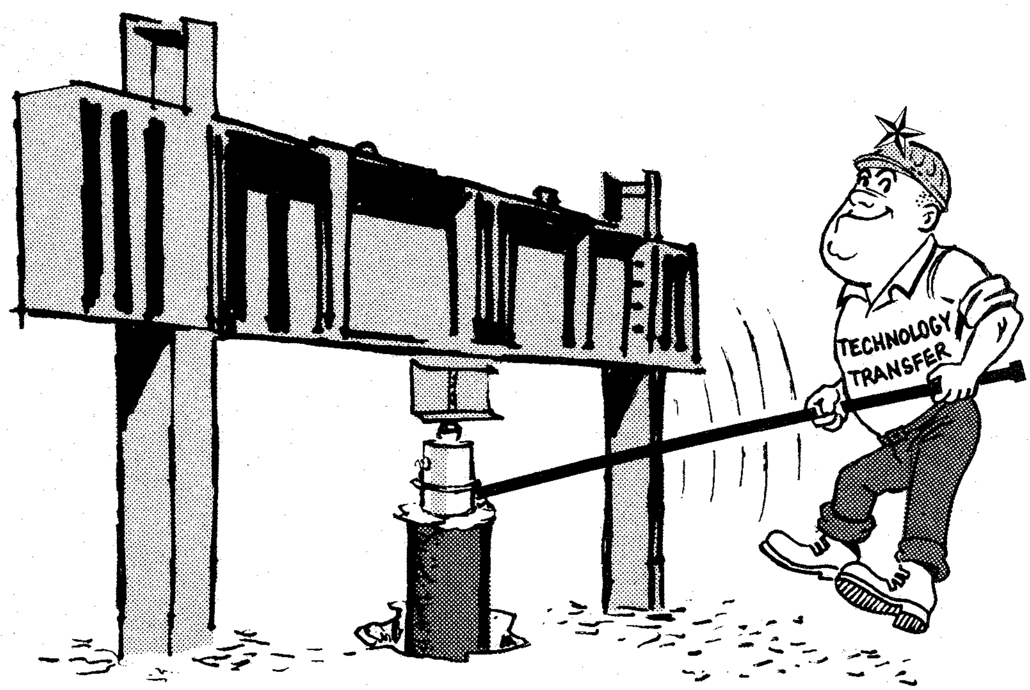
IP 77-8
Implementation Package

Users Manual for

The Texas Quick-Load Method for Foundation Load Testing



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H. D. Butler, Horace E. Hoy

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16. Abstract
The Texas State Department of Highways and Public Transportation has developed and implemented a "quick-load" method for load testing piling and drilled shafts. Using this method a load test can be completed in a relatively short time of one to two hours. On small projects where the time consuming AASHTO test cannot be economically justified, use of this test makes it feasible to use full-scale load tests to verify foundation designs on these jobs.

The purpose of the information presented herein is to assist highway engineers in understanding, using, and applying quick-load test methods. Additionally it will provide them with the information necessary to prepare specifications and cost estimates for quick-load testing.

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INTRODUCTION

Since 1965, the Texas State Department of Highways and Public Transportation has been using a "quick-load" method as the standard method for load testing driven piling and drilled shafts. Using this method, a load test can be completed in a relatively short time, normally one to two hours, whereas the standard AASHTO test may require well over one hundred hours. Use of this method on large projects can result in a substantial decrease in the cost of the tests and in the time required to complete a test program. On small projects, where the time consuming AASHTO test cannot be economically justified, use of the "quick-load" method makes it feasible to use full-scale load tests to verify foundation designs.

PURPOSE OF LOAD TESTS

Full-scale load tests should be performed on a pile or drilled shaft foundation at any time when it is readily apparent that substantial economic benefits will be derived from the testing. Whenever the strength and characteristics of the underlying soil are questionable, design values, construction procedures, and anticipated performance of the foundation should be verified by load testing. Load tests may be performed on a pile or drilled shaft for any one or more of the following reasons:

1. To verify the ability of the pile or drilled shaft to support the proposed design load at a predetermined elevation and in a particular soil stratum.
2. To determine the ultimate static bearing capacity for the pile or drilled shaft from which a maximum safe static load can be determined.
3. To determine a correlation factor between the static bearing capacity of a pile proven by load test and the capacity obtained by hammer formula, wave equation analysis or static analysis.
4. To determine a correlation factor between the frictional load capacity of a drilled shaft proven by load test and that obtained from a static analysis.
5. To determine typical correlation factors that can be used in future designs of pile and drilled shaft foundations in a variety of soil types.

DEVELOPMENT OF THE TEXAS QUICK-LOAD TEST METHOD

In 1961, Whitaker and Cook (1) developed a new method for testing piles which they termed the Constant Rate of Penetration (CRP) test. In this test the pile is forced into the ground at a constant rate of speed while the force required to maintain this rate is continuously measured. The CRP Method made it possible to perform a pile load test in a very short time, often less than one hour, and afforded a significant improvement over the 24 or more hours required by the conventional methods commonly used at that time.

The CRP test was further discussed by Esrig (2), in an article that appeared in the January 31, 1963 issue of Engineering News Record. After publication of this article, engineers of the Texas State Department of Highways and Public Transportation realized that a rapid test method such as this could significantly reduce the amount of time and money required for pile load testing. Following this, simplifying modifications were made to the CRP test to utilize available test equipment and promote standardization of the test procedure throughout the State. This modified CRP test has become known as the Texas Quick-Load Method of testing. Basically, this method requires that load be applied in increments of 5 to 10 tons (4536-9072 kg) with load, gross settlement, and other pertinent data recorded immediately before and after the addition of each increment of load. After an increment of load is added the load is maintained constant for a time interval of two and one-half minutes before the next increment is added.

Correlation Studies. Between January 1963 and March 1965, 11 pile load tests were performed by the Texas State Department of Highways and Public Transportation using both the AASHTO 48-24 Hour and the Quick-Load test methods. Of these tests, eight were loaded to theoretical failure by the 48-24 Hour method. All tests were carried to plunging failure with the Quick-Load method. Data from these tests are summarized in Tables 1, 2 and 3. The maximum proven design loads obtained from the eight tests carried to failure by both methods are shown plotted in Figure 1. Correlation between load values obtained by the two methods is considered to be quite good with the deviation being about four percent (5).

The costs incurred in performing a foundation load test are primarily due to manpower requirements and time delay to the foundation contractor. Table 4 is a summary of these data averaged for the 11 tests performed using both the Quick-Load and 48-24 Hour methods. It is evident from this data that the Quick-Load method offers a significant advantage over the 48-24 Hour method. Bid prices for pile load tests performed in Texas during the period 1963-1975 are shown in Table 5.

Based upon the results of these tests, the Texas State Department of Highways and Public Transportation adopted the Quick-Load method as the standard method for load testing piling and drilled shafts and have used it since 1965.

