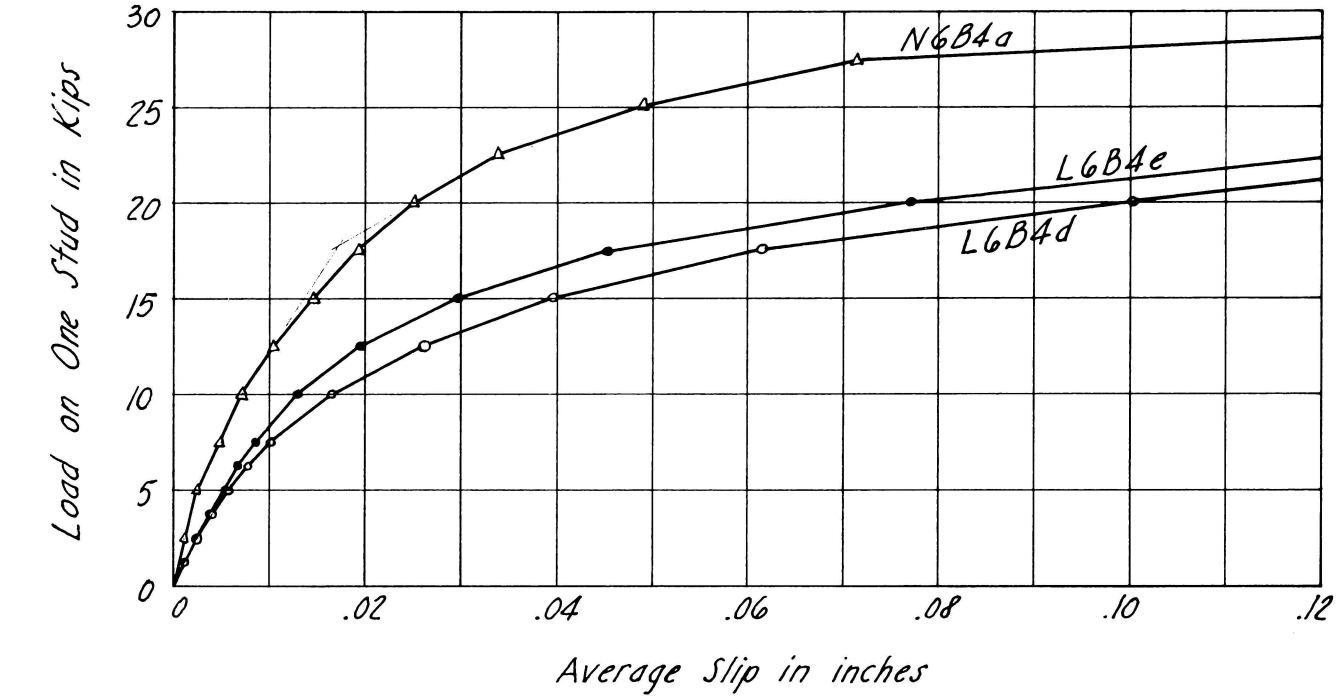


Figure 5 - Load-Slip Characteristics of 7/8 Studs.



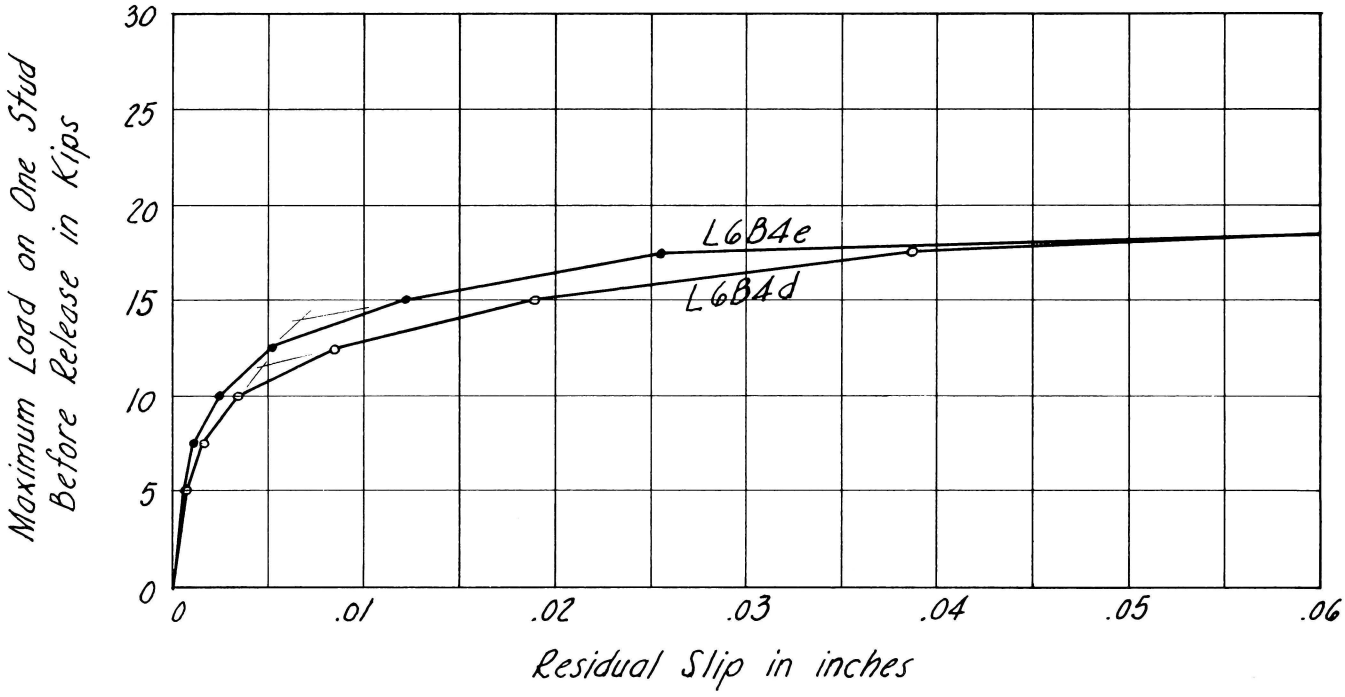
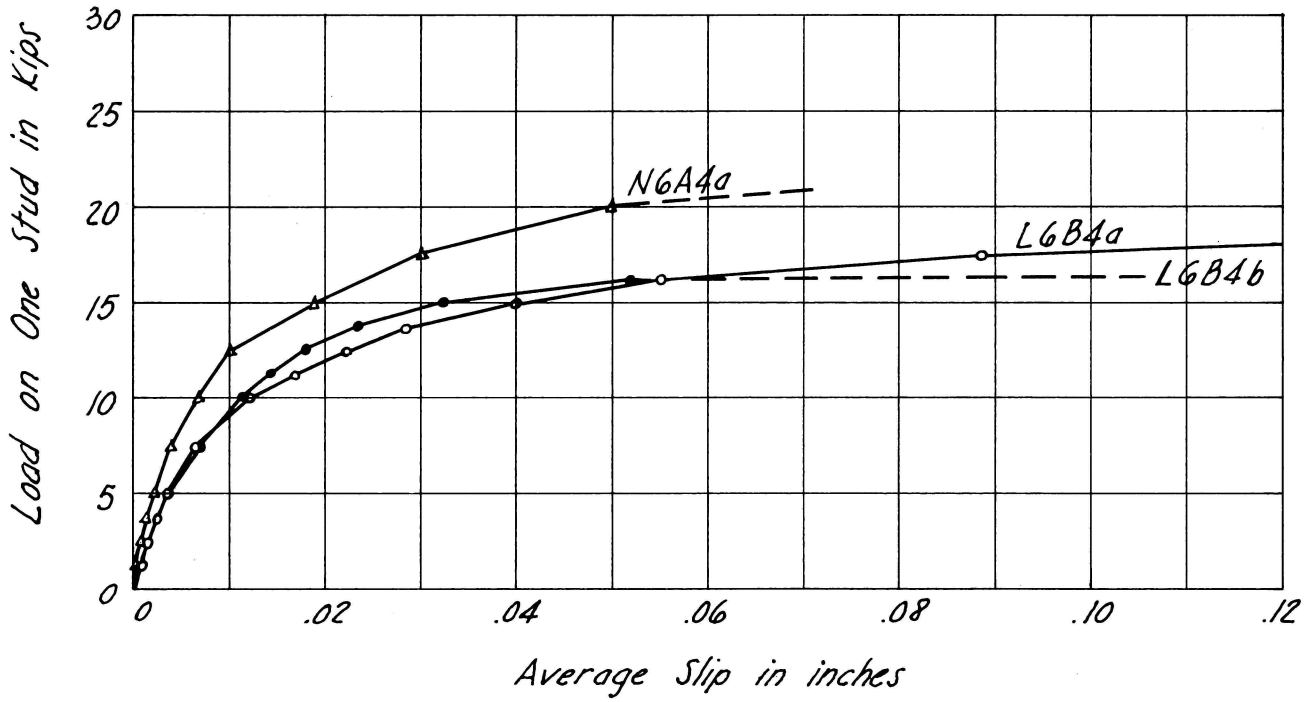


Figure 6 - Load-Slip Characteristics of 3/4 Studs.



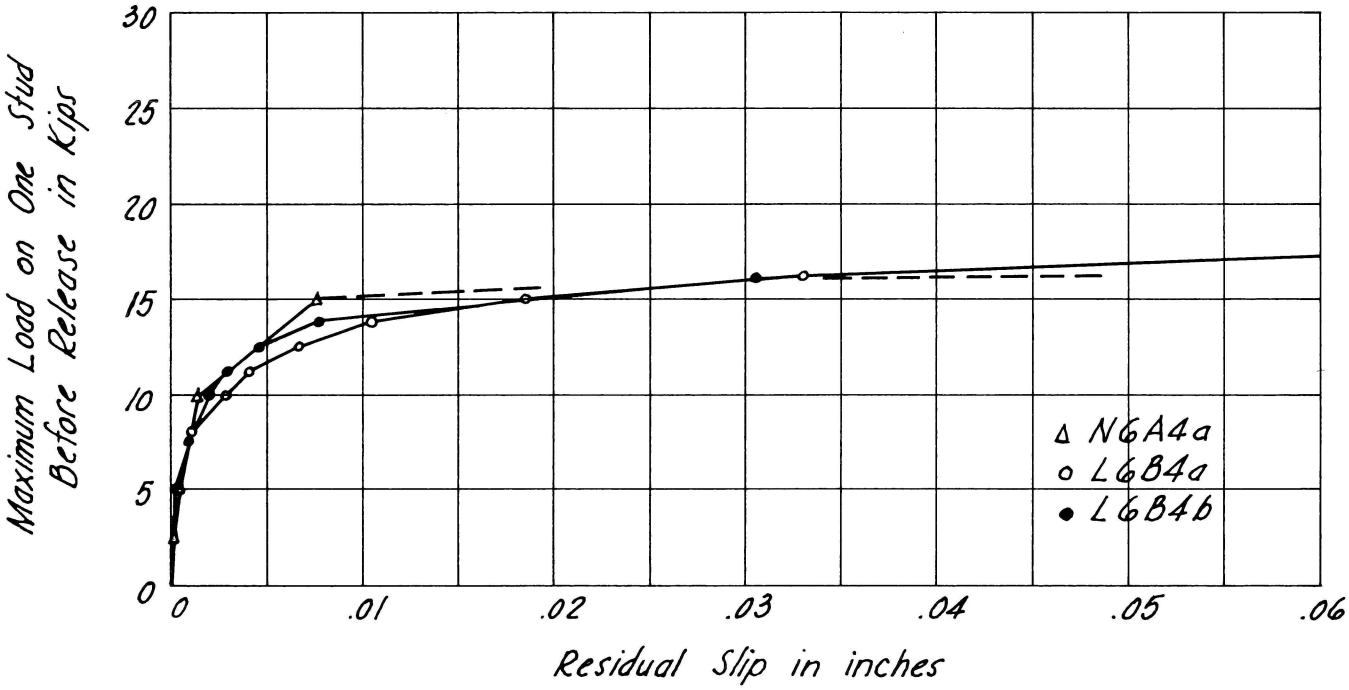
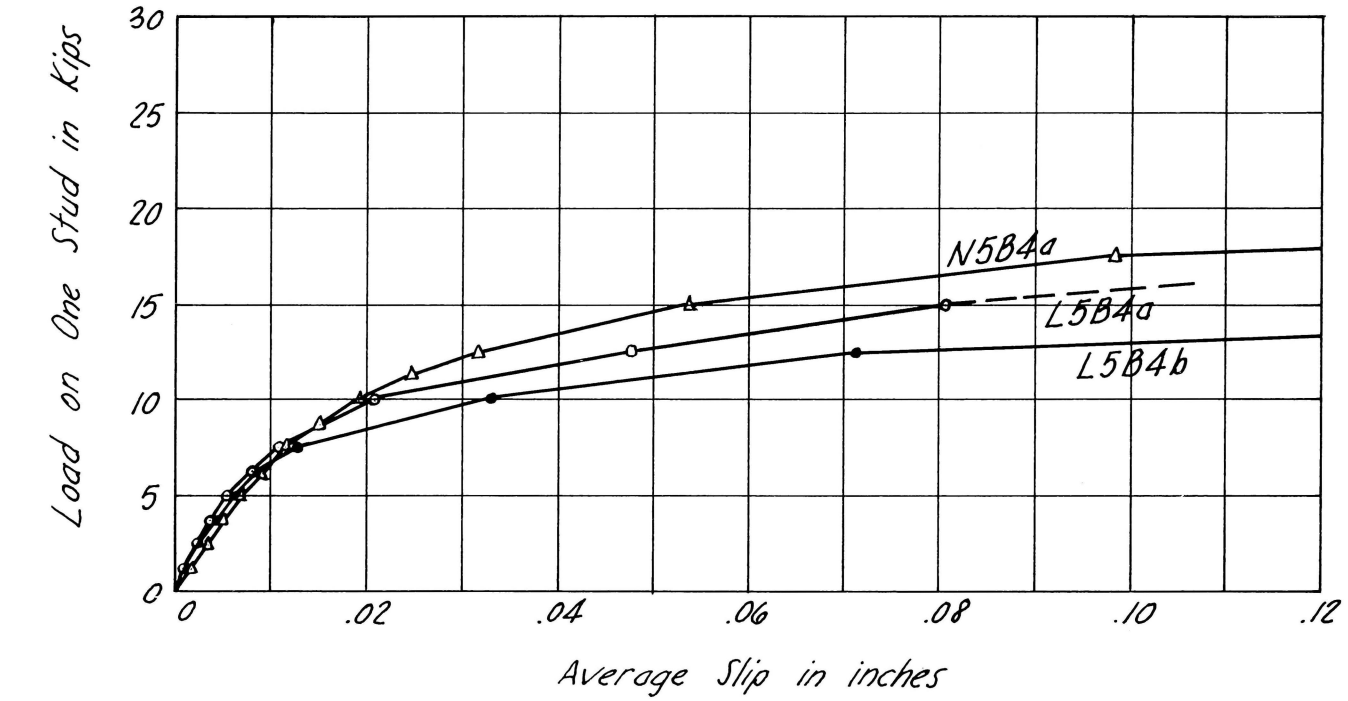


Figure 7 - Load-Slip Characteristics of 3/4 Studs With Bad Welds.



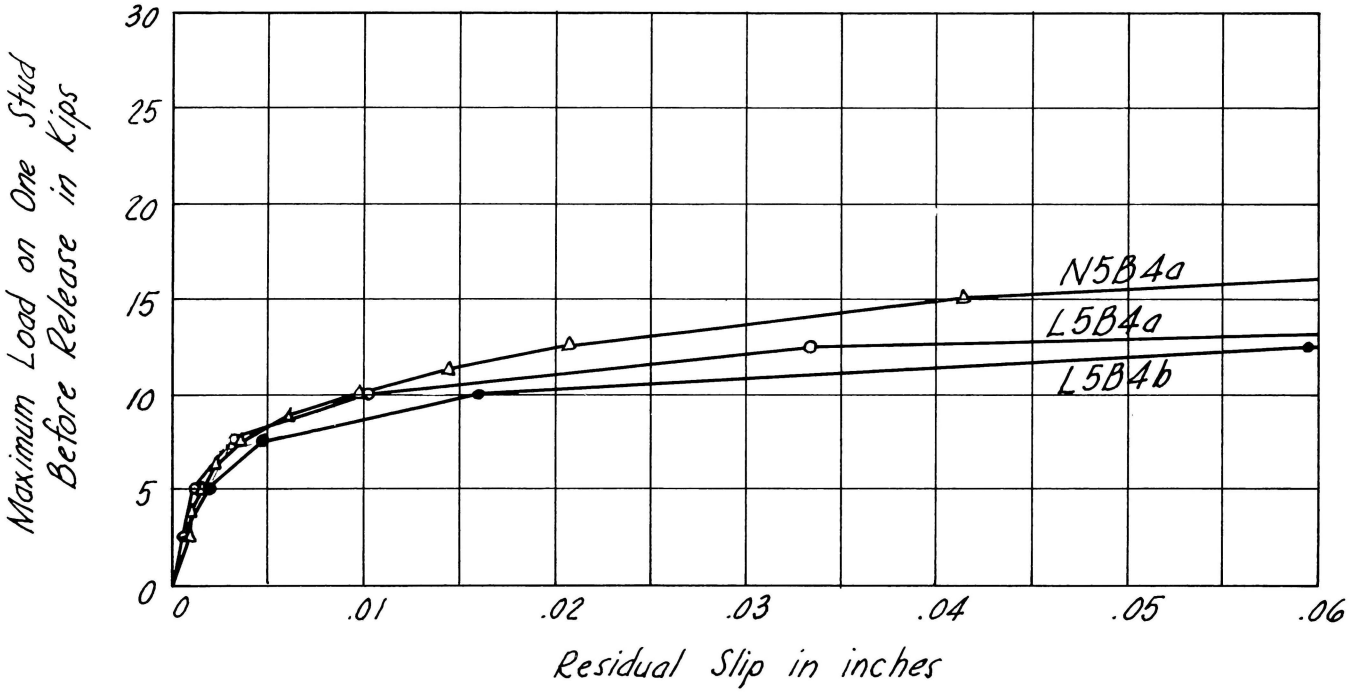
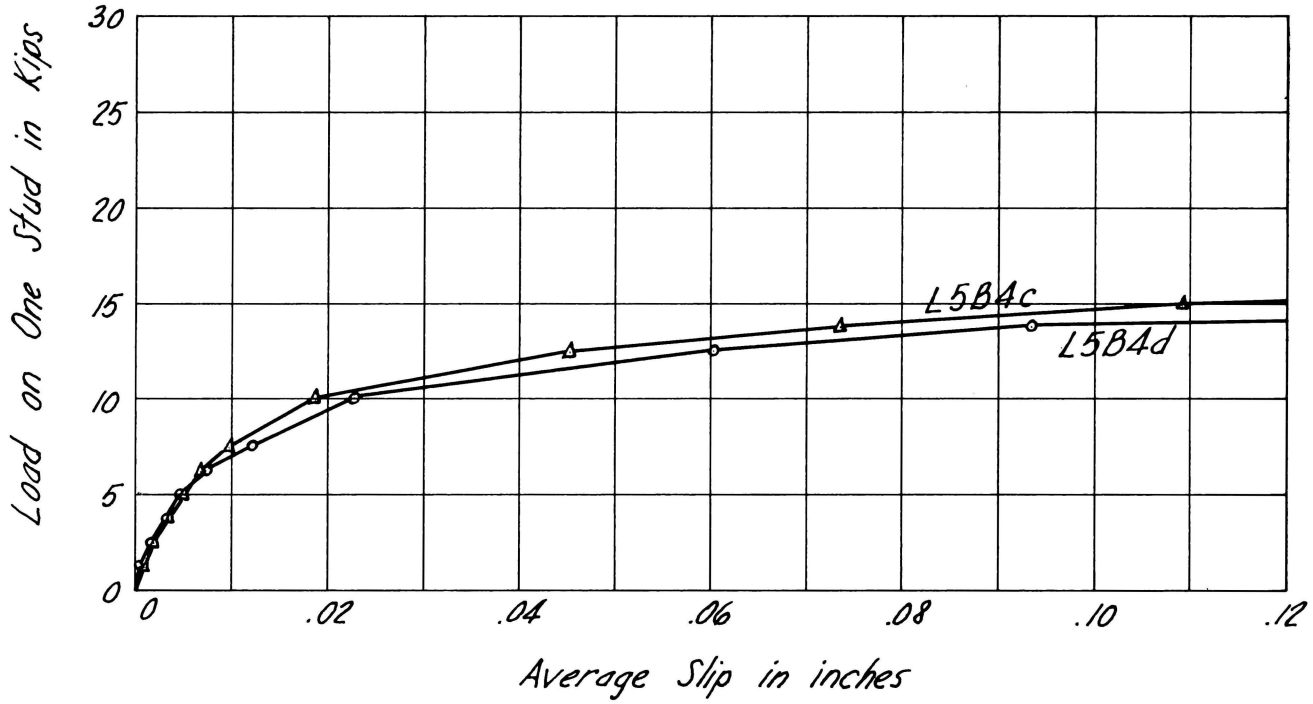


Figure 8 - Load-Slip Characteristics of 5/8 Studs.



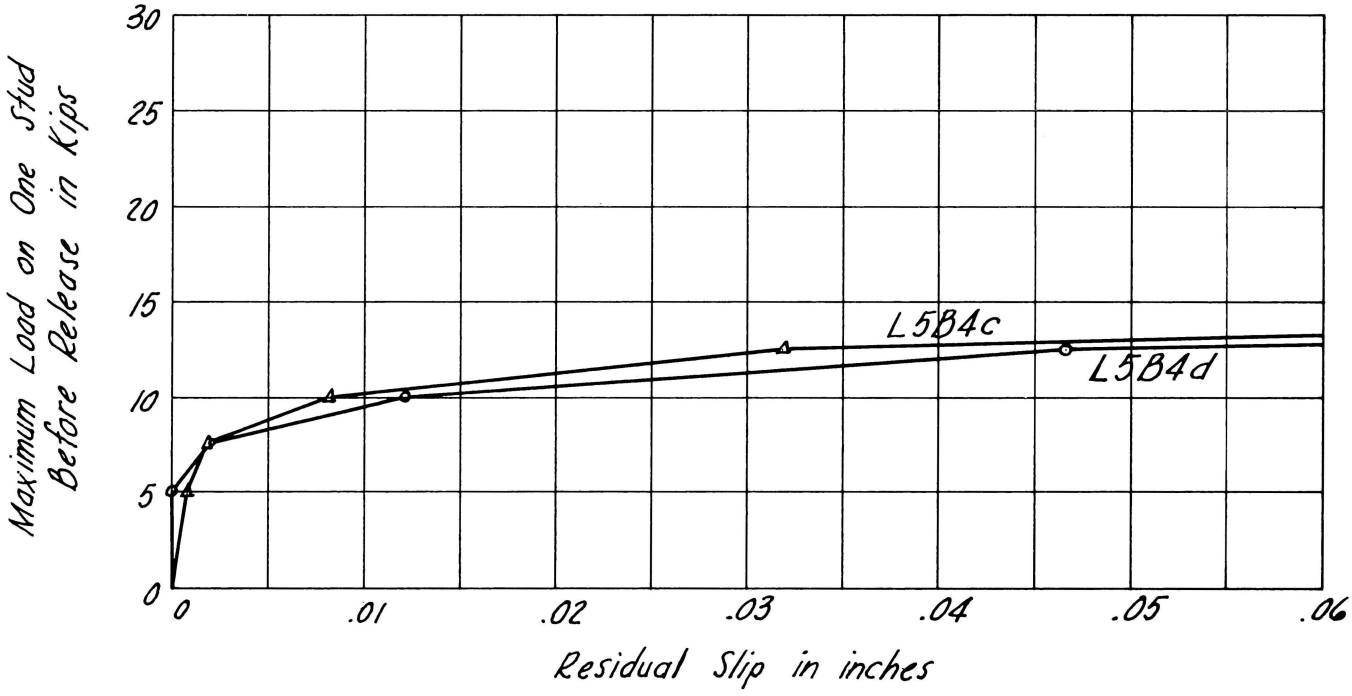


Figure 9 - Load-Slip Characteristics of 5/8 Studs With Concrete Failure.

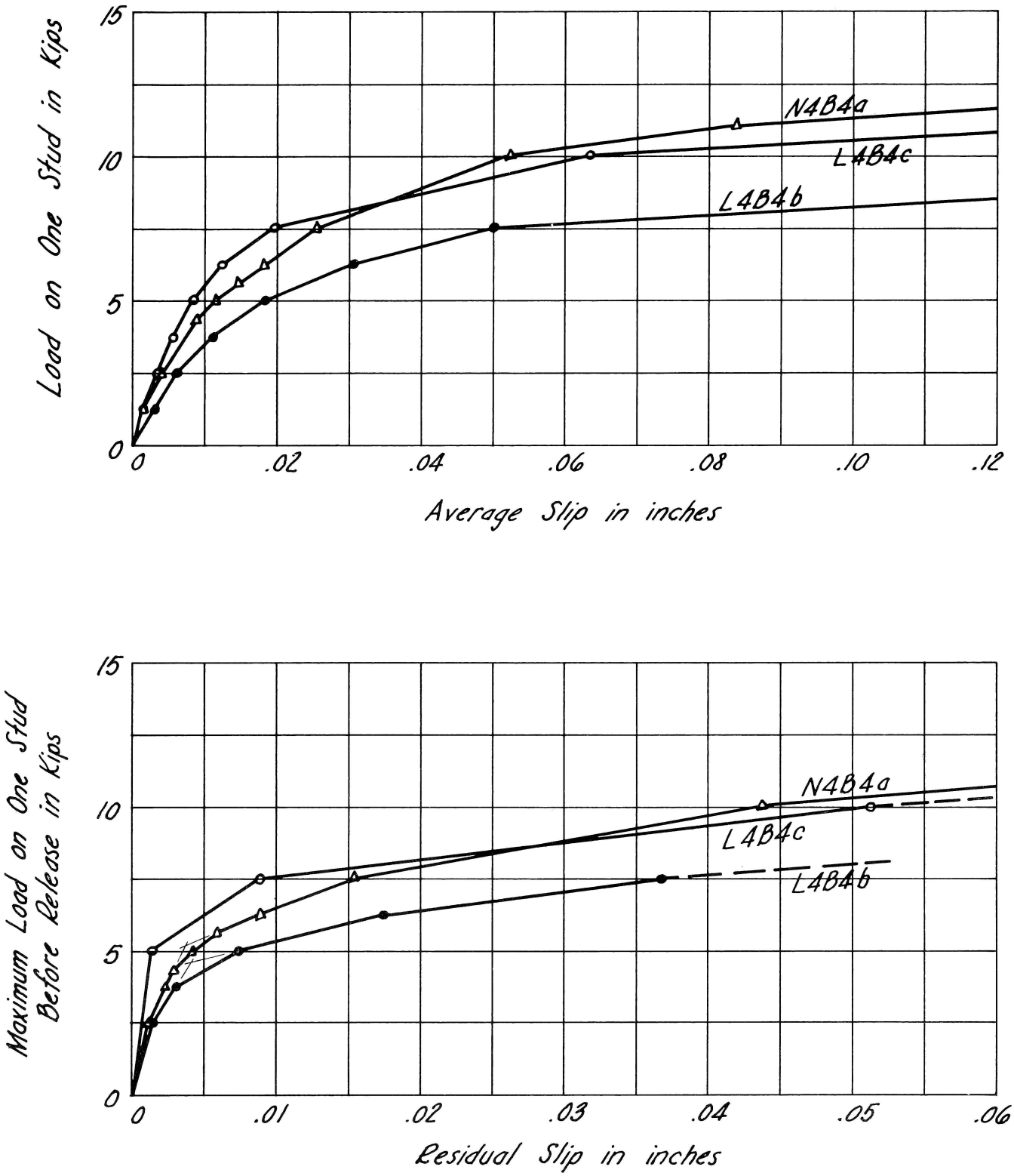
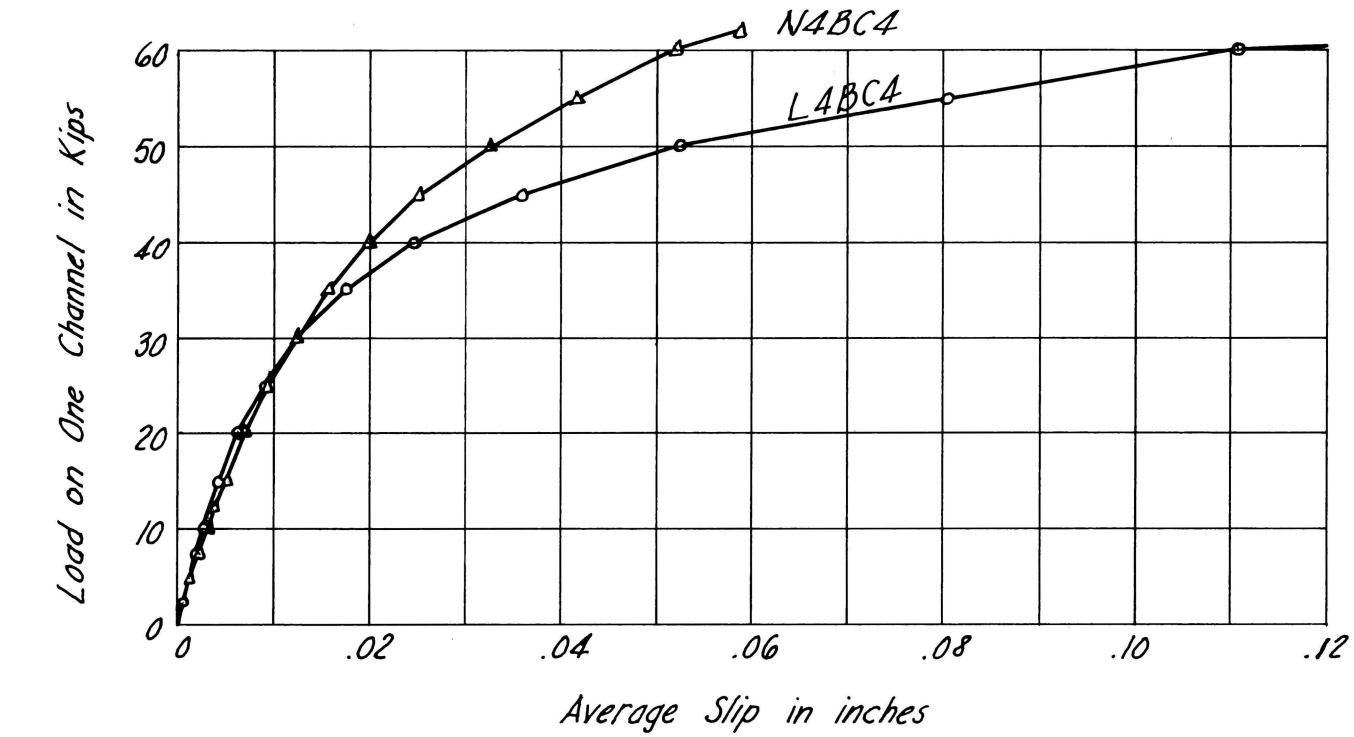


Figure 10 - Load-Slip Characteristics of 1/2 Studs.