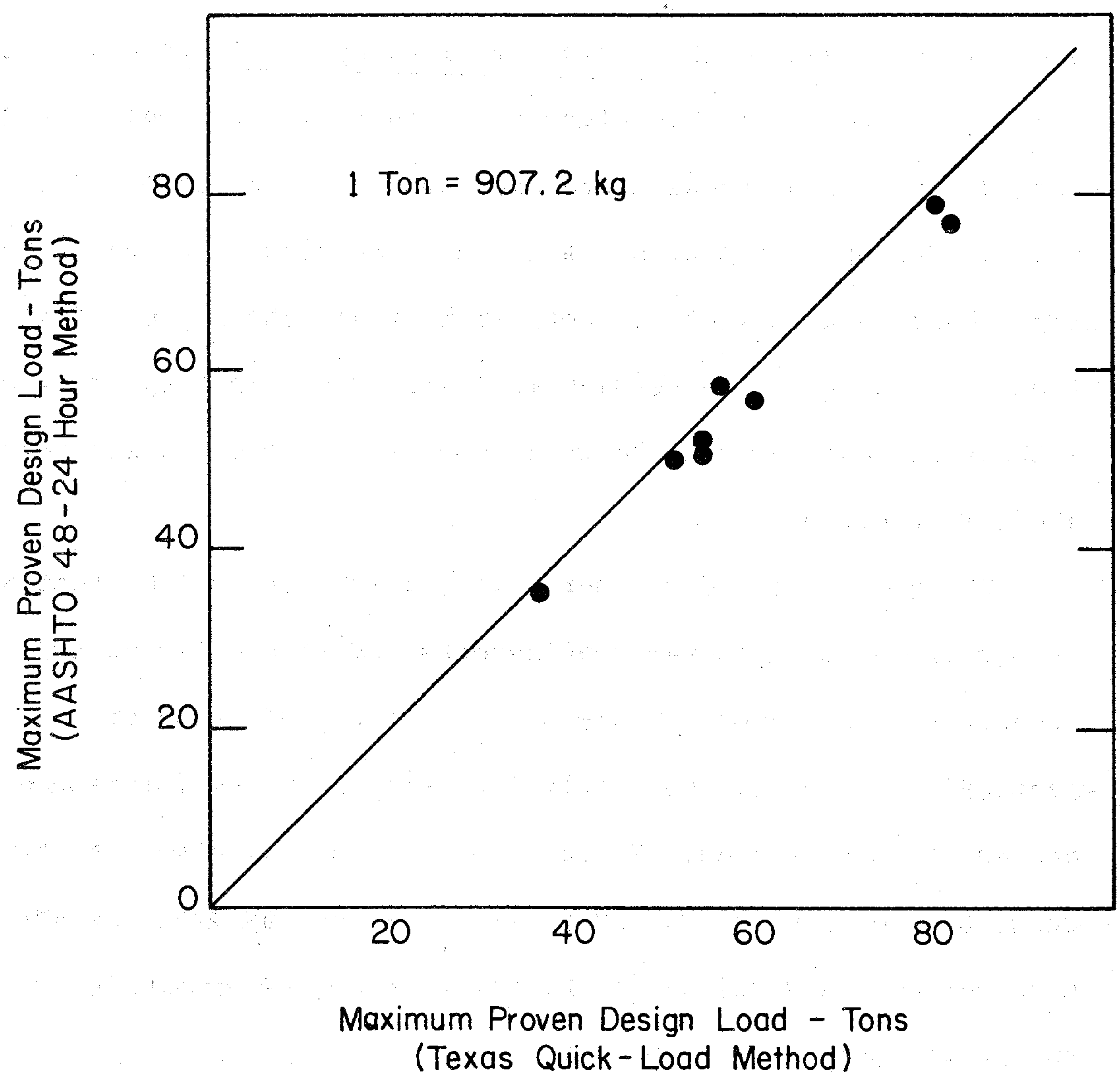


Figure 1. Correlation of Proven Design Load Between AASHTO 48-24 Hour and Texas Quick-Load Methods (After Fuller-Hoy 1970)

TABLE 1. DESCRIPTION OF PILES, SOIL, AND HAMMER
(After Fuller and Hoy, 1970)

Test Number	Pile Type	Total Pile Length (ft.-in.)		Effective Pile Length (ft.-in.)		General Soil Type	Pile Design Load (tons)	Type of Hammer	ENR Bearing Value (tons)	Final Penetration (in./blow)
1	16 in.sq PC/PS	40	0	36	0	Clay, sand, silty	47	Link-Belt 520	40.2	0.429
2	12BP53	51	0	49	0	Sand, clay	46	McK-T DE-30	42.8	0.260
3	18 in.sq PC/PS	103	0	83	6	Sand, clay	40	Vulcan 014 Vulcan 014	83.7	0.385
4	12BP53	32	4	25	0	Sand, clay	36.4	Vulcan 1	15.0	0.90
5	14 in.sq PC	28	8	21	0	Clay, silty, sandy	53	Vulcan 1	65.2	0.130
6	16 in.pipe	63	8	60	0	-	44	Delmag D-12	25.3	0.444
7	14 by 11 in. step-taper	31	0	31	0	Silt, clay	60	Raymond 1-S	39.0	0.400
8	12BP53	29	0	24	0	Clay, sand, silty	60	Delmag D-12	79.8	0.150
9	12BP53	32	0	31	0	Clay, sand, silty	60	Delmag D-12	97.1	-
10	16 by 11 in. step-taper	47	10	44	0	Clay, silty, sand	31	Raymond 1	11.22	1.20
11	12BP53	21	1	21	0	Sand, clay silty	52	Delmag D-12	63.7	0.170

1 inch = 2.54 cm
1 foot = 0.305 m
1 ton = 907.2 kg

TABLE 2. AASHTO 48-24 HOUR TEST METHOD
(After Fuller and Hoy, 1970)

Test Number	Duration of Test (hr)	Maximum Load on Pile (tons)	Maximum Load Held 48 Hours (tons)	Gross Settlement	Net Settlement	Proven Design Load (tons)	K-Factor[c]
1	102.25	110.0	105.0	0.313	0.251	52.5[a]	1.31
2	55.67	110	110	0.420	0.167	55 [b]	1.28
3	57	95	90	0.156	0.049	45 [b]	0.54
4	140.25	80	80	0.324	0.161	40 [b]	2.67
5	258	155	155	0.379	0.259	77 [a]	1.18
6	83.25	75	75	0.412	0.349	35 [a]	1.38
7	114.5	120	115	0.562	0.447	56.9[a]	1.46
8	132	160	160	0.501	0.281	79 [a]	0.99
9	192	115	115	0.496	0.362	57.52[a]	0.59
10	140.25	115	110	0.566	0.448	52.5[a]	4.67
11	111	105	105	0.390	0.262	50 [a]	0.784

Note: Piles loaded by hydraulic jack and reaction beam supported by anchor piling. Settlement was obtained by extensometers.

[a]In those cases where the standard 48-24 hour test load caused a permanent net settlement of more than 0.25 in. and other criteria were met, then the maximum proven design load is taken to be 50 percent of that load obtained by interpolation from the computed net settlement line value of 0.25 in. This line was obtained by calculations based on actual recorded recovery.

[b]Not failed.