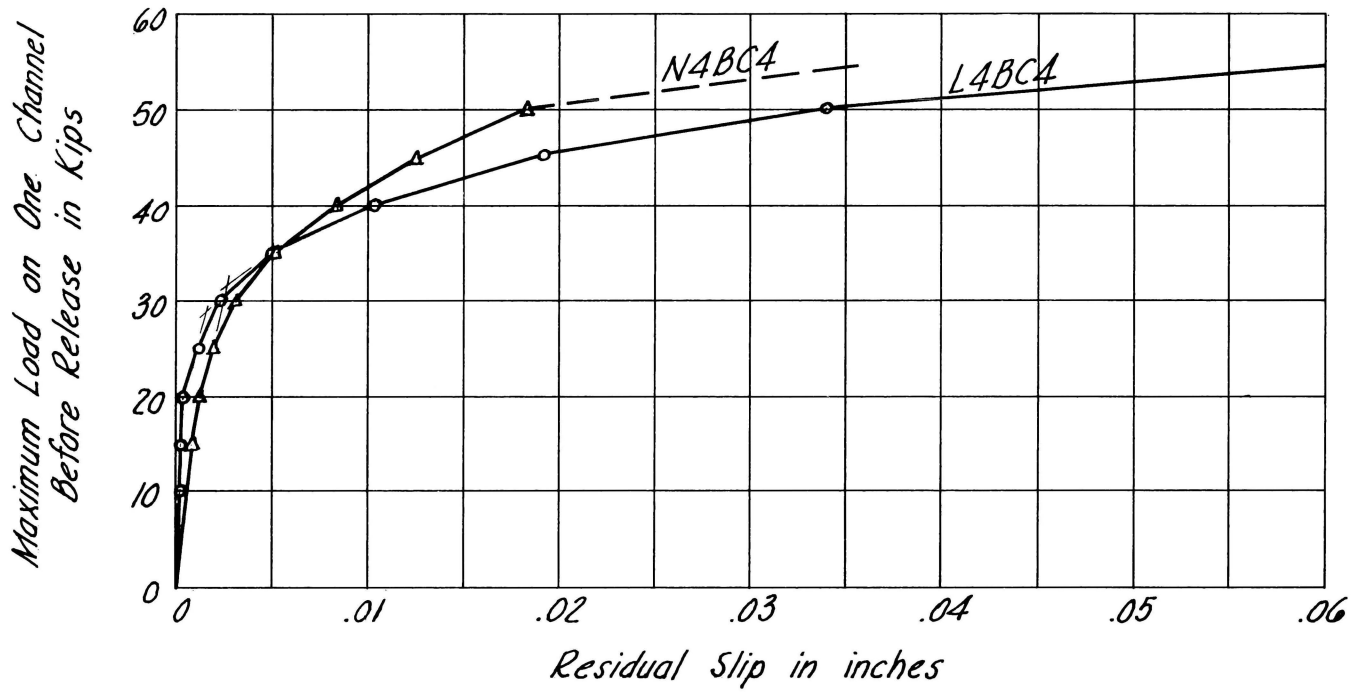
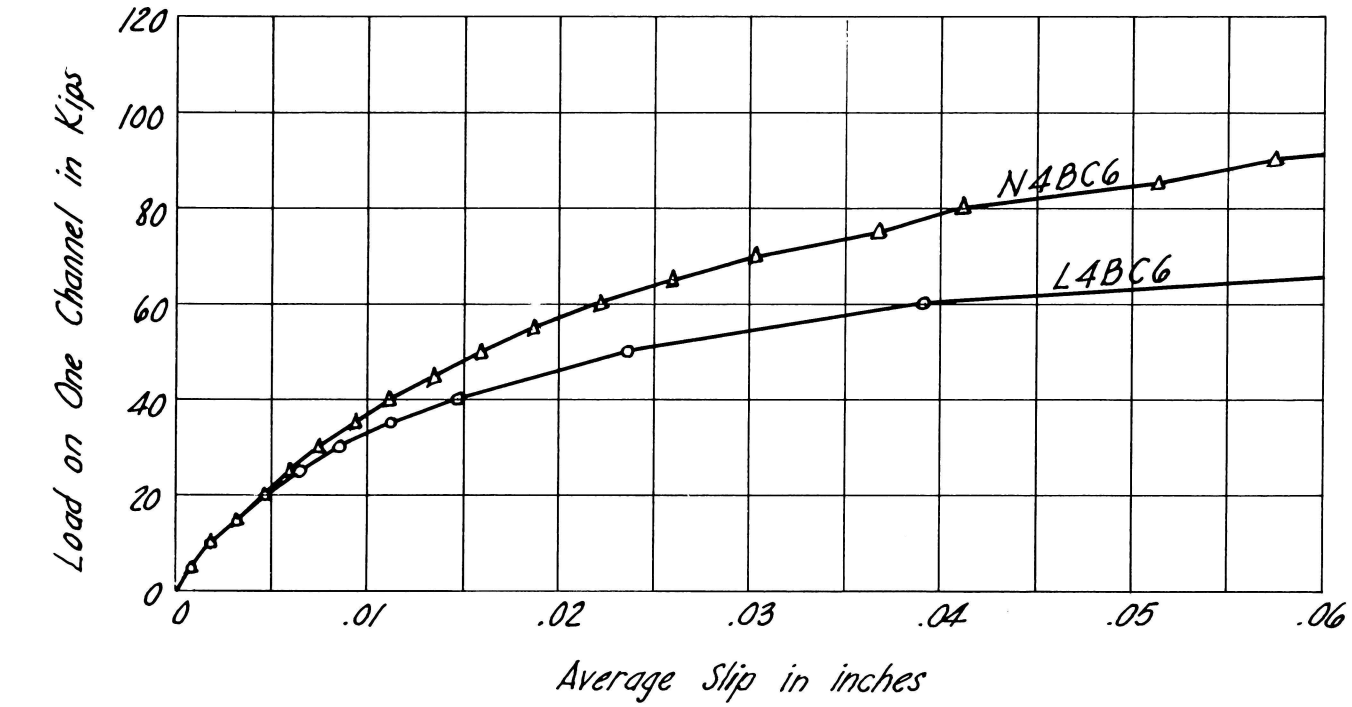


Figure 11 - Load-Slip Characteristics of 4-inch Long Channels.



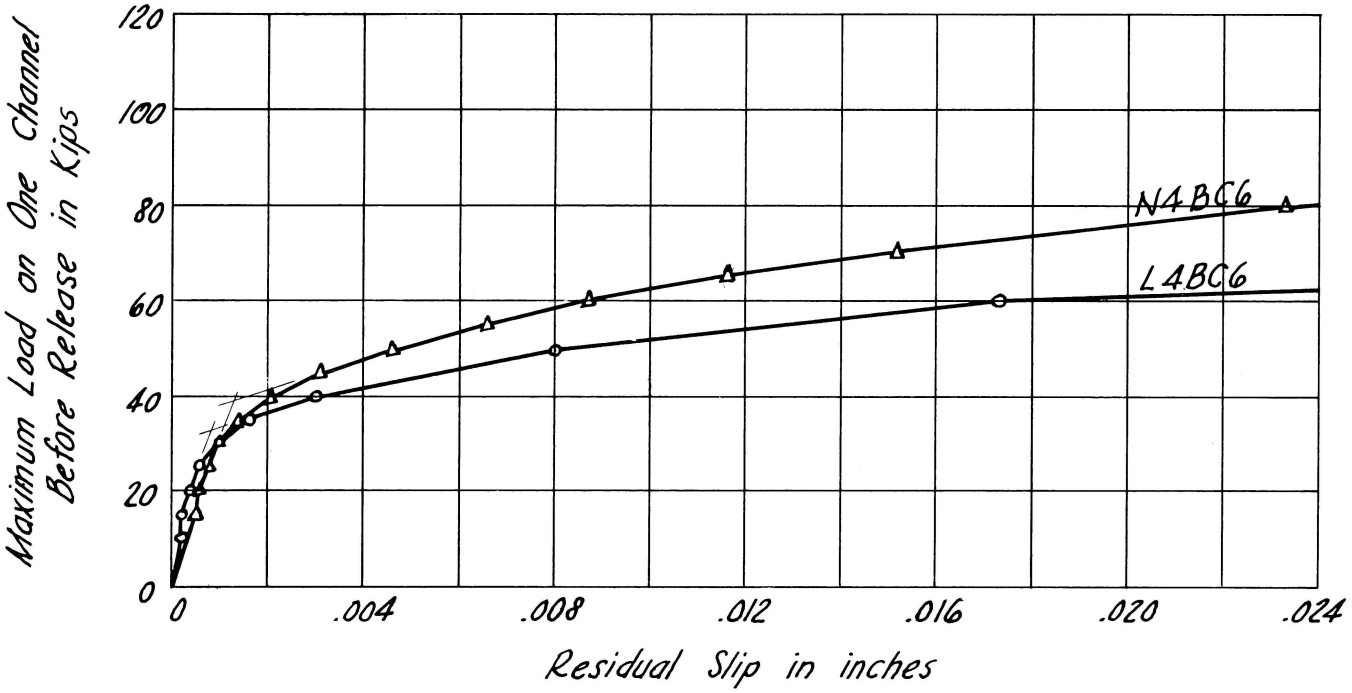


Figure 12 - Load-Slip Characteristics of 6-inch Long Channels.

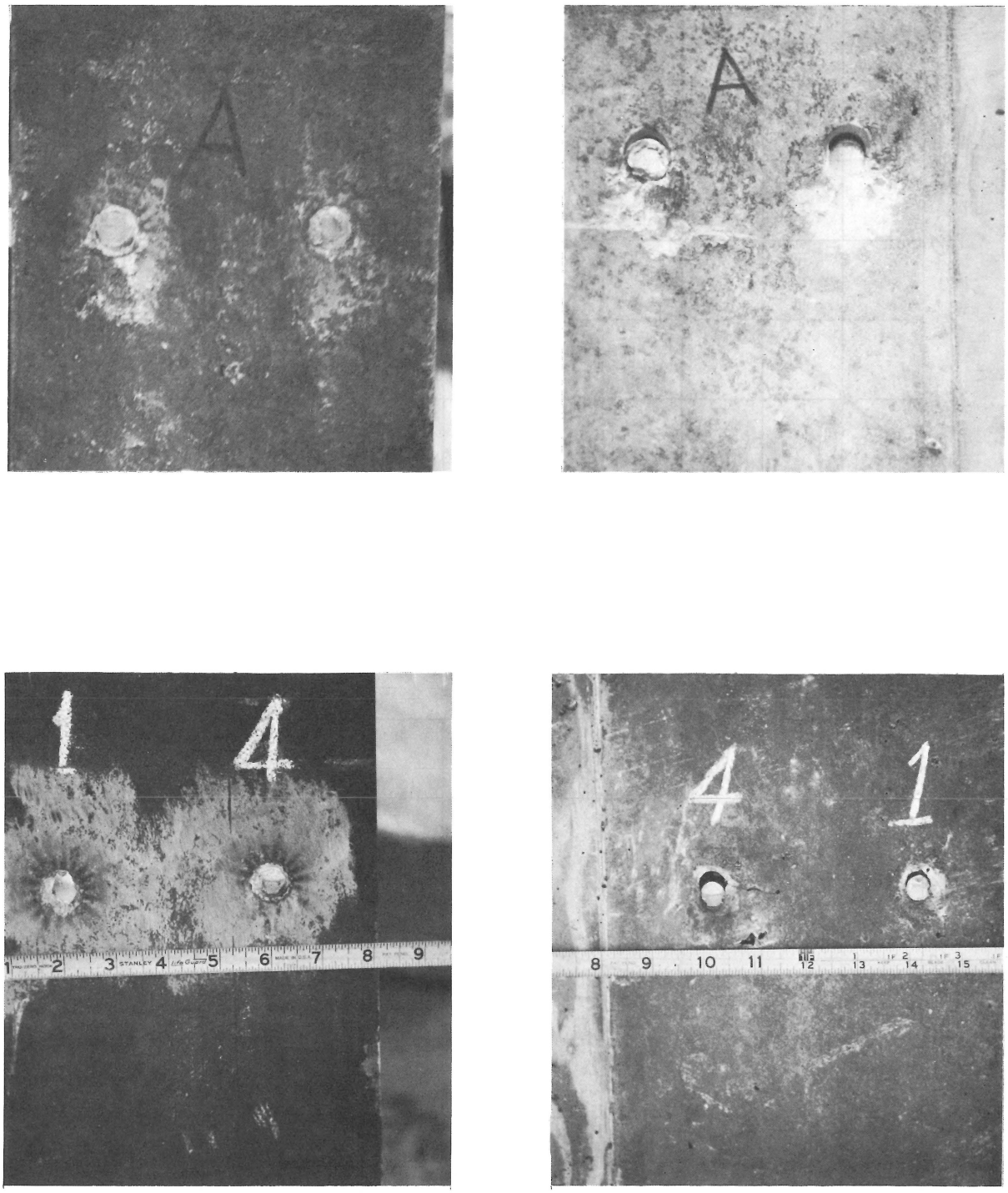


Figure 13 - Typical Stud Failures.

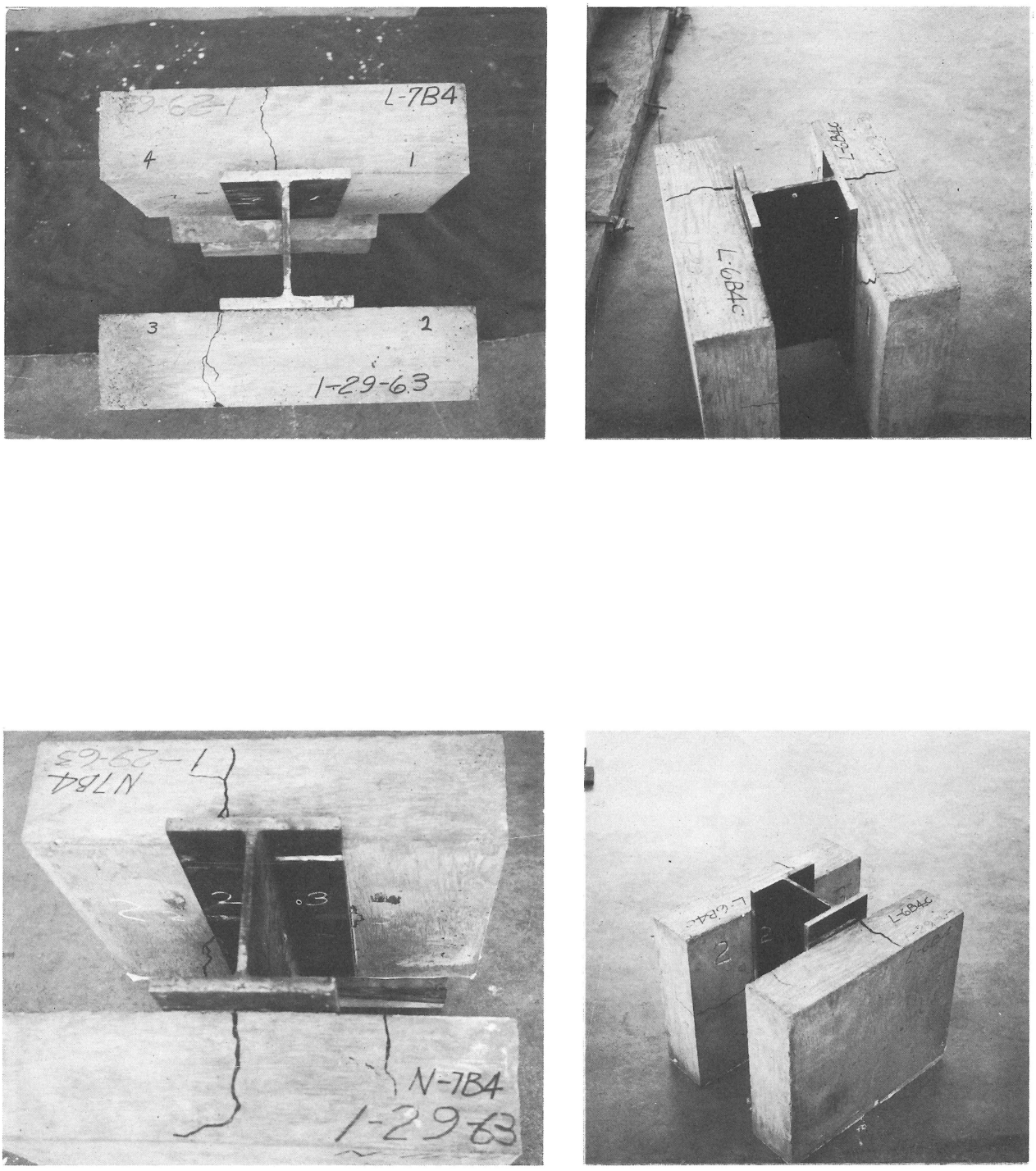


Figure 14 - Typical Concrete Failures.

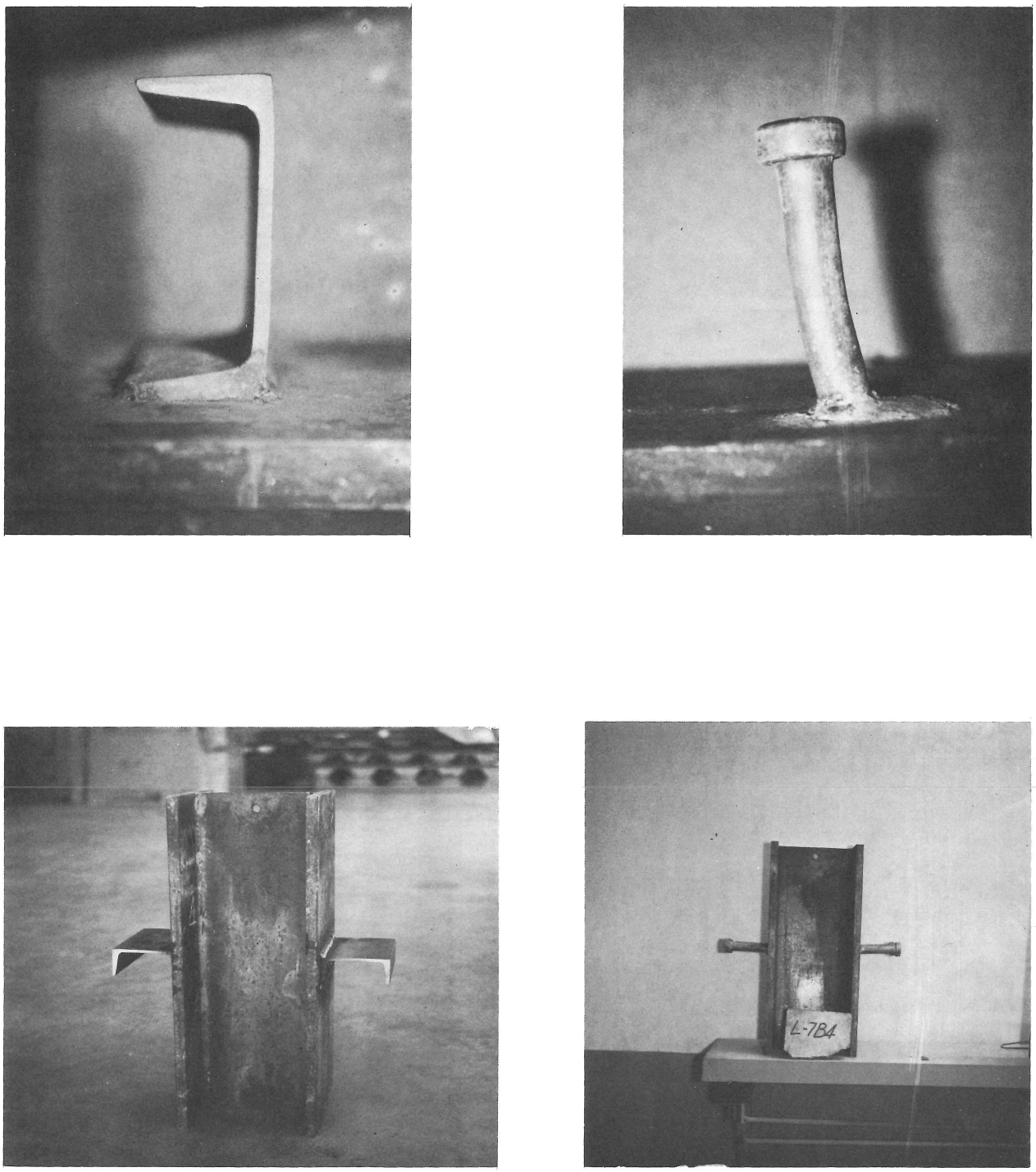


Figure 15 - Condition of Connectors After Concrete Failure.

TABLE 1

DIMENSIONS OF STUDS AND CHANNELS

Specimen	d in.	D in.	t in.	H[1] in.	h in.	W[2] in.
1/2	0.500	1.00	0.313	4.0	---	---
5/8	0.625	1.25	0.313	4.0	---	---
3/4	0.750	1.25	0.500	4.0	---	---
7/8	0.875	1.375	0.500	4.0	---	---
Channels	---	---	0.188	---	0.406	4.0
Channels	---	---	0.188	---	0.406	6.0

(1) Height of stud after welding.

(2) Length of channel.

Note: Dimensions shown are the average of all specimens.

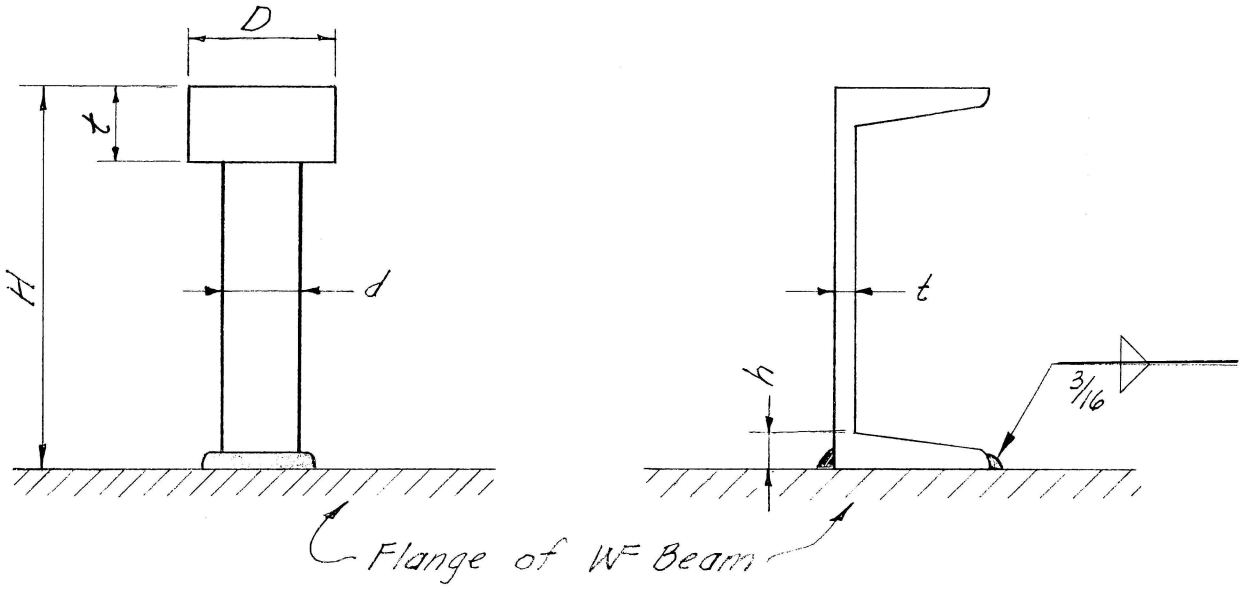


Table 2

Tensile Properties of Steel in Studs

Push-out Specimen	Stud Diameter (inches)	Coupon Diameter (inches)	Yield Stress (psi)	Ultimate Stress (psi)	Reduction in Area (per cent)
L7B4b	.875	.500	57,700	58,600	59.6
None	.875	.501	58,300	59,300	58.7
L6B4d	.750	.503	67,500	68,400	64.7
L6B4e	.750	.503	75,000	75,700	47.8

Manufacturer's Specifications:

Ultimate Tensile; 60,000 psi min.

Yield; 55,000 psi min.

Elongation; 20% min.

TABLE 3

COMPRESSIVE STRENGTH OF CONCRETE

Specimen No.	Type of Agg.	Age (Days)	f'_c in psi of Cylinder No.				Avg.	Remarks
			1	2	3	4		
1,5	Normal	34	6280	5000	5900		5730	
2,9	Haydite	34	4670	5600			5140	
3	Haydite	30	5600	6580	5800	6450	6110	
4	Normal	36	6830	6670	5980		6490	
6	Haydite	35	3730	4050			3900	7½" slump
7,19	Haydite	31	5060	5040			5050	
8	Haydite	38	5000	4890	4400		4760	
10,11	Haydite	28	5430	4950	5390		5260	
12,17	Normal	28	6000	6110	4140		5420	
13,14,18	Haydite	36	5600	5450			5520	
15,20	Haydite	32	4800	5070			4940	
16	Haydite	85	4920	4340	4900		4720	
21,22	Normal	43	5480	5690	6030		5730	
23	Haydite	40	4000	3965			3980	Cylinders Honeycombed
24	Haydite	40	4315	5304			4810	Cylinders Honeycombed

TABLE 4

PROPERTIES OF PUSH-OUT SPECIMENS

Specimen		Connector		Concrete		Ultimate Ld. (kips per connector)	Type of Failure	Remarks
No.	Mark	Stud Diam (in.)	Channel length (in.)	Type (1)	f'_c (psi)			
1	N7B4a	7/8		R-Normal	5730	32.2	Concrete	
2	L7B4a	7/8		Light	5140	27.9	Concrete	
3	L7B4b	7/8		R-Light	6110	25.0	Concrete	
4	N6A4a	3/4		R-Normal	6490	21.6	Weld	Bad Welds
5	N6B4a	3/4		R-Normal	5730	29.4	Concrete	
6	L6A4a	3/4		R-Light	3900	15.9	Weld	Bad Welds
7	L6B4a	3/4		R-Light	5050	19.4	Weld	Bad Welds
8	L6B4b	3/4		Light	4760	16.5	Weld	Bad Welds
9	L6B4c	3/4		Light	5140	18.9	Weld	Bad Welds
10	L6B4d	3/4		R-Light	5260	22.5	Concrete	
11	L6B4e	3/4		R-Light	5260	23.6	Concrete	
12	N5B4a	5/8		Normal	5420	19.2	Stud	
13	L5B4a	5/8		Light	5520	18.0	Stud	
14	L5B4b	5/8		Light	5520	18.6	Stud	
15	L5B4c	5/8		Light	4940	16.2	Concrete	
16	L5B4d	5/8		R-Light	4720	16.5	Concrete	
17	N4B4a	1/2		Normal	5420	12.2	Stud	
18	L4B4a	1/2		Light	5520	8.6	Stud	Eccent. Ld.
19	L4B4b	1/2		R-Light	5050	10.8	Stud	
20	L4B4c	1/2		Light	4940	11.9	Stud	
21	N4BC4		4	R-Normal	5730	62.0	Concrete	
22	N4BC6		6	R-Normal	5730	97.5	Concrete	
23	L4BC4		4	R-Light	4810	60.2	Concrete	
24	L4BC6		6	R-Light	3980	69.5	Concrete	

(1) The prefix R denotes that the concrete was proportioned and mixed at a local readymix plant.

TABLE 5

SUMMARY OF TEST RESULTS OF PUSH-OUTS WITH STUDS

Specimen No.	Specimen Mark	Stud Diam. (in.)	f'_c (psi)	Load on One Stud in Kips at Avg. Slip of: .003 in.	.006 in.	.020 in.	Critical Load (Q_{cr}) Avg. Slip (in.)	Load on One Stud in Kips	Res. Slip (in.)	Ultimate Load (Q_u) Avg. Slip (in.)	Load on One Stud in Kips	$\frac{Q_{cr}}{Q_u}$
1	N7B4a	7/8	5730	4.5	7.8	17.2	.018	16.3	.005	.356*	32.2	.506
2	L7B4a	7/8	5140	4.5	8.2	17.2	.018	16.5#	---	.148	27.9	.592
3	L7B4b	7/8	6110	3.3	6.1	14.1	.020	14.2	.004	.125	25.0	.569
5	N6B4a	3/4	5730	5.3	8.5	17.9	.019	17.5#	---	.203	29.4	.595
10	L6B4d	3/4	5260	2.9	5.1	10.9	.022	11.5	.004	.162	22.5	.511
11	L6B4e	3/4	5260	2.9	5.5	12.6	.017	11.7	.003	.177	23.6	.496
12	N5B4a	5/8	5420	2.2	4.7	10.0	.013	8.0	.004	.174	19.2	.416
13	L5B4a	5/8	5520	3.2	5.1	10.3	.011	7.5	.002	.317*	18.0	.417
14	L5B4b	5/8	5520	2.7	4.8	8.7	.013	7.5	.003	.418	18.6	.403
17	N4B4a	1/2	5420	1.9	3.1	6.5	.013	5.2	.004	.188*	12.2	.424
19	L4B4b	1/2	5520	1.2	2.4	5.1	.016	4.6	.004	.273	10.8	.428
20	L4B4c	1/2	4940	2.0	3.8	7.5	.009	5.0	.002	.222*	11.9	.421

* Ultimate residual slip.

Determined from load vs. average slip curve.

TABLE 6

SUMMARY OF TEST RESULTS OF PUSH-OUTS WITH CHANNELS

Specimen		Length of 4-in. x 5.4-lb. Channel (in.)	f'_c (psi)	Load on One Channel in Kips at Avg. Slip of:			Critical Load (Qcr)			Ultimate Load (Qu)		$\frac{Qcr}{Qu}$
No.	Mark			.003 in.	.006 in.	.020 in.	Avg. Slip (in.)	Ld. on One Ch. in Kips	Res. Slip (in.)	Avg. Slip (in.)	Ld. on One Ch. in Kips	
21	N4BC4	4.0	5730	9.0	18.0	40.0	.013	31.0	.003	.058	62.0	.472
22	N4BC6	6.0	5730	14.0	25.0	57.0	.011	39.5	.001	.083	97.5	.462
23	L4BC4	4.0	4810	11.0	19.0	37.0	.012	29.0	.002	.111*	60.3	.481
24	L4BC6	6.0	3980	14.0	23.0	46.5	.012	36.0	.001	.079	69.5	.518

* Slip at 60.0 kips per channel.

TABLE 7

COMPARISON OF STUDS WITH REPORTED PUSH-OUT TESTS

Investigator	Stud Diam. (in.)	Concrete		Load on One Stud in Kips at Avg. Slip of:			Critical Load, Qcr			Ultimate Ld. (Qu)		No. of Tests
		Type of Agg.	f'c (psi)	.003 in.	.006 in.	.020 in.	Avg. Slip (in.)	Ld. on One Stud in Kips	Res. Slip (in.)	Avg. Slip (in.)	Ld. on One Stud in Kips	
Univ. of Missouri	7/8	Haydite	5620	3.9	7.1	15.6	.019	15.4	.004	.137	26.4	2
Univ. of Missouri	7/8	Normal	5730	4.5	7.8	17.2	.018	16.3	.005	.356	32.2	1
Viest (2)	7/8	Normal	5340	5.9	9.4	19.3	.0165	17.4	.004	.257	37.6	1
Chinn (4)	7/8	Idealite	5400	---	---	---	---	18.7	.0043	---	32.0	1
Univ. of Missouri	3/4	Haydite	5260	2.9	5.3	11.8	.020	11.6	.0035	.170	23.1	2
Univ. of Missouri	3/4	Normal	5730	5.3	8.5	17.9	.019	17.5	---	.203	29.4	1
Viest (2)	3/4	Normal	4060	5.3	8.3	14.3	.0102	11.7	.0019	.382	32.3	2
Thurlimann (3)	3/4	Normal	5080	3.5	6.2	12.4	---	---	---	---	24.7	1
Chinn (4)	3/4	Idealite	5340	4.1	6.0	16.6	.016	15.0	.0045	---	25.8	2
Univ. of Missouri	5/8	Haydite	5520	3.0	5.0	9.5	.012	7.5	.0025	.418	18.3	2
Univ. of Missouri	5/8	Normal	5420	2.2	4.7	10.0	.013	8.0	.004	.174	19.2	1
Viest (2)	5/8	Normal	4020	4.3	6.8	12.2	.012	9.6	.0025	.299	23.2	2
Univ. of Missouri	1/2	Haydite	5230	1.6	3.1	6.3	.012	4.8	.003	.248	11.4	2
Univ. of Missouri	1/2	Normal	5420	1.9	3.1	6.5	.013	5.2	.004	.188	12.2	1
Viest (2)	1/2	Normal	4120	2.9	4.3	8.2	.0098	5.8	.0023	.167	14.2	2

Note: All tests used 4-inch-high headed studs.