[c]$K = \frac{\text{Proven Design Load (AASHTO 48-24 Hour Test Method)}}{\text{ENR Bearing Value (Table 1)}}$

1 inch = 2.54 cm
1 foot = 0.305 m
1 ton = 907.2 kg

TAALE 3. QUICK TEST METHOD
(After Fuller and Hoy, 1970)

Test Number	Duration of Test (min)	Plunging Failure Load (tons)	Ultimate Bearing Capacity[a] (tons)	Gross Settlement	Net Settlement	Proven Design Load (tons)	K-Factor[b]
1	65	120	109	0.185	0.087	54.5	1.36
2	45	145	125	1.151	-	62.5	1.46
3	55	180	150	0.651	0.379	75	0.89
4	65	140	96	0.818	-	48	3.2
5	-	190	166	0.397	0.256	83	1.27
6	50	85	74	0.666	0.596	37	1.46
7	-	134	121.5	0.476	0.356	60.7	1.56
8	75	170	162	0.597	0.371	81	1.01
9	-	120	113.5	0.301	0.168	56.75	0.58
10	105	120	109	0.403	0.284	54.5	4.86
11	67	115	103	0.337	0.226	51.5	0.81

1 inch = 2.54 cm
1 foot = 0.305 m
1 ton = 907.2 kg

[a] obtained by Double Tangent Method (5)

[b] $K = \frac{\text{Proven Design Load (Quick Test Method)}}{\text{ENR Bearing Value (Table 1)}}$

TABLE 4. AVERAGE MANPOWER REQUIREMENTS AND TIME DELAY TO CONTRACTOR

Test Method	Average Time/Test	Required Personnel	Man hours/ Test	Time Delay to Contractor
Quick-Load	1.1 hrs.	5	5.5	0.5 day
AASHTO 48-24 Hour	125 hrs.	2	250	5.2 days

TABLE 5. UNIT BID PRICE FOR PILE LOAD TESTS IN TEXAS, 1963 through 1975

Year	No. of Load Tests	No. of Projects	Unit Bid Price
1963	4	3	$1,850
1964	6	3	5,166
1965*	7	3	1,814
1966	6	3	1,400
1967	2	1	4,400
1968	7	4	1,671
1969	11	6	2,681
1970	3	2	5,000
1971	5	3	8,220
1972	2	1	2,500
1973	1	1	4,000
1974	0	0	0
1975	1	1	4,000

* Adopted Quick-Load Method as standard in March of 1965.

Advantages and Limitations of the Texas Quick-Load Method. Since adopting the Quick-Load method as a standard, the Texas State Department of Highways and Public Transportation has tested many piles and drilled shafts using this method and has obtained very reliable results. Based on this experience they have concluded that the Quick-Load method of testing offers the following advantages:

1. A load test can be expeditiously performed in approximately one hour with resultant savings in time and money;
2. Construction delay to the project caused by load testing is greatly reduced;
3. Full-scale load testing on small projects is feasible because of reduced time and costs.
4. Simplicity of the testing procedure ensures standardization of the test and easy interpretation and utilization of the results;
5. Load settlement curves can be easily duplicated by repeated tests; and
6. The tests generally result in more nearly undrained conditions of shear failure, thus providing a condition in which load capacities can be more rationally correlated to static analyses utilizing undrained laboratory shear tests.

There are no limitations on the use of the Quick-Load method when it is used to determine the load carrying capacity of a particular foundation-soil system. It can not be used, however, to define the settlement behavior of a foundation under a sustained load.

THE TEXAS QUICK-LOAD TEST METHOD

Load testing using the Texas Quick-Load method requires the application of incremental static loads to a pile or drilled shaft and measuring the resultant settlement. These incremental loads are applied by jacking against a reaction beam with one or more hydraulic jacks. The reaction beam is anchored, in turn, by two to four piles or drilled shafts. This arrangement is shown schematically in Figure 2.

Test Pile. The test pile should be of the same type and cross-section as the piling that will be used in the foundation and should be driven with the same equipment that will be used to drive the foundation piling. Complete records should be kept during driving of the test pile and anchor piling if used. These records should include type and size of hammer, cushion material and its thickness, capblock material, driving resistance of the piling, and any other pertinent information.

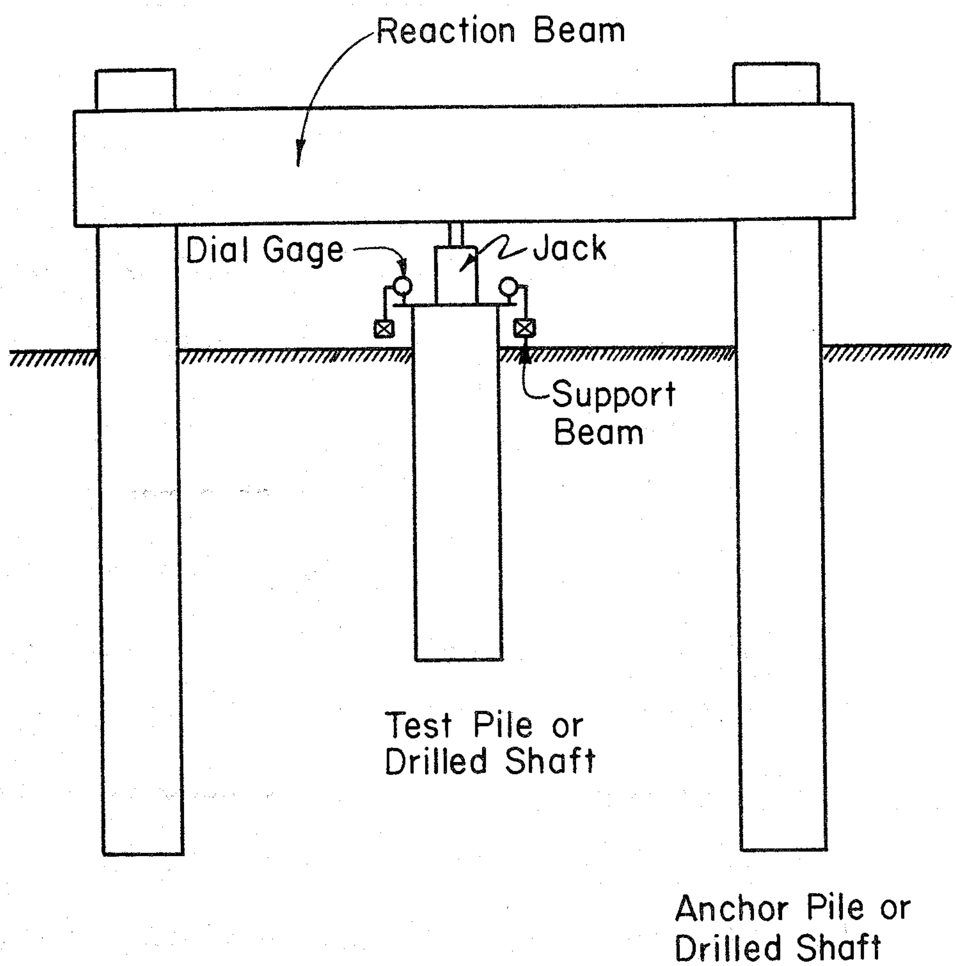


Figure 2. Typical Arrangement for Load Testing a Pile or Drilled Shaft

Some reasonable time interval between driving and loading the test pile should be provided. When the test pile is driven into a cohesive soil this will permit the soil to regain some of the shear strength lost because of the remolding effects of pile driving. If the pile is driven into a cohesionless sand there may be a relaxation of the soil around the pile with a corresponding reduction in load capacity. The Texas State Department of Highways and Public Transportation has adopted a minimum waiting period of five days between driving and loading a test pile. This permits the soil disturbed during the driving operation to regain some of its natural characteristics before testing but does not cause an excessive delay to the contractor. Local driving conditions may, however, warrant a different waiting period.

Test Drilled Shaft. A drilled shaft that is to be test loaded should be constructed using the same method that will be used throughout the structure, i. e., dry hole, cased, or slurry displacement. A test shaft is normally the same diameter as those in the structure; however, if there is reason to believe the shaft-soil system cannot be failed, then a shaft with a slightly smaller diameter may be tested and the results scaled up. During installation of the test shaft, a complete record of all pertinent drilling, construction, and soils data should be kept.

Before loading a test shaft, the concrete must have reached its design strength and the surrounding soil should be given sufficient time to adjust to the changes brought about by the migration of water and cement particles from the fresh concrete (6). If the surrounding soil is porous, a layer of soil-cement layer will form at the concrete-soil interface resulting in a gain in the soil shear strength. For soils such as clay, there will be only water migration and this will cause a decrease in shear strength. Current Texas State Department of Highways and Public Transportation Specifications require a minimum waiting period of seven days between concrete placement and load testing and in no case can testing begin before the concrete has attained its design strength.

Reaction System. The reaction system for load testing a pile or drilled shaft must be strong enough to withstand a load large enough to cause a plunging failure. For design purposes, this load is normally assumed to be four times that used in the structure foundation design.

Anchorage for the reaction system generally consists of two piles or drilled shafts spaced to provide a clear distance from the supports to the test pile or shaft of not less than 7 feet (2m). Closer spacing may be permitted if permanent piling or shafts in the structure are to be used as anchors. The uplift forces produced by the load test must be resisted by soil strata deep enough to prevent them from affecting the test results. This will require piling or drilled shafts used for anchorage to be somewhat longer than the one being tested. Drilled shafts that are used for anchorage should be constructed with an enlarged base (bell) if soil conditions will permit it. Typical test and anchor shaft details are shown in Figure 3. An alternate to using anchor shafts or piles is to jack against a weighted platform.

Piling and drilled shafts that can be incorporated into the permanent foundation should be utilized as anchorage whenever possible as this will reduce the cost of the load test. When this is done, the pile or drilled shaft must be designed to resist the additional uplift forces created by the test load.

Utilization of structure foundation elements as anchorage for load tests requires that consideration be given to the design of the reaction beam. There is obviously a wide range of pile and drilled shaft spacings in foundations and a reaction beam should be designed to accommodate as many of these spacings as practicable. A beam that has a working range of 15 to 30 feet (4.6-9.2m) should be adequate for normal usage. Close attention must be given to the design and fabrication details of the reaction beam because failure under the high loads attained during a load test would be extremely hazardous. Details and photographs of typical reaction systems are shown in Figures 4 through 7.