TABLE 8

COMPARISON OF CHANNELS WITH REPORTED PUSH-OUT TESTS

Investigator	Length of Channel (in.)	Concrete		Load on One Channel in Kips at Avg. Slip of:			Ultimate Load on One Channel in Kips	Qcr or Qyp* Kips
		Type of Agg.	f'c (psi)	.003 in.	.006 in.	.020 in.		
Univ. of Missouri	4	Haydite	4810	11.0	19.0	37.0	60.3	29.0
Univ. of Missouri	4	Normal	5730	9.0	18.0	40.0	62.0	31.0
Univ. of Illinois (5)	4	Normal	4430	23.4	29.6	46.0	81.9	31.5
Univ. of Missouri	6	Haydite	3980	14.0	23.0	46.5	69.5	36.0
Univ. of Missouri	6	Normal	5730	14.0	25.0	57.0	97.5	39.5
Univ. of Illinois (5)	6	Normal	6320	----	30.0	65.8	118.2	40.0
" " "	6	"	5340	20.7	33.7	60.5	116.1	38.2
" " "	6	"	4770	22.0	32.0	57.2	98.2	36.0
" " "	6	"	4140	28.7	37.7	60.0	102.5	39.5
" " "	6	"	3500	20.6	29.3	51.5	95.0	---
" " "	6	"	3470	22.8	31.6	52.5	91.0	35.1
" " "	6	"	3140	21.6	30.0	47.3	79.0	29.3
" " "	6	"	2570	14.0	21.8	36.9	67.5	---
" " "	6	"	2300	16.8	23.8	39.7	72.5	---
" " "	6	"	2070	20.3	26.8	43.3	74.8	29.1

Note: All connectors are 4-in. x 5.4-lb. standard channel sections.

*Qyp is the load per channel at the yield point strain (110×10^{-5} in/in.) of the channel.

TABLE 9

COMPARISON OF STUDS AND CHANNELS WITH CURRENT SPECIFICATIONS

Connector	Type of Aggregate	Avg. f'_c psi	Useful Capacity of One Connector in Kips Without Factor of Safety			
			Univ. of Missouri	1961 AASHO *	1961 AISC x	Missouri State Highway Specs.
7/8 Stud	Normal	5730	16.3	19.3 (16.0)	18.0	15.977
7/8 Stud	Haydite	5620	15.4	19.0 (16.0)	----	----
3/4 Stud	Normal	5730	17.5	14.1 (11.7)	13.3	11.739
3/4 Stud	Haydite	5260	11.6	13.5 (11.7)	----	----
5/8 Stud	Normal	5420	8.0	9.5 (8.1)	9.2	----
5/8 Stud	Haydite	5520	7.5	9.6 (8.1)	----	----
1/2 Stud	Normal	5420	5.2	6.1 (5.2)	5.9	----
1/2 Stud	Haydite	5230	4.8	6.0 (5.2)	----	----
4-in. x 5.4-lb. Channel of 4" length	Normal	5730	31.0	27.4 (22.9)	21.2	22.9
4-in. x 5.4-lb. Channel of 4" length	Haydite	4810	29.0	25.1 (22.9)	----	----
4-in. x 5.4-lb. Channel of 6" length	Normal	5730	39.5	41.2 (34.4)	31.8	34.4
4-in. x 5.4-lb. Channel of 6" length	Haydite	3980	36.0	34.3 (34.4)	----	----

* Values in parentheses are computed for f'_c = 4000 psi; other values are computed for avg. f'_c of tests.

x Values are for f'_c = 4000 psi.

APPENDIX

PUSH-OUT TEST

Specimen N7B4a

Date Cast 1-29-63 Date Tested 2-27-63

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Res. Slip	Remarks
0	3913	3911	3895	3920			
5	908	910	881	912	.0007		
10	898	908	869	903	.0015		
15	889	902	857	893	.0024		
20	880	896	846	884	.0033		
15	882	897	849	886	.0031		
10	888	902	855	891	.0076		
5	895	908	863	899	.0018		
0	911	908	892	914	.0004	.0004	
5	898	910	870	906	.0014		
10	890	905	859	898	.0022		
15	884	899	851	892	.0028		
20	877	893	844	885	.0035		
15	879	894	847	888	.0033		
10	884	900	854	893	.0027		
5	892	907	862	900	.0020		
0	910	907	893	914	.0004	.0004	
5	897	909	867	905	.0015		
10	889	903	857	898	.0023		
15	883	897	850	891	.0030		
20	877	891	843	885	.0036		
25	867	881	834	877	.0045		
30	857	869	822	865	.0056		
25	857	868	824	867	.0056		
20	862	874	830	872	.0050		
15	868	882	836	879	.0044		
10	874	889	843	886	.0037		
5	882	898	853	895	.0028		
0	905	903	889	911	.0008	.0008	
5	890	903	860	902	.0021		
10	878	894	848	894	.0031		
15	871	887	840	887	.0038		
20	864	880	834	881	.0045		
25	857	872	828	874	.0052		
30	848	861	820	866	.0061		
25	850	864	824	870	.0058		
20	855	870	829	874	.0053		
15	862	878	834	881	.0046		
10	869	885	841	888	.0039		
5	880	896	851	896	.0029		
0	905	901	889	909	.0009	.0009	
10	876	892	847	894	.0032		
20	860	875	831	880	.0048		
30	845	858	819	865	.0063		
40	822	835	799	843	.0085		
30	830	842	804	851	.0078		
20	840	855	817	863	.0066		
10	856	873	831	880	.0050		
0	900	896	883	904	.0014	.0014	
10	867	882	839	886	.0041		
20	850	865	822	870	.0058		
30	834	848	809	854	.0074		

Specimen N7B4a Continued

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Res. Slip	Remarks
40	821	832	795	838	.0088		
30	826	837	802	846	.0082		
20	838	852	814	860	.0069		
10	853	870	828	877	.0053		
0	899	895	881	902	.0016	.0016	
10	865	880	837	885	.0043		
20	848	861	819	868	.0061		
30	831	843	805	852	.0077		
40	817	826	792	836	.0092		
50	796	802	769	812	.0115		
40	801	805	775	819	.0110		
30	811	818	787	830	.0098		
20	823	834	800	846	.0084		
10	840	855	818	865	.0065		
0	893	887	873	894	.0023	.0023	
10	857	870	824	874	.0054		
20	836	850	805	855	.0073		
30	821	832	792	838	.0089		
40	807	815	777	824	.0104		
50	790	796	761	805	.0122		
40	798	804	770	815	.0113		
30	808	815	780	825	.0103		
20	820	831	793	839	.0089		
10	838	853	811	860	.0069		
0	892	885	869	891	.0026	.0026	
10	855	868	821	868	.0057		
20	832	846	803	849	.0077		
30	817	827	788	832	.0094		
40	801	808	773	817	.0110		
50	788	793	759	801	.0124		
60	760	766	732	773	.0152		
50	764	768	748	780	.0145		
40	775	781	749	791	.0136		
30	788	795	763	805	.0122		
20	802	812	777	821	.0107		
10	823	837	798	842	.0085		
0	880	874	855	879	.0038	.0038	
10	838	851	806	853	.0073		
20	817	829	787	832	.0094		
30	801	809	771	817	.0110		
40	785	791	757	800	.0126		
50	770	775	741	784	.0142		
60	754	756	724	765	.0160		
50	759	761	731	773	.0154		
40	770	773	742	785	.0142		
30	782	788	755	799	.0129		
20	798	804	771	815	.0113		
10	819	829	791	836	.0091		
0	878	871	850	875	.0041	.0041	
10	832	848	801	846	.0078		
20	811	825	781	826	.0099		
30	794	805	764	810	.0116		
40	778	787	749	793	.0133		
50	763	771	734	777	.0148		

Specimen N7B4a Continued

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Res. Slip	Remarks
60	748	754	718	759	.0165		
70	714	720	680	718	.0202		
60	717	723	687	724	.0197		
50	727	733	698	736	.0186		
40	739	747	710	750	.0173		
30	755	763	724	765	.0158		
20	771	782	741	784	.0140		
10	793	806	763	808	.0117		
0	858	852	818	839	.0068	.0068	
10	812	825	776	819	.0102		
20	791	801	755	794	.0124		
30	772	782	737	778	.0142		
40	756	764	721	761	.0159		
50	741	746	705	742	.0176		
60	725	729	689	725	.0193		
70	707	709	669	705	.0212		
60	712	713	676	710	.0207		
50	722	724	686	721	.0196		
40	734	737	699	735	.0184		
30	749	752	713	751	.0168		
20	766	772	731	772	.0150		
10	789	798	755	798	.0125		
0	853	846	808	831	.0075	.0075	
20	786	794	744	785	.0132		
40	751	755	708	747	.0170		
60	720	721	678	714	.0202		
80	663	657	606	635	.0270		
60	674	668	619	648	.0258		
40	699	694	644	677	.0231		
20	729	730	678	713	.0197		
0	817	804	750	774	.0124	.0124	
20	763	760	691	726	.0175		
40	720	719	657	690	.0213		
60	690	685	626	655	.0246		
80	655	645	586	610	.0286		
60	671	661	602	625	.0270		
40	696	687	628	654	.0244		
20	3728	3723	3661	3691	.0209		
0	816	803	736	756	.0132		
20	756	755	679	711	.0184		
40	717	712	643	673	.0224		
60	686	676	610	635	.0258		
80	650	636	567	587	.0300		
90	592	571	488	500	.0372		Dials won't stabilize.
100	493	453	350	355	.0497		
110	3340	3288	3154	3145	.0678		
120	3080	3017	2860	2850	.0958		
129	Dials moving too	fast to	read.		-----		Slab cracked.
0	0629	0309	----	0137	.3556	.3556	

PUSH-OUT TEST

Specimen L7B4a

Date Cast 1-29-63 Date Tested 2-25-63

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Average Res. Slip	Remarks
Preloaded to 50 kips (40% of expected ultimate load).							
0	3913	4030	3799	3944	0	0	
10	908	4009	796	919	.0014		
20	891	3989	782	898	.0032		
30	869	966	765	875	.0053		
40	839	936	744	848	.0080		
50	805	902	719	820	.0110		
60	762	860	686	785	.0148		
50	759	861	690	789	.0147		
40	774	876	706	807	.0131		
30	795	895	723	826	.0112		
20	817	917	739	845	.0092		
10	842	942	757	868	.0069		
0	3876	3988	3780	3908	.0034	.0034	
10	861	964	765	880	.0054		
20	834	939	748	858	.0077		
30	811	914	732	838	.0098		
40	788	891	715	819	.0118		
50	765	869	698	800	.0139		
60	740	845	676	778	.0162		
70	688	797	635	733	.0208		
80	595	717	555	650	.0292		
90	450	563	420	510	.0436		
100	3162	3266	3140	3210	.0727		
110	2690	2780	2670	2720	.1207		
111.5	2413	2536	2397	2406	.1484		Slab cracked.

PUSH-OUT TEST

Specimen L7B4b

Date Cast 2-6-63 Date Tested 3-8-63

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Res. Slip	Remarks
0	4537	4462	3950	3922	0		
5	531	453	946	909	.0008		
10	525	437	940	890	.0020		
15	516	421	933	876	.0031		
20	505	403	925	861	.0044		
15	509	405	926	865	.0042		
10	518	414	933	874	.0033		
5	578	425	941	883	.0024		
0	536	451	948	910	.0006	.0006	
5	535	438	947	886	.0016		
10	524	425	940	875	.0027		
15	514	414	932	865	.0037		
20	504	403	924	855	.0046		
25	490	387	915	841	.0060		
30	475	368	903	825	.0075		
25	477	369	904	830	.0073		
20	485	378	912	838	.0065		
15	497	388	920	848	.0055		
10	509	399	928	858	.0044		
5	521	414	937	869	.0033		
0	532	444	945	905	.0011	.0011	
10	515	411	935	861	.0037		
20	492	385	919	842	.0058		
30	471	361	900	822	.0079		
40	437	321	872	791	.0113		
30	448	330	882	804	.0102		
20	469	352	900	822	.0082		
10	494	380	918	842	.0059		
0	523	435	940	899	.0019	.0019	
10	4502	4392	3925	3848	.0051		
20	477	364	908	827	.0074		
30	455	338	889	808	.0095		
40	432	313	868	786	.0118		
50	390	267	829	747	.0164		
40	400	276	838	758	.0150		
30	420	295	858	777	.0130		
20	444	319	876	797	.0109		
10	470	352	900	820	.0082		
0	505	419	928	888	.0033	.0033	
10	482	370	911	828	.0070		
20	454	336	890	805	.0097		
30	428	309	868	783	.0121		
40	403	284	848	763	.0143		
50	378	257	825	738	.0168		
60	321	200	780	685	.0221		
50	330	208	787	696	.0213		
40	349	226	805	714	.0194		
30	372	250	824	734	.0173		
20	397	277	845	756	.0149		
10	428	311	870	784	.0120		
0	466	387	908	862	.0062	.0062	
10	441	329	885	799	.0104		

Specimen L7B4b Continued

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Res. Slip	Remarks
20	410	294	861	771	.0134		
30	382	264	838	746	.0160		
40	355	235	816	724	.0185		
50	333	214	797	703	.0206		
60	300	282	768	672	.0212		
70	4220	4100	3700	3600	.0313		
50	246	125	718	625	.0290		
40	269	146	738	643	.0269		
30	293	172	760	663	.0246		
20	321	200	785	689	.0219		
10	354	240	814	722	.0185		
0	393	317	855	803	.0126	.0126	
20	355	220	810	715	.0198		
40	277	----	761	666	.0190		
60	222	4105	710	615	.0305		
80	4040	3920	540	445	.0482		
60	064	943	562	466	.0460		
50	085	462	580	485	.0440		
40	106	3986	600	505	.0419		
20	157	4042	651	557	.0366		
0	238	161	735	683	.0264	.0264	
20	178	069	686	592	.0337		
40	122	4006	632	538	.0393		
60	4068	3952	582	488	.0445		
80	4085	3870	509	410	.0499		
90	3750	3640	3280	3180	.0755		
100	260	160	2800	2660	.1248		Cracked by #4.
0	3300	3220	2915	2830	.1152	.1152	

PUSH-OUT TEST

Specimen N6A4a

Date Cast 11-6-62 Date Tested 12-12-62

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Res. Slip	Remarks
0	500	500	5000	5000	0		
2.5	500	500	4999	4999	.0001		
5	500	500	996	998	.0002		
7.5	4995	499	992	997	.0007		
10	995	99	986	995	.0009		
7.5	99	99	987	995	.0010		
5	995	99	989	995	.0008		
2.5	995	995	993	996	.0005		
0	500	500	996	996	.0002	.0002	
5	4995	4995	991	997	.0006		
10	99	99	985	995	.0010		
15	99	98	974	991	.0016		
20	98	97	961	987	.0026		
15	985	975	963	987	.0023		
10	985	98	969	988	.0020		
5	99	985	978	991	.0014		
0	995	0	990	997	.0005	.0005	
10	99	985	973	991	.0015		
20	98	97	957	986	.0027		
30	97	95	931	975	.0044		
40	95	92	892	957	.0070		
30	955	93	901	962	.0063		
20	96	94	911	965	.0056		
10	97	96	931	975	.0041		
0	99	99	973	991	.0014	.0014	
10	97	965	940	981	.0036		
20	96	95	919	972	.0050		
30	955	935	902	964	.0061		
40	95	92	882	950	.0075		
50	92	885	847	929	.0105		
60	81	81	864	915	.0150		
50	82	82	871	919	.0143		
40	825	83	884	930	.0133		
30	84	845	800	944	.0143		
20	85	86	819	861	.0153		
10	875	885	848	883	.0128		
0	92	935	911	927	.0077	.0077	
10	89	905	866	898	.0110		
20	865	885	839	876	.0134		
30	85	865	817	856	.0153		
40	83	845	797	838	.0173		
50	81	83	777	820	.0191		
60	77	80	748	783	.0225		
70	67	715	660	683	.0318		
80	41	515	453	425	.0549		
86.5	38	40	395	----	.0608		Ultimate.