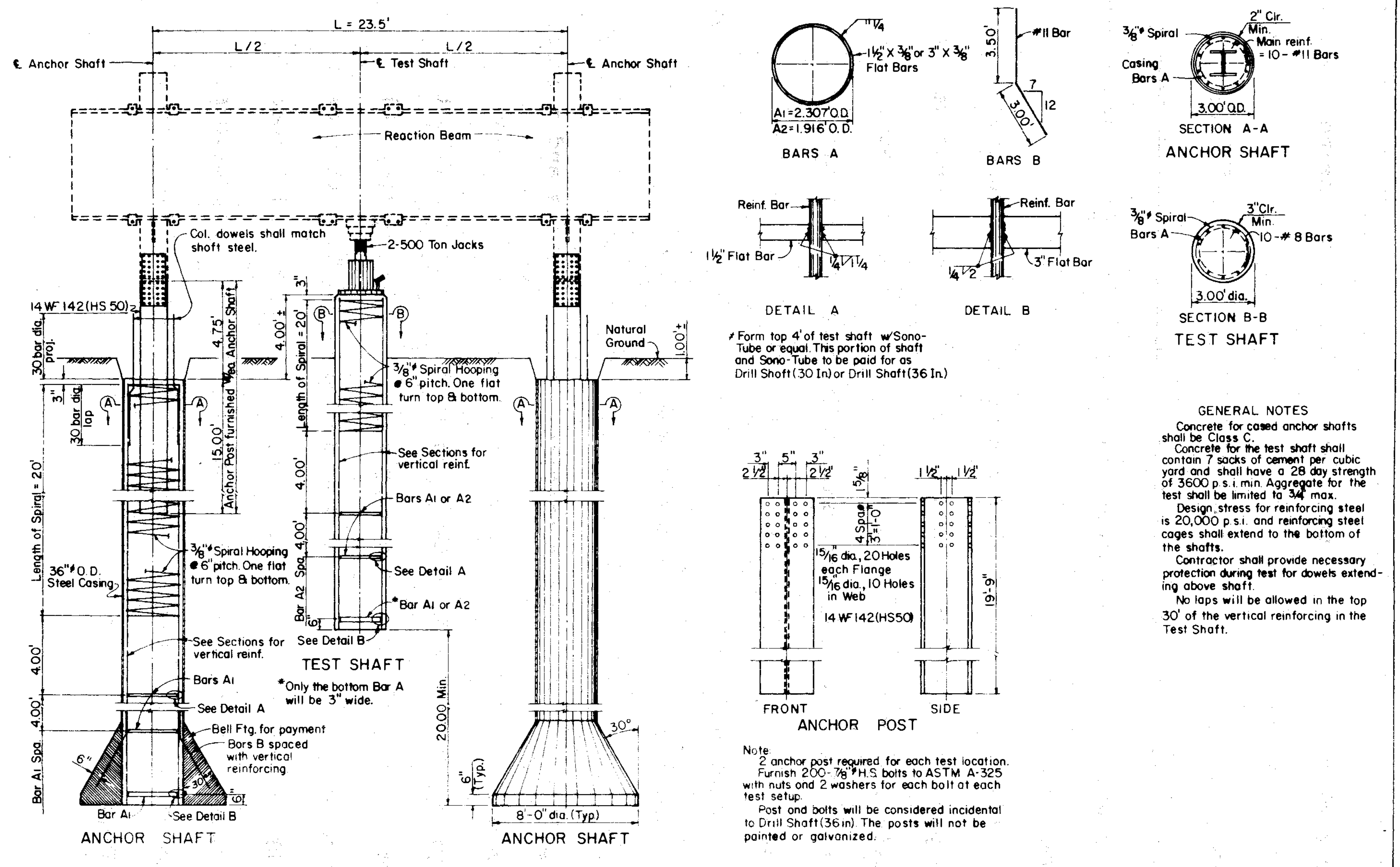


Figure 3. Details of Anchor Shafts and Test Shafts

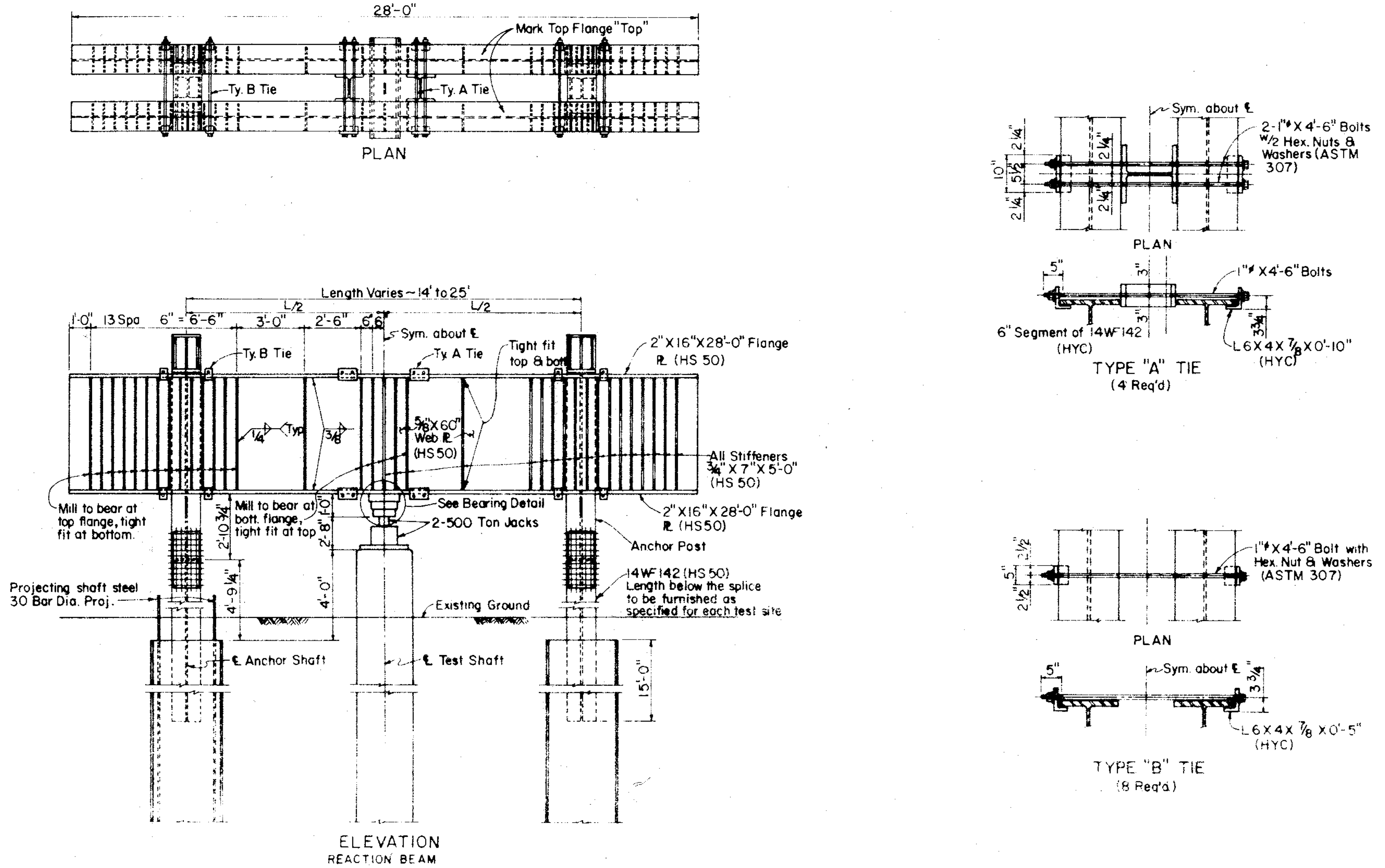
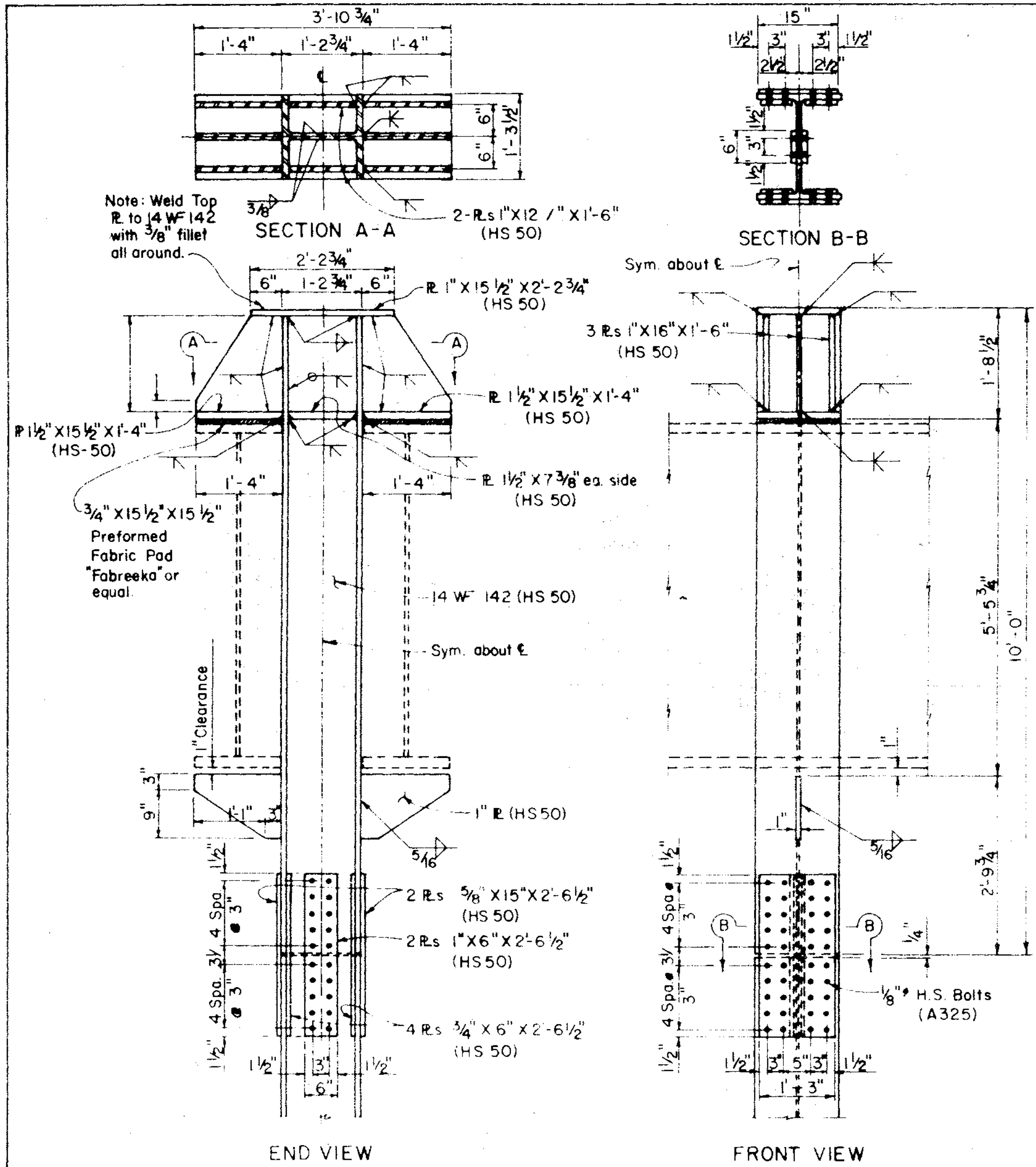
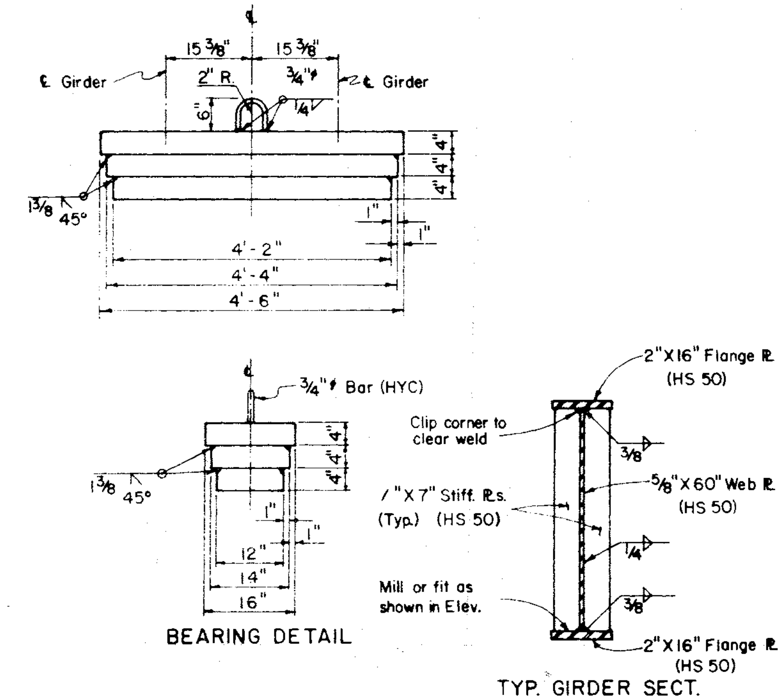


Figure 4a. Details of Reaction Beam and Anchor Posts

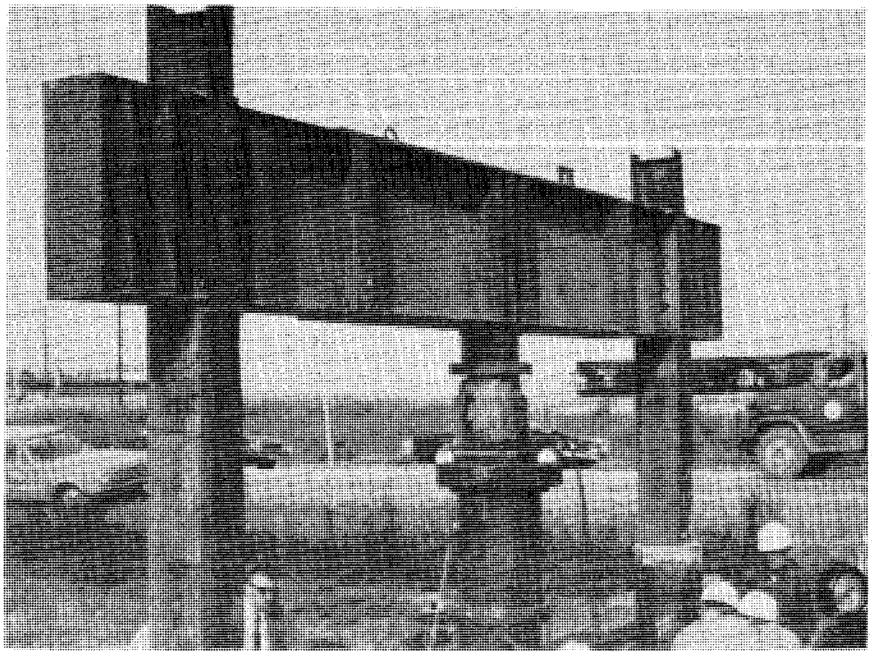




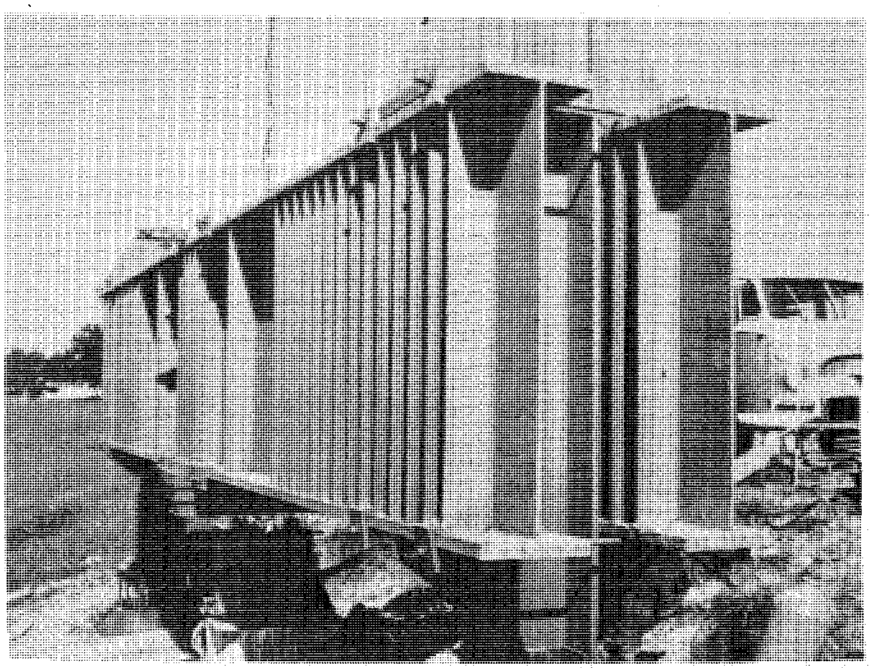
Notes:

1. Max. design load at jacking point, 1000 Tons.
2. Max. design uplift at each anchor post, 500 Tons.
3. Max. design length between anchor posts = 25 ft.
4. Allowable stresses are in accordance with AASHO specifications with an overstress of 25 %.
5. Total weight of steel not including 14 WF 142 below the bolted splice is 40,700 lbs.
6. All steel above the anchor post splice including the splice plates shall be painted using paint Schedule 3S or as alternate galvanized.
7. Preformed fabric pads shall be bonded to the anchor post bearing plates using an epoxy adhesive for full adhesion and weather sealing.
8. Anchor posts below splice, and all splice bolts at each test site to be considered incidental to drilled anchor shafts.
9. Cost for steel in ties A & B included in unit price bid for Struct. Steel.