PUSH-OUT TEST

Specimen N6B4a

Date Cast 1-29-63 Date Tested 3-4-63

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Res. Slip	Remarks
0	3891	4058	3490	4876			
10	3880	4050	3477	4859	.0012		
20	3868	4036	3460	4838	.0028		
30	3854	4014	3436	4809	.0051		
40	3849	3988	3411	4766	.0075		
50	3837	3958	3379	4720	.0105		
40	3845	3963	3383	4728	.0099		
30	3857	3974	3396	4740	.0090		
20	3867	3988	3411	4757	.0073		
10	3879	4004	3431	4780	.0055		
0	3886	4046	3468	4848	.0017	.0017	
10	3878	4015	3446	4793	.0046		
20	3868	3999	3426	4769	.0063		
30	3856	3985	3408	4748	.0080		
40	3843	3970	3393	4730	.0095		
50	3827	3953	3375	4707	.0113		
40	3835	3960	3382	4716	.0106		
30	3847	3972	3395	4729	.0093		
20	3860	3985	3411	4747	.0078		
10	3872	4002	3432	4771	.0060		
0	3882	4046	3465	4843	.0020	.0020	
10	3878	4012	3442	4784	.0050		
20	3866	3995	3421	4757	.0069		
30	3853	3980	3404	4738	.0085		
40	3839	3966	3388	4720	.0101		
30	3848	3974	3397	4731	.0091		
20	3860	3987	3411	4747	.0078		
10	3873	4004	3432	4771	.0059		
0	3881	4047	3465	4845	.0019	.0019	
10	3878	4011	3441	4782	.0051		
20	3865	3993	3420	4757	.0070		
30	3851	3978	3402	4736	.0087		
40	3838	3965	3387	4720	.0101		
30	3847	3973	3396	4731	.0092		
20	3860	3986	3411	4747	.0078		
10	3873	4004	3432	4771	.0059		
0	3880	4048	3464	4841	.0021	.0021	
10	3879	4012	3438	4779	.0052		
20	3866	3994	3417	4753	.0071		
30	3854	3980	3400	4733	.0087		
40	3841	3967	3385	4715	.0102		
50	3826	3951	3371	4696	.0118		
60	3803	3927	3340	4664	.0145		
70	3764	3886	3290	4610	.0191		
80	3715	3832	3220	4540	.0252		
90	3640	3750	3125	4445	.0339		
100	3500	3606	2965	4289	.0489		
110	3280	3385	2730	4060	.0715		
117.5	2600	2700	2000	3340	.1419		Held for some time
117.75	2100		1590		.1846		
0	2220	2342	1618	2031	.2026		

PUSH-OUT TEST

Specimen L6B4a

Date Cast 12-14-62 Date Tested 1-15-63

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Average Res. Slip	Remarks
0	3955	4398	4301	4395			
2.5	955	398	299	387	.0003		
5	951	388	289	374	.0012		
7.5	949	388	286	371	.0014		
10	946	387	284	368	.0016		
5	950	387	286	371	.0014		
0	955	395	298	389	.0003	.0003	
5	949	390	292	381	.0009		
10	942	384	284	372	.0017		
15	933	376	276	362	.0026		
20	921	366	268	349	.0036		
10	927	368	275	359	.0030		
0	949	391	295	388	.0007	.0007	
10	930	374	280	369	.0024		
20	914	361	268	351	.0039		
30	882	333	245	322	.0067		
15	891	338	257	341	.0056		
0	939	384	292	385	.0012	.0012	
10	911	357	272	363	.0037		
20	891	340	257	340	.0052		
30	872	326	244	322	.0071		
40	817	272	195	275	.0123		
30	817	270	201	284	.0119		
15	843	290	222	313	.0095		
0	917	363	280	375	.0029	.0029	
20	849	296	223	313	.0092		
40	800	254	185	268	.0136		
45	765	220	155	239	.0168		
30	775	225	166	257	.0157		
15	809	256	199	293	.0123		
0	900	346	269	365	.0042	.0042	
20	815	266	200	294	.0119		
40	761	219	157	246	.0107		
50	701	162	111	195	.0220		
30	726	181	133	227	.0196		
15	3760	4210	4164	4262	.0163		
0	868	319	250	344	.0067	.0067	
20	776	226	170	263	.0154		
40	713	171	121	206	.0210		
55	633	090	055	135	.0284		
30	665	113	081	171	.0255		
15	708	159	121	214	.0212		
0	822	280	219	311	.0104	.0104	
20	722	174	130	221	.0201		
40	657	108	073	161	.0263		
60	510	3967	3950	030	.0398		
30	556	4003	986	077	.0357		
15	604	054	4030	124	.0309		
0	738	195	141	234	.0185	.0185	
30	588	4035	013	103	.0328		
60	458	3914	3905	3985	.0447		
65	355	805	810	880	.0550		

Specimen L6B4a Continued

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Res. Slip	Remarks
30	390	843	833	912	.0518		
15	---	---	---	---	-----		Skipped
0	3587	4058	4001	4080	.0331	.0331	
30	428	3883	3870	3950	.0480		
60	300	765	765	830	.0597		
70	3000	3460	3500	3550	.0885		
30	044	507	502	566	.0858		
15	100	567	554	624	.0801		
0	250	741	684	755	.0655	.0655	
30	096	569	546	610	.0807		
60	2960	439	425	475	.0938		
77,500	2000		2480		.1888		
0	1017	2495	2458	2440	.2160		

PUSH-OUT TEST

Specimen L6B4b

Date Cast 12-20-62 Date Tested 2-1-63

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Res. Slip	Remarks
0	4257	4307	4467	4580			
2.5	254	305	461	579	.0003		
5	251	306	453	576	.0006		
7.5	246	306	443	571	.0011		
10	243	305	436	566	.0015		
5	246	306	441	568	.0013		
0	255	308	462	578	.0002	.0002	
5	245	308	448	577	.0008		
10	237	303	436	571	.0016		
15	227	296	429	561	.0025		
20	216	286	410	550	.0037		
10	228	295	424	559	.0026		
0	252	307	459	577	.0004	.0004	
10	230	296	431	569	.0021		
20	212	281	410	553	.0039		
30	185	250	377	525	.0069		
15	204	269	400	544	.0049		
0	246	300	452	574	.0010	.0010	
10	221	289	421	563	.0029		
20	199	268	397	542	.0051		
30	179	247	375	522	.0072		
40	140	205	336	485	.0111		
30	150	214	345	494	.0102		
15	182	244	377	525	.0071		
0	234	290	440	567	.0020	.0020	
20	182	249	374	521	.0071		
40	136	201	325	473	.0119		
45	133	177	300	447	.0144		
30	132	194	319	465	.0125		
15	167	228	356	502	.0090		
0	225	284	427	559	.0029	.0029	
20	170	229	354	505	.0088		
40	122	181	304	454	.0138		
50	083	132	259	410	.0182		
30	109	158	285	438	.0155		
15	4144	4198	4326	4478	.0116		
0	209	264	407	545	.0047	.0047	
20	148	204	328	482	.0112		
40	098	148	275	430	.0165		
55	030	077	200	360	.0236		
30	068	112	243	400	.0197		
15	104	155	287	442	.0156		
0	179	227	378	520	.0077	.0077	
60	3942	3970	120	280	.0325		
0	4110	4143	318	474	.0142	.0142	
65	3740	3750	3935	4110	.0519		
0	3935	3940	4163	4356	.0304	.0304	
66							Ultimate.
0	3200	3122	3439	3693	.1039	.1039	

PUSH-OUT TEST

Specimen L6B4c

Date Cast 1-29-63 Date Tested 3-6-63

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Average Res. Slip	Remarks
0	3529	4023	3866	4139	0	0	
10	500	4002	857	134	.0016		
20	468	3971	843	117	.0040		
30	430	933	821	092	.0070		
40	376	875	784	4055	.0117		
50	305	800	727	3999	.0182		
40	312	807	737	4008	.0173		
30	334	827	759	028	.0152		
20	360	852	782	050	.0128		
10	395	885	808	076	.0098		
0	475	950	843	110	.0045	.0045	
10	437	920	804	075	.0080		
20	404	887	777	046	.0111		
30	374	857	751	4021	.0139		
40	347	827	725	3998	.0165		
50	315	790	688	963	.0200		
40	328	802	692	973	.0191		
30	350	824	713	3993	.0169		
20	377	851	738	4015	.0144		
10	413	887	770	044	.0111		
0	479	943	826	100	.0052	.0052	
10	435	909	781	055	.0094		
20	398	874	750	024	.0128		
30	368	843	722	4000	.0156		
40	341	815	697	3977	.0182		
30	358	832	710	3991	.0167		
20	384	858	733	4013	.0142		
10	420	892	764	040	.0110		
0	481	945	826	099	.0052	.0052	
10	433	909	3778	4051	.0097		
20	395	872	745	4021	.0131		
30	366	841	719	3999	.0158		
40	339	814	696	976	.0183		
30	357	832	710	3991	.0167		
20	384	859	733	4013	.0142		
10	420	893	763	039	.0111		
0	481	946	826	099	.0051	.0051	
10	431	904	776	052	.0099		
20	394	868	744	4021	.0133		
30	366	838	718	3998	.0159		
40	338	811	693	975	.0185		
50	307	776	658	945	.0218		
60	200	655	531	832	.0335		
70	2910	340	320	550	.0609		
75.5	No readings, moving too fast - load held until slab cracked.						
0	1497	1714	1754	2130	.2116		

PUSH-OUT TEST

Specimen L6B4d

Date Cast 3-18-63 Date Tested 4-15-63

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Res. Slip	Remarks
0	4268	3636	3619	3429			
5	253	614	618	415	.0013		
10	241	598	607	400	.0026		
15	227	580	593	384	.0042		
20	212	561	577	368	.0059		
15	218	565	579	372	.0055		
10	230	576	589	382	.0044		
5	243	590	604	395	.0030		
0	262	622	616	421	.0008	.0008	
5	250	597	608	395	.0026		
10	237	581	594	382	.0040		
15	226	570	583	371	.0051		
20	215	559	571	360	.0062		
25	201	542	551	342	.0079		
30	182	518	526	319	.0102		
25	186	521	527	322	.0099		
20	196	531	536	331	.0090		
15	217	543	548	343	.0075		
10	219	555	560	354	.0066		
0	258	613	607	411	.0016	.0016	
10	226	564	574	362	.0057		
20	202	537	545	336	.0083		
30	180	512	520	312	.0107		
40	126	454	457	251	.0166		
30	135	462	463	260	.0158		
20	159	485	486	283	.0135		
10	190	518	520	313	.0103		
0	243	595	585	390	.0035	.0035	
10	4199	3529	3542	3330	.0088		
20	168	495	505	300	.0121		
30	139	467	475	270	.0150		
40	110	439	446	240	.0179		
50	025	353	362	157	.0264		
40	035	360	369	167	.0255		
30	058	382	390	189	.0233		
20	089	409	419	215	.0205		
10	120	448	458	250	.0169		
0	194	537	535	345	.0085	.0085	
10	140	466	481	270	.0149		
20	105	430	440	233	.0186		
30	077	398	405	200	.0218		
40	050	371	376	171	.0246		
50	4015	337	340	134	.0282		
60	3907	222	220	015	.0397		
50	910	226	225	025	.0392		
40	929	245	246	043	.0372		
30	954	271	273	070	.0346		
20	3980	299	301	096	.0319		
10	4018	342	346	137	.0278		
0	095	432	427	244	.0189	.0189	
10	042	364	378	170	.0250		
20	4004	324	333	129	.0291		

Specimen L6B4d Continued

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Average Res. Slip	Remarks
30	3974	292	295	094	.0324		
40	946	262	264	050	.0358		
50	917	234	232	3030	.0385		
60	875	189	3181	2976	.0433		
70	3700	3013	2995	2785	.0615		
60	3686	2997	2985	2784	.0625		
50	702	3015	3005	803	.0607		
40	722	037	029	826	.0585		
30	745	061	055	851	.0560		
20	776	093	090	882	.0528		
10	817	137	127	2929	.0486		
0	909	229	219	3046	.0387	.0387	
10	858	167	175	2930	.0456		
20	817	128	129	931	.0487		
30	785	095	090	891	.0523		
40	755	064	056	858	.0555		
50	725	035	3025	825	.0586		
60	694	3002	2990	787	.0620		
70	628	2930	910	702	.0696		
80	327	628	590	390	.1004		Dials running.
90	2750		1900		.1619		Crack at #1 stud.
0	2750	2021	2014	1817	.1588	.1588	

PUSH-OUT TEST

Specimen L6B4e

Date Cast 3-18-63 Date Tested 4-15-63

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Res. Slip	Remarks
0	3467	3873	3063	4484			
5	462	865	052	457	.0013		
10	448	853	040	445	.0025		
15	431	839	030	432	.0039		
20	415	823	019	418	.0053		
15	418	828	025	425	.0048		
10	428	837	035	435	.0038		
5	443	850	046	447	.0025		
0	464	868	059	474	.0006	.0006	
5	450	852	048	450	.0022		
10	437	840	037	439	.0034		
15	424	829	026	427	.0045		
20	415	820	017	418	.0054		
25	401	804	004	404	.0069		
30	383	786	2989	386	.0086		
25	382	789	2994	391	.0083		
20	391	797	3003	402	.0074		
15	402	807	013	412	.0063		
10	415	820	025	423	.0051		
5	432	836	038	437	.0036		
0	458	862	053	469	.0011	.0011	
10	425	829	029	427	.0044		
20	398	803	007	405	.0069		
30	377	780	2986	383	.0090		
40	3333	3736	2948	4339	.0130		
30	335	754	962	354	.0121		
20	362	770	2983	376	.0099		
10	391	800	3007	401	.0072		
0	440	850	044	454	.0025	.0025	
10	404	809	3014	408	.0063		
20	372	780	2990	383	.0091		
30	344	752	967	358	.0117		
40	319	729	942	333	.0141		
50	265	670	892	278	.0196		
40	268	682	903	290	.0186		
30	292	704	924	312	.0164		
20	315	728	944	333	.0142		
10	352	760	2974	362	.0110		
0	408	825	3021	425	.0052	.0052	
10	368	779	987	375	.0095		
20	333	746	958	343	.0127		
30	382	716	932	317	.0135		
40	277	690	907	293	.0180		
50	252	662	878	261	.0209		
60	162	575	790	170	.0298		Dials Running
50	165	584	797	177	.0291		
40	184	605	817	200	.0270		
30	206	624	838	221	.0250		
20	236	654	864	247	.0222		
10	274	689	897	280	.0187		
0	338	767	949	344	.0122	.0122	
10	295	714	905	296	.0169		

Specimen L6B4e Continued

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Res. Slip	Remarks
20	256	677	886	267	.0200		
30	221	646	857	232	.0233		
40	194	619	830	211	.0258		
50	166	591	803	183	.0286		
60	130	555	761	138	.0326		Dials won't stabilize
70	3000	430	637	013	.0452		
60	2993	427	634	010	.0456		
40	3033	463	675	051	.0416		
20	091	518	726	104	.0362		
0	3200	641	815	203	.0257	.0257	
10	167	594	787	159	.0295		
20	127	562	753	128	.0329		
30	093	523	721	098	.0363		
40	063	494	692	069	.0392		
50	032	465	664	039	.0422		
60	3000	436	632	4009	.0453		
70	2955	382	575	3949	.0507		
80	2685		304		.0771		
90	2220		1830		.1240		
94.5	1700		1285		.1773		Crack at #3 Stud
0	1945	2348	1535	2962	.1524		

PUSH-OUT TEST

Specimen N5B4a

Date Cast 1-9-63 Date Tested 2-8-63

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Res. Slip	Remarks
0	3813	3851	3990	3927			
5	3807	3823	3977	3906	.0017		
10	795	807	960	889	.0033		
5	798	814	967	894	.0027		
0	811	844	981	917	.0007	.0007	
5	800	813	972	901	.0024		
10	792	800	961	890	.0035		
15	778	781	948	875	.0050		
7.5	784	792	958	884	.0041		
0	809	840	977	915	.0010	.0010	
10	783	788	957	884	.0042		
15	774	776	948	873	.0053		
20	757	755	934	855	.0070		
10	767	770	946	869	.0057		
0	803	833	972	912	.0015	.0015	
10	774	778	946	874	.0052		
20	756	753	927	851	.0074		
25	739	732	911	833	.0092		
12.5	752	751	928	851	.0075		
0	796	822	966	906	.0023	.0023	
15	755	752	928	853	.0073		
30	714	701	889	810	.0117		
14	730	724	910	832	.0096		
0	782	806	954	896	.0036	.0036	
15	738	731	915	838	.0090		
30	706	692	885	806	.0123		
35	676	661	857	779	.0152		
17.5	694	685	880	802	.0130		
0	756	778	929	873	.0061	.0061	
15	712	702	896	820	.0113		
30	680	663	866	786	.0147		
40	635	612	824	743	.0192		
20	652	636	847	766	.0170		
0	717	737	897	842	.0097	.0097	
15	677	667	866	790	.0145		
30	646	627	834	756	.0180		
45	578	555	770	690	.0247		
22.5	602	585	798	715	.0220		
0	668	690	853	800	.0143	.0143	
15	632	617	828	753	.0188		
30	600	577	799	717	.0222		
50	503	478	712	628	.0315		
25	529	508	742	659	.0286		
0	600	617	800	744	.0205	.0205	
20	560	540	765	685	.0258		
40	517	493	722	640	.0302		
60	278	253	495	407	.0537		
30	312	292	530	444	.0501		
0	385	404	600	542	.0413	.0413	
25	347	328	560	478	.0468		
50	3295	3272	3505	3420	.0522		
70	2837	2810	3060	2970	.0976		

Specimen N5B4a Continued

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Average Res. Slip	Remarks
35	2876	2851	3098	3012	.0936		
0	3056	2974	3188	3119	.0786	.0786	
30	2911	2893	3136	3050	.0898		
60	2842	2816	3067	3980	.0969		
77	2064	2035	2309	2219	.1739		Ultimate
0	2193	2207	2446	2380	.1589	.1589	

PUSH-OUT TEST

Specimen L5B4a

Date Cast 11-28-62 Date Tested 1-3-63

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Res. Slip	Remarks
0	4396	4699	4614	4754			
2.5	389	699	612	752	.0003		
5	378	699	608	745	.0008		
7.5	368	699	603	736	.0014		
10	356	699	598	727	.0021		
7.5	356	699	597	726	.0021		
5	359	700	599	730	.0019		
2.5	366	702	602	737	.0014		
0	382	702	608	756	.0004	.0004	
5	368	702	601	735	.0014		
10	356	700	592	725	.0023		
15	334	698	578	707	.0037		
20	307	694	557	687	.0055		
15	307	694	558	688	.0054		
10	312	700	565	694	.0048		
5	325	705	579	709	.0036		
0	365	708	595	747	.0012	.0012	
10	327	704	571	702	.0040		
15	315	700	559	693	.0049		
20	302	696	544	682	.0060		
25	277	687	520	659	.0080		
30	240	673	494	628	.0107		
25	236	672	493	627	.0109		
20	239	679	499	631	.0104		
10	259	696	523	656	.0082		
0	330	710	569	721	.0033	.0033	
10	284	704	539	673	.0066		
20	251	689	507	643	.0093		
30	217	670	477	614	.0121		
40	110	617	395	514	.0207		
30	099	617	392	511	.0211		
20	114	637	410	530	.0193		
10	142	661	440	562	.0165		
0	223	697	503	632	.0102	.0102	
10	181	685	465	588	.0136		
20	141	660	428	553	.0170		
30	111	636	396	520	.0200		
40	060	600	344	467	.0248		
50	3830	415	100	210	.0477		
40	3783	382	080	200	.0505		
30	797	400	098	215	.0488		
20	822	425	124	245	.0462		
10	858	458	161	282	.0426		
0	031	516	231	350	.0334	.0334	
10	896	499	198	316	.0389		
20	854	462	161	278	.0427		
30	817	430	125	240	.0463		
40	780	398	090	203	.0498		
50	680	314	995	095	.0595		
60	480	120	770	870	.0806		
72.0							Ultimate.

PUSH-OUT TEST

Specimen L5B4b

Date Cast 11-28-62 Date Tested 1-4-63

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Average Res. Slip	Remarks
0	4149	4040	4361	3901			
2.5	140	044	350	896	.0005		
5	130	050	336	891	.0011		
7.5	119	056	320	886	.0018		
10	107	062	304	879	.0024		
7.5	108	062	304	879	.0025		
5	111	063	309	882	.0022		
2.5	118	062	319	886	.0017		
0	133	052	338	897	.0008	.0008	
5	115	061	318	889	.0017		
10	102	064	301	880	.0026		
15	077	068	275	865	.0042		
20	041	066	247	843	.0064		
15	042	067	248	844	.0063		
10	049	073	258	851	.0055		
5	065	076	277	866	.0042		
0	109	059	322	890	.0018	.0018	
10	055	075	276	871	.0044		
15	036	068	262	861	.0056		
20	017	059	250	850	.0069		
25	3998	040	228	829	.0089		
30	925	010	200	800	.0129		
25	921	011	201	800	.0130		
20	926	017	209	805	.0124		
10	950	038	234	826	.0101		
0	4042	049	301	871	.0047	.0047	
10	3980	063	244	847	.0079		
20	941	039	211	816	.0111		
30	898	009	178	781	.0146		
40	735	3894	055	634	.0283		
30	725	890	059	637	.0285		
20	748	914	083	661	.0261		
10	783	942	115	695	.0229		
0	883	975	193	744	.0164	.0164	
10	820	976	137	717	.0200		
20	777	943	100	679	.0238		
30	739	912	068	644	.0272		
40	675	864	010	575	.0332		
50	300	510	3630	160	.0713		
40	225	465	597	137	.0757		
30	247	485	621	160	.0735		
20	278	513	649	193	.0705		
10	319	548	687	235	.0666		
0	417	602	773	289	.0593	.0593	
10	358	584	731	270	.0627		
20	312	548	695	231	.0666		
30	269	510	658	192	.0706		
40	227	472	620	152	.0745		
50	120	375	500	020	.0859		
60	2130	2400	2560	2000	.1840		
74.3	----	----	0181	----	.4180		
0	052	250	485	005	.3915	.3915	

PUSH-OUT TEST

Specimen L5B4c

Date Cast 3-1-63 Date Tested 4-8-63

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Res. Slip	Remarks
0	3959	3904	3720	3636	0	0	
5	950	893	716	626	.0009		
10	934	879	709	616	.0020		
15	916	863	699	605	.0034		
20	897	845	687	592	.0050		
15	899	848	687	596	.0047		
10	911	860	695	605	.0037		
5	925	872	705	615	.0026		
0	947	893	713	630	.0009	.0009	
5	937	882	707	616	.0019		
10	923	871	697	605	.0031		
15	912	860	688	594	.0041		
20	900	848	678	584	.0052		
25	884	831	661	568	.0069		
30	859	808	639	546	.0092		
20	870	821	647	558	.0081		
10	896	845	671	580	.0057		
0	936	887	701	617	.0020	.0020	
10	908	853	683	586	.0047		
20	882	827	660	563	.0072		
30	854	801	634	538	.0098		
40	764	708	550	450	.0187		Dials running.
28.5	770	717	557	460	.0179		
20	790	739	576	481	.0158		
10	818	769	604	508	.0130		
0	863	817	651	555	.0083	.0083	
10	834	783	625	525	.0113		
20	804	751	595	494	.0144		
30	779	724	568	467	.0170		
40	3742	3787	3531	3431	.0182		
50	505	444	285	180	.0451		
40	500	442	283	184	.0453		
30	521	464	304	205	.0432		
20	545	491	331	231	.0405		
10	574	521	364	267	.0373		
0	620	570	425	328	.0319	.0319	
10	596	546	388	294	.0349		
20	565	516	354	261	.0381		
30	525	486	320	228	.0415		
40	504	455	288	195	.0444		
50	430	385	210	115	.0520		
53.5	340	---	100	---	.0620		
55	220	---	2990	---	.0735		
60	2920	---	2575	---	.1092		
65	2180	---	2000	---	.1750		Slabs cracked over #1 & #2 studs.
0	2223	2142	2050	1938	.1717	.1717	

PUSH-OUT TEST

Specimen L5B4d

Date Cast 4-11-63 Date Tested 6-13-63

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Res. Slip	Remarks
0	4616	4651	4513	4663			
5	614	644	503	663	.0005		
10	603	631	488	649	.0018		
15	591	617	472	631	.0033		
20	579	600	456	612	.0049		
15	585	602	457	620	.0045		
10	593	612	465	632	.0035		
5	604	624	479	646	.0022		
0	624	645	506	669	0	0	
5	617	633	487	643	.0016		
10	605	623	472	628	.0029		
15	594	615	460	615	.0040		
20	584	605	449	604	.0050		
25	568	587	432	574	.0071		Dials running.
30	555	562	307	535	.0121		
20	555	572	415	554	.0087		
10	577	596	435	583	.0063		
0	613	637	486	634	.0018	.0018	
10	589	605	446	587	.0054		
20	578	582	422	555	.0077		
30	537	556	401	521	.0107		
40	417	435	296	382	.0228		Dials running.
30	416	438	294	386	.0227		
20	439	463	312	411	.0205		
10	4473	4497	4337	4446	.0173		
0	514	546	391	505		.0122	
10	489	512	353	456	.0158		
20	464	485	325	419	.0188		
30	428	456	301	388	.0218		
40	394	421	4266	4346	.0254		
50	4085	4093	3840	4020	.0601		Dials running.
40	4052	4075	3910	3991	.0604		
30	4074	4088	3930	4011	.0585		
20	4091	4115	3956	4038	.0536		
10	4124	4157	3987	076	.0525		
0	4181	4211	4047	140		.0466	
10	4161	4181	4019	099	.0496		
20	4124	4150	3982	4060	.0532		
30	4091	4121	3947	4027	.0564		
40	4078	4087	3914	3995	.0592		
50	3985	---	3830	---	.0657		
55	3721	---	3540	---	.0934		
60	3143	---	2975	---	.1506		
65	2322	---	2145	---	.2331		Cracking sounds.
66	1962	2051	1833	1839	.2690		Ultimate
0	1962	2051	1833	1839	.2690	.2690	Cracks between #1 & #4 on top.

PUSH-OUT TEST

Specimen N4B4a

Date Cast 1-9-63 Date Tested 2-6-63

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Average Res. Slip	Remarks
0	4444	4581	4448	4523			
2.5	441	580	433	515	.0007		
5	435	574	420	505	.0016		
8.5	424	561	405	490	.0029		
10	416	552	395	480	.0038		
5	419	558	405	483	.0033		
0	434	572	434	503	.0013	.0013	
5	421	559	410	489	.0029		
10	410	545	396	478	.0042		
15	383	514	367	446	.0072		
10	382	517	374	446	.0069		
0	421	558	425	493	.0025	.0025	
10	387	525	383	455	.0062		
15	373	510	361	438	.0079		
17.5	360	497	347	423	.0092		
10	362	501	360	427	.0087		
0	418	555	422	488	.0028	.0028	
10	372	510	370	434	.0078		
15	360	496	355	420	.0091		
20	330	470	331	389	.0119		
10	338	477	345	396	.0011		
0	397	543	411	470	.0044	.0044	
10	352	494	349	408	.0098		
20	321	460	318	376	.0130		
22.5	303	441	300	355	.0149		
10	315	455	319	367	.0135		
0	390	526	390	446	.0061	.0061	
10	331	473	327	384	.0120		
20	304	443	297	350	.0151		
25	4267	4405	4264	4310	.0188		
15	274	413	275	318	.0179		
0	363	500	359	412	.0091	.0091	
10	306	447	299	350	.0149		
20	275	415	269	316	.0180		
30	199	336	195	235	.0258		
15	210	353	211	250	.0243		
0	298	439	294	341	.0156	.0156	
10	247	395	237	285	.0208		
20	215	364	206	253	.0240		
30	4172	4320	4163	4210	.0283		
40	3930	4080	3920	3960	.0527		
20	3987	4087	3912	3953	.0514		
0	4022	4172	4004	4048	.0438	.0438	
10	3995	4147	3971	4010	.0468		
20	3964	4118	3934	3975	.0501		
30	3933	4088	3901	3939	.0534		
40	3865	4020	3830	3860	.0605		
45	3650	3800	3580	3610	.0839		
25	3629	3786	3573	3602	.0852		
0	3725	3877	3673	3706	.0754	.0754	
10	3703	3861	3645	3677	.0778		
20	3676	3834	3612	3640	.0809		

Specimen N4B4a Continued

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Res. Slip	Remarks
30	645	806	579	604	.0841		
40	610	777	538	560	.0878		
45	530	700	440	460	.0967		
49	2930	3085	2800	2810	.1593		Ultimate.
0	2633	2786	2512	2538	.1882	.1822	

PUSH-OUT TEST

Specimen I4B4a

Date Cast 11-28-62 Date Tested 1-4-63

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Average Res. Slip	Remarks
0	4740	4049	4053	4008			
2.5	724	049	039	008	.0008		
5	697	049	006	008	.0023		
7.5	666	050	3994	004	.0034		
10	639	050	972	3994	.0049		
5	642	052	976	996	.0046		
0	4667	062	4006	4021	.0024	.0024	
5	644	060	3989	4011	.0037		
10	617	054	968	3998	.0053		
15	572	040	931	976	.0083		
10	573	042	933	976	.0082		
5	584	049	944	3986	.0072		
0	626	063	985	4022	.0039	.0039	
5	597	060	966	4006	.0055		
10	575	049	943	3992	.0073		
15	553	035	922	979	.0090		
20	482	3995	865	927	.0145		
10	484	4005	871	3933	.0139		
0	562	047	943	4008	.0073	.0073	
10	495	016	895	3961	.0121		
20	440	3967	833	916	.0174		
25	300	840	700	770	.0310		
15	274	838	697	775	.0317		
0	395	940	804	895	.0204		
10	319	883	745	825	.0270		
20	262	827	694	778	.0322		
34.5	1975	1625	1502	1515	.2558		Ultimate failure.