Figure 4b. Details of Reaction Beam and Anchor Posts



(a) Load Test Set-up (Metal Shell Pile)



(b) Load Test Set-Up (Drilled Shaft)

Figure 5. Reaction Systems for Foundation Load Testing

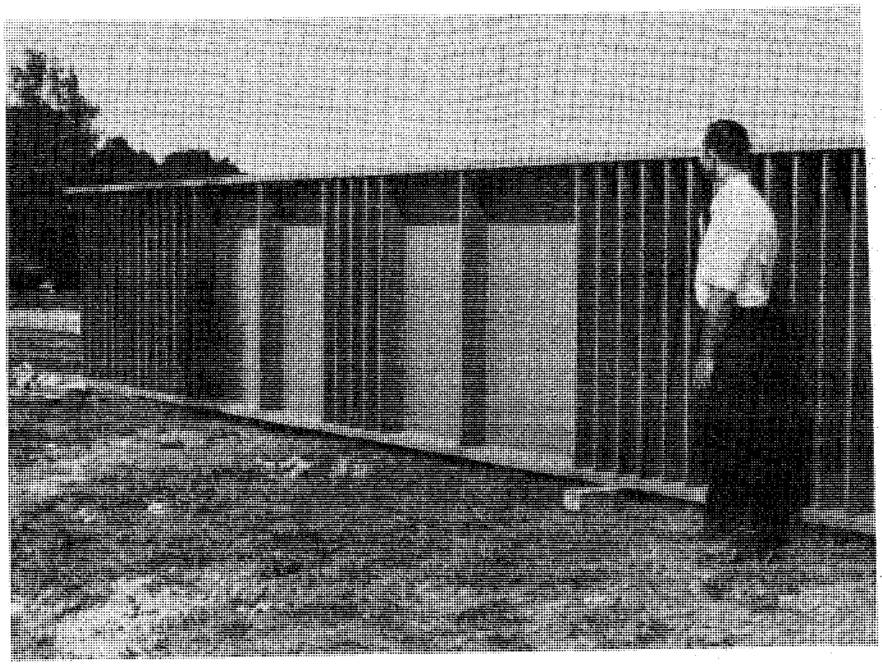


Figure 6. Reaction Beam Designed for Variable Anchor Spacing

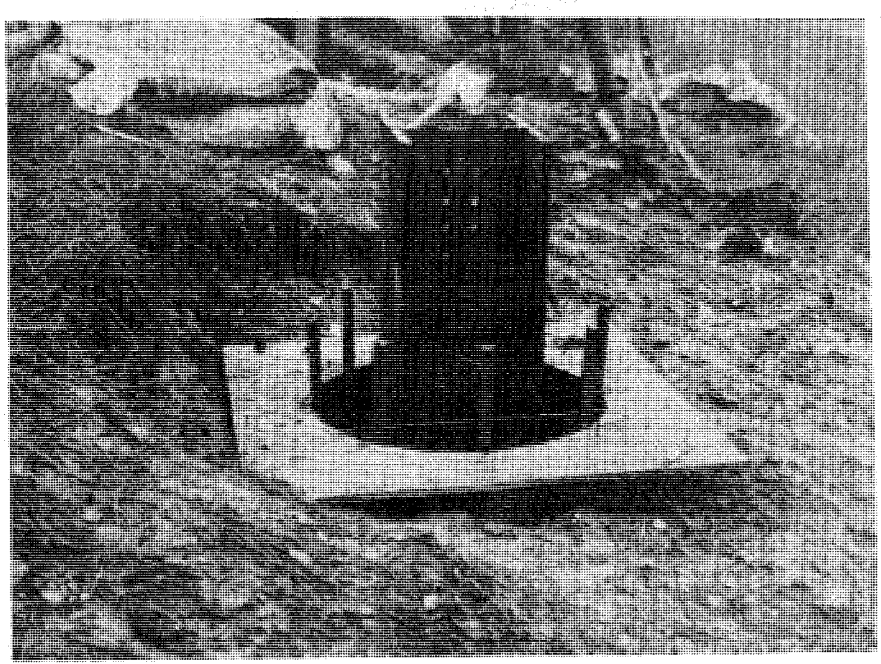


Figure 7. Connection Between Reaction Beam and Anchorage

Jacking Equipment. Load should be applied to the test pile or drilled shaft by one or more hydraulic jacks with sufficient capacity to cause a plunging failure of the pile or shaft. Available jacking capacity should be at least four times the pile or shaft design load shown on the project plans and the jack(s) should have a minimum ram travel of six inches (15.2 cm).

The applied load may be measured by jack pressures or by a load cell. When using jack pressures, two pressure gages with different ranges may be required to obtain accurate measurements. The pressure gages and the jacks they are to be used with should be periodically calibrated and certified accurate to within five percent.

An important factor to be considered when using jack pressures to measure the applied load is the friction which develops in the jack piston. Care must be taken to make certain that the loading surfaces of the reaction beam and pile or shaft are parallel and that the piston is perpendicular to both. Otherwise, eccentric loads will develop on the piston that will cause some amount of frictional binding and result in indicated loads that may be too high by as much as five to ten percent. The possibility of having eccentric loads on the piston can be minimuzed by using steel plates or spherical leveling blocks between the piston and reaction beam and leveling plates on top of the pile or shaft.

When testing drilled shafts or large diameter piling it is generally necessary to use more than one hydraulic jack (Figure 8). When using more than one jack each should have the same rated capacity and be from the same manufacturer. All jacks used should be connected to a common manifold and pressure gage with pressure supplied by one hydraulic pump. A hand operated pump (Figure 9) may be used, however an air operated pump (Figure 10) significantly increases the efficiency of the operation.

Settlement Measurements. The most common method for measuring settlements is by dial indicators mounted on an independent support system. Other methods include (1) using a mirror, scale, and tightly stretched wire, and (2) reading a target rod (or scale fixed to the pile or shaft) with an engineer's level referenced to a fixed benchmark. It is advisable that one of the latter methods be used as a backup system for checking the primary system of dial indicators.

The dial indicator support system will consist of a beam independently supported by anchors or stakes firmly driven into the ground at a distance not less than eight feet from the test pile or shaft. Beams used to support dial indicators may be made of wood, steel, or aluminum, but must be of sufficient stiffness to prevent excessive deflections. Dial indicators