PUSH-OUT TEST

Specimen L4B4b

Date Cast 12-14-62 Date Tested 1-14-63

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Res. Slip	Remarks
0	3991	4149	4094	4100			
2.5	977	142	058	086	.0018		
5	958	145	032	070	.0032		
7.5	941	145	006	053	.0047		
10	935	136	3980	034	.0062		
5	927	145	994	038	.0058		
0	3963	4165	4062	4086	.0015	.0015	
5	932	140	006	054	.0051		
10	914	116	978	036	.0073		
15	878	072	933	3998	.0113		
10	877	077	943	4001	.0109		
5	889	099	966	017	.0091		
0	3943	4146	4044	4074	.0032	.0032	
5	900	101	982	033	.0080		
10	879	076	956	013	.0103		
15	861	049	931	3994	.0125		
20	802	3978	865	933	.0189		
10	808	4000	866	945	.0179		
0	3897	4093	3999	4038	.0077	.0077	
10	822	011	903	3963	.0159		
20	775	3955	845	913	.0212		
25	685	855	750	820	.0306		
15	678	863	754	816	.0306		
0	793	985	900	948	.0177		
10	714	893	804	867	.0264		
20	673	843	750	821	.0312		
30	490	640	560	640	.0501		
20	469	633	542	617	.0518		
10	500	671	585	654	.0481		
0	600	774	705	779	.0369	.0369	
10	535	698	621	694	.0447		
20	483	645	564	640	.0501		
30	410	560	490	570	.0576		
43	1270		1356		..2730		
0	1441	1577	1510	1580	.2557		

PUSH-OUT TEST

Specimen L4B4C

Date Cast 3-1-63 Date Tested 4-2-63

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Average Res. Slip	Remarks
0	3883	3967	2904	3949			
5	865	951	883	933	.0018		
10	840	937	859	914	.0038		
15	818	922	835	892	.0059		
20	791	901	802	864	.0086		#1 dial jumped.
15	797	909	806	871	.0080		
10	811	920	820	885	.0067		
5	830	933	840	903	.0049		
0	867	954	885	936	.0015	.0015	
5	837	937	852	915	.0041		
10	815	921	833	899	.0059		
15	798	908	815	885	.0074		
20	782	895	798	868	.0090		
25	745	864	762	833	.0125		
30	670	797	685	753	.0200		
20	681	810	694	768	.0188		
10	718	844	732	805	.0151		
0	790	892	802	857	.0091	.0091	
10	738	848	739	812	.0142		
20	691	819	709	782	.0176		
30	646	775	662	733	.0222		
40	235	370	250	310	.0635		
30	215	356	235	302	.0649		
20	252	390	270	337	.0614		
10	279	418	293	366	.0587		
0	374	495	360	421	.0513	.0513	
10	325	456	322	388	.0553		
20	282	416	282	349	.0594		
30	241	378	243	310	.0633		
40	120	260	110	170	.0761		Dials running.
46.5	2230	----	1210	----	.1674		Dials running.
47.5	----	----	----	----	------		Ultimate
0	1902	1001	864	2047	.2222		

PUSH-OUT TEST

Specimen N4BC4

Date Cast 5-8-63 Date Tested 6-14-63

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Res. Slip	Remarks
0	4701	4700	4716	4700	0	0	
5	700	700	711	686	.0005		
10	693	691	696	675	.0016		
15	685	681	684	665	.0026		
20	683	670	673	646	.0036		
25	682	662	664	635	.0043		
30	679	652	654	621	.0053		
20	686	656	655	621	.0050		
10	699	669	665	629	.0039		
0	710	700	697	675	.0009	.0009	
10	697	672	681	640	.0032		
20	685	658	671	628	.0044		
30	675	646	662	615	.0055		
40	660	628	649	594	.0072		
30	664	630	651	596	.0069		
20	677	641	658	605	.0059		
10	692	656	670	617	.0046		
0	703	694	697	673	.0013	.0013	
10	694	661	680	628	.0039		
20	678	645	669	614	.0053		
30	666	632	660	603	.0064		
40	655	620	651	592	.0075		
50	645	597	634	573	.0092		Dials running slightly.
40	638	599	635	575	.0092		
20	4661	4620	4652	4591	.0073		
0	691	684	694	668	.0020	.0020	
10	683	647	678	622	.0047		
20	666	628	665	606	.0063		
30	650	613	654	594	.0077		
40	638	601	645	584	.0087		
50	625	587	635	572	.0100		
60	601	561	617	552	.0122		Running slightly.
40	613	570	624	561	.0112		
20	641	596	644	581	.0089		
0	672	667	690	660	.0032	.0032	
20	648	608	658	595	.0077		
40	618	578	636	572	.0103		
60	590	549	614	547	.0129		
70	562	517	593	521	.0156		Running.
60	564	518	594	523	.0155		
40	583	536	607	538	.0138		
20	614	566	628	561	.0112		
0	647	640	677	644	.0052	.0052	
20	623	583	647	583	.0095		
40	590	549	622	556	.0125		
60	563	520	602	531	.0150		
80	509	462	563	486	.0199		Running.
60	519	470	568	494	.0192		
40	4501	4489	4584	4510	.0183		
20	574	523	607	536	.0144		
0	612	600	652	619	.0084	.0084	

Specimen N4BC4 Continued

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Res. Slip	Remarks
20	587	546	629	563	.0123		
40	553	509	604	532	.0155		
60	525	479	583	508	.0181		
80	490	440	556	478	.0213		
90	449	395	524	444	.0251		Running.
60	474	421	542	463	.0229		
40	492	437	553	476	.0215		
20	523	470	576	502	.0187		
0	562	549	620	587	.0125	.0125	
20	543	500	603	533	.0160		
40	508	462	577	502	.0192		
60	477	428	552	475	.0221		
80	445	394	527	448	.0251		
100	365	310	463	381	.0325		Running.
80	370	317	464	386	.0320		
60	388	335	477	400	.0304		
40	414	362	494	420	.0282		
20	450	400	523	450	.0249		
0	493	481	572	537	.0184	.0184	
20	477	435	557	483	.0216		
40	4444	4398	4529	4451	.0249		
60	413	363	502	423	.0279		
80	381	332	487	398	.0305		
100	332	280	435	354	.0354		Dials running.
110	267	216	376	298	.0415		
120	107	020	290	215	.0520		
124	060	----	197	----	.0580		Ultimate.

PUSH-OUT TEST

Specimen L4BC4

Date Cast 4-11-63 Date Tested 5-20-63

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Res. Slip	Remarks
0	3957	3869	3595	3703			
5	957	860	596	691	.0005		
10	952	855	589	679	.0012		
15	943	856	577	670	.0020		
20	933	855	566	661	.0027		
10	943	863	570	670	.0020		
0	958	870	590	700	.0002	.0002	
10	934	855	584	691	.0015		
20	918	848	572	678	.0027		
30	898	835	554	662	.0044		
20	906	841	558	668	.0038		
10	922	853	569	683	.0024		
0	954	869	590	701	.0003	.0003	
10	923	852	580	695	.0019		
20	905	840	568	681	.0033		
30	891	829	555	668	.0045		
40	869	810	537	650	.0065		
20	888	826	552	669	.0047		
10	907	840	566	686	.0031		
0	948	864	590	701	.0005	.0005	
10	913	845	578	697	.0023		
20	893	831	564	681	.0039		
30	877	818	551	666	.0053		
40	862	803	537	651	.0068		
50	3834	3779	3514	3628	.0092		
40	840	785	519	634	.0087		
20	866	806	540	661	.0063		
0	936	853	589	700	.0012	.0012	
10	902	835	573	692	.0031		
20	879	818	556	675	.0049		
30	860	802	541	658	.0066		
40	844	789	527	643	.0080		
50	826	772	512	627	.0097		
60	791	740	485	597	.0128		Dials running.
40	807	755	498	611	.0113		
20	838	785	523	644	.0084		
0	915	838	584	692	.0024	.0024	
20	858	799	548	663	.0064		
40	819	764	514	625	.0101		
60	779	726	481	589	.0137		
70	736	685	445	551	.0177		Dials running.
40	763	711	467	576	.0152		
20	800	745	499	614	.0117		
0	880	807	507	669	.0065	.0065	
20	826	772	528	638	.0090		
40	784	731	491	597	.0130		
60	744	695	456	560	.0167		
80	3660	3615	3383	3480	.0247		
60	670	625	390	489	.0238		
40	694	649	413	514	.0214		
20	734	687	449	557	.0174		
0	816	755	525	617	.0103	.0103	

Specimen L4BC4 Continued

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Res. Slip	Remarks
20	768	720	489	591	.0139		
40	722	677	446	545	.0184		
60	681	639	409	504	.0223		
80	625	585	358	449	.0277		Dials running.
90	540	502	280	368	.0359		
60	562	524	298	388	.0338		
30	611	570	344	439	.0290		
0	713	667	448	527	.0192	.0192	
20	674	635	414	504	.0224		
40	628	590	371	457	.0270		
60	584	547	327	412	.0314		
80	537	503	285	368	.0358		
90	489	459	240	319	.0404		
100	3365	3337	3120	3198	.0526		
80	369	340	121	197	.0524		
60	393	363	145	222	.0500		
30	442	410	195	276	.0450		
0	556	515	311	381	.0340	.0340	
20	522	488	280	358	.0369		
40	3474	3443	3232	3310	.0416		
60	426	399	188	261	.0463		
80	379	353	140	210	.0511		
100	285	265	3057	3120	.0599		Dials running.
110	3080	3055	2860	2915	.0804		
120	2775	2750	2560	2615	.1106		Concrete crack.
120.5	----	----	----	----	------		Ultimate
0	3031	3025	2855	2850	.0841	.0841	

PUSH-OUT TEST

Specimen N4BC6

Date Cast 5-8-63 Date Tested 6-21-63

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Average Res. Slip	Remarks
0	4596	4596	4580	4600			
5	594	590	580	592	.0004		
10	588	583	583	583	.0009		
15	581	576	582	576	.0014		
20	575	569	578	570	.0020		
25	569	562	573	566	.0026		
30	568	554	567	561	.0031		
20	568	555	568	562	.0030		
10	571	560	578	571	.0023		
0	591	584	586	590	.0005	.0005	
10	582	572	580	572	.0017		
20	572	562	570	563	.0026		
30	563	553	562	555	.0035		
40	555	541	551	541	.0046		
20	561	547	559	552	.0038		
0	592	585	584	588	.0006	.0006	
10	580	568	576	567	.0020		
20	569	557	564	556	.0032		
30	560	549	555	547	.0040		
40	552	541	549	537	.0048		
50	542	530	538	522	.0060		
40	543	530	538	524	.0059		
20	558	541	552	544	.0044		
0	591	584	582	584	.0008	.0008	
10	4577	4565	4573	4562	.0024		
20	565	553	560	550	.0036		
30	555	543	551	539	.0046		
40	547	535	544	529	.0054		
50	540	528	536	519	.0062		
60	527	517	524	503	.0075		
40	534	521	528	512	.0069		
20	553	536	547	536	.0050		
0	589	582	581	581	.0010	.0010	
20	560	548	555	544	.0041		
40	540	529	536	519	.0062		
60	524	514	521	500	.0078		
70	511	501	507	483	.0093		
60	512	501	507	485	.0092		
40	524	511	517	501	.0080		
20	546	528	539	529	.0058		
0	584	579	576	576	.0014	.0014	
20	553	542	547	536	.0049		
40	532	522	527	509	.0071		
60	517	507	511	488	.0087		
80	497	485	488	459	.0111		
60	504	490	592	467	.0105		
40	518	503	506	486	.0090		
20	541	522	529	518	.0066		
0	4577	4574	4569	4568	.0021	.0021	
20	548	535	540	528	.0055		
40	526	515	518	498	.0079		
60	510	498	501	474	.0097		

Specimen N4BC6 Continued

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Res. Slip	Remarks
80	493	481	483	452	.0116		
90	478	464	465	431	.0134		
60	492	474	474	446	.0122		
30	518	498	502	485	.0092		
0	567	567	557	556	.0031	.0031	
20	538	525	530	516	.0066		
40	517	505	506	484	.0090		
60	500	486	487	458	.0110		
80	483	469	470	437	.0128		
100	457	442	439	403	.0158		
60	478	456	455	425	.0140		
30	505	483	486	465	.0108		
0	556	555	540	539	.0046	.0046	
20	529	516	515	500	.0078		
40	508	494	491	466	.0103		
60	489	473	470	438	.0126		
80	471	455	451	416	.0145		
100	453	436	430	392	.0165		
110	434	415	408	366	.0187		
90	439	418	409	371	.0184		
60	4159	4433	4428	4395	.0164		
30	489	463	460	437	.0131		
0	540	538	518	513	.0066	.0066	
30	502	487	485	560	.0110		
60	470	454	449	416	.0146		
90	444	426	421	381	.0175		
120	400	381	375	329	.0222		Dials running slightly.
90	413	389	385	343	.0211		
60	435	407	405	369	.0189		
30	465	439	440	414	.0154		
0	519	516	498	489	.0087	.0087	
30	483	467	463	434	.0131		
60	451	434	428	391	.0167		
90	423	405	398	354	.0198		
120	390	371	363	315	.0233		
130	367	345	338	286	.0259		Dials running slightly.
90	383	356	350	303	.0245		
60	407	378	374	332	.0220		
30	439	411	410	380	.0183		
0	493	490	469	455	.0116	.0116	
30	458	443	437	405	.0157		
60	426	408	401	359	.0195		
90	396	377	369	321	.0227		
120	366	344	337	285	.0260		
140	4323	4300	4294	4234	.0305		Dials running.
120	329	302	297	239	.0301		
90	347	317	313	258	.0284		
60	370	340	337	291	.0259		
30	404	377	376	338	.0219		
0	459	457	437	417	.0151	.0152	
30	427	412	406	367	.0190		
60	392	375	367	319	.0230		

Specimen N4BC6 Continued

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Res. Slip	Remarks
90	362	342	334	281	.0263		
120	332	310	304	244	.0296		
150	268	241	240	160	.0366		
160	225	192	195	117	.0411		
90	258	220	222	153	.0380		
60	284	248	251	190	.0350		
30	319	286	293	238	.0309		
0	377	376	359	329	.0233	.0233	
30	350	333	331	280	.0270		
60	315	292	293	231	.0310		
90	282	257	256	188	.0347		
120	251	221	222	147	.0383		
150	208	175	177	095	.0429		
160	172	140	145	057	.0465		Dials running.
170	132	092	099	4007	.0511		
180	4071	4026	4040	3940	.0574		
190	3942	3883	3897	3787	.0716		
195	830	770	790	673	.0827		Ultimate
0	4157	4143	4047	3997	.0507	.0507	Cracked top between #2 and #3 dials.

PUSH-OUT TEST

Specimen L4BC6

Date Cast 4-11-63 Date Tested 5-10-63

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Res. Slip	Remarks
0	4830	4697	4089	4150	0	0	
5	830	694	086	143	.0003		
10	828	687	083	134	.0009		
15	824	680	079	126	.0014		
20	820	674	075	120	.0019		
10	826	679	079	124	.0015		
0	831	693	089	146	.0002	.0002	
10	825	680	085	132	.0011		
20	816	669	077	122	.0021		
25	811	663	073	117	.0026		
30	804	655	069	111	.0032		
20	810	659	073	114	.0028		
10	820	671	081	124	.0018		
0	830	692	090	147	.0002	.0002	
10	817	672	088	138	.0013		
20	806	660	078	128	.0024		
30	796	648	070	118	.0034		
40	778	629	060	108	.0048		
30	783	633	064	111	.0044		
20	792	643	072	118	.0035		
10	804	657	084	130	.0023		
0	826	690	089	147	.0004	.0004	
10	812	666	087	135	.0017		
20	799	649	078	124	.0029		
30	4788	4638	4069	4114	.0039		
40	775	626	060	106	.0050		
50	755	607	047	093	.0066		
40	760	611	051	097	.0062		
20	779	631	070	113	.0043		
0	821	687	088	147	.0006	.0006	
10	805	660	087	132	.0021		
20	790	641	077	121	.0034		
30	776	626	067	110	.0047		
40	764	615	057	101	.0057		
50	750	603	047	093	.0068		
60	728	583	032	077	.0087		
40	741	595	043	088	.0075		
20	767	620	067	109	.0051		
0	815	683	086	143	.0010	.0010	
20	781	634	072	114	.0041		
40	751	603	050	094	.0067		
60	721	578	029	073	.0091		
70	693	553	013	053	.0114		
50	705	565	021	063	.0103		
30	728	586	033	080	.0085		
20	745	604	052	094	.0068		
0	805	676	081	139	.0016	.0016	
20	4766	4623	4064	4106	.0052		
40	731	590	040	083	.0081		
60	700	563	4019	061	.0106		
80	651	518	3985	023	.0147		
60	662	528	3994	032	.0138		

Specimen L4BC6 Continued

Total Load	Slip Dial Reading at Location No. 1	2	3	4	Average Slip	Res. Slip	Remarks
40	683	550	4011	050	.0118		
20	715	583	035	078	.0089		
0	781	661	074	131	.0030	.0030	
20	748	610	052	097	.0065		
40	707	574	027	069	.0097		
60	673	542	4004	042	.0126		
80	635	508	3978	4016	.0157		Dials running.
100	543	421	911	3949	.0236		
80	552	431	918	956	.0227		
60	572	450	935	973	.0209		
40	598	476	956	3994	.0186		
20	638	512	3985	4021	.0153		
0	718	595	4041	093	.0080		
30	653	529	4001	4041	.0136		
60	594	475	3959	3997	.0185		
90	535	418	916	954	.0236		
120	355	240	781	822	.0392		
90	366	252	792	835	.0380		
60	401	286	820	863	.0349		
30	454	333	861	3906	.0303		
0	4569	4448	3958	4098	.0173	.0173	
30	505	389	914	3954	.0251		
60	438	320	864	902	.0310		
90	377	262	816	851	.0365		
120	4255	4140	732	765	.0469		
139	3920	3800	430	470	.0787		Cracked over channels on both slabs.

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