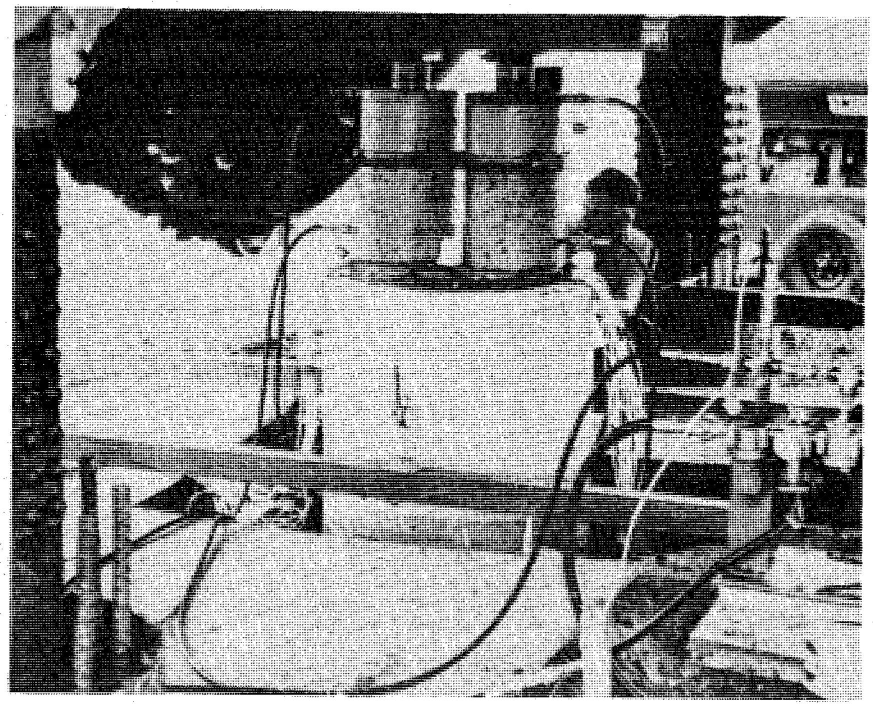


Figure 8. Jacking Equipment for Drilled Shaft Load Test

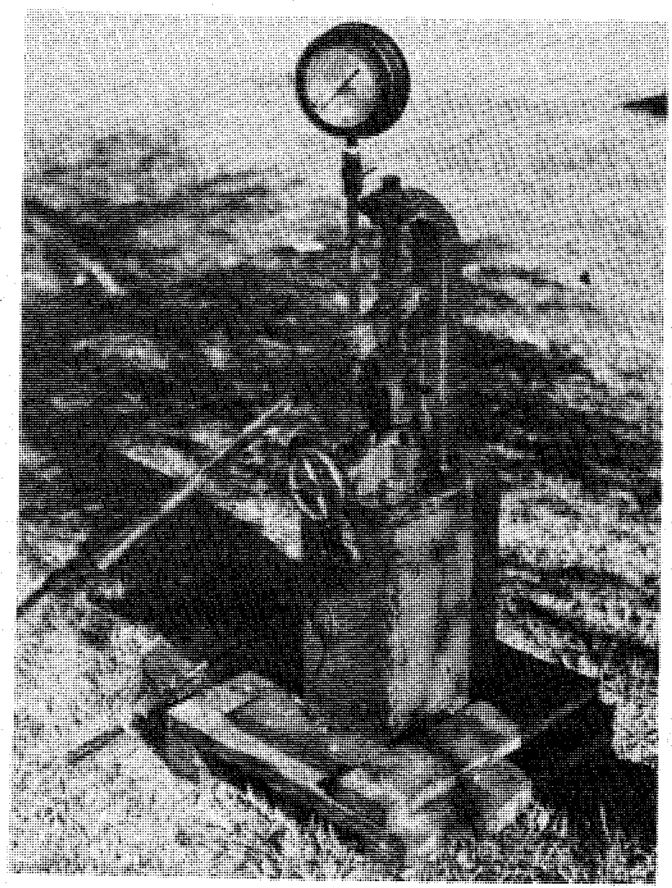


Figure 9. Hand Operated Hydraulic Pump

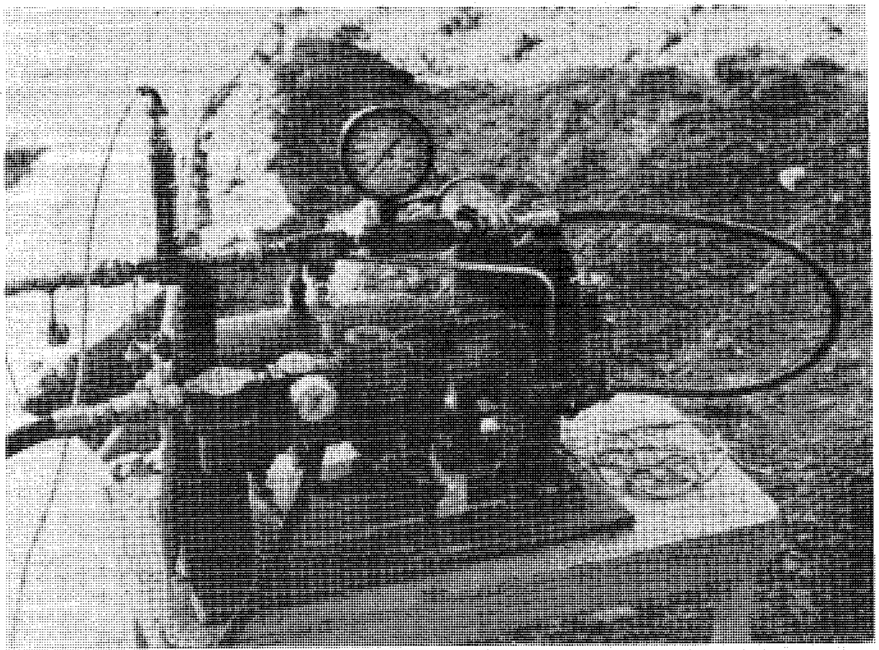


Figure 10. Air Operated Hydraulic Pump

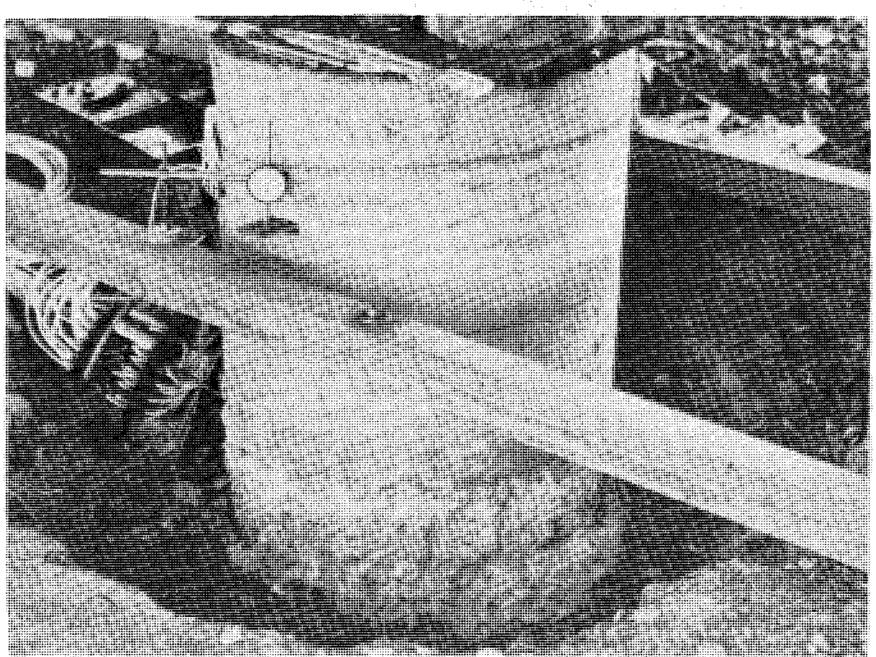


Figure 11. Dial Indicator Support System for a Drilled Shaft Load Test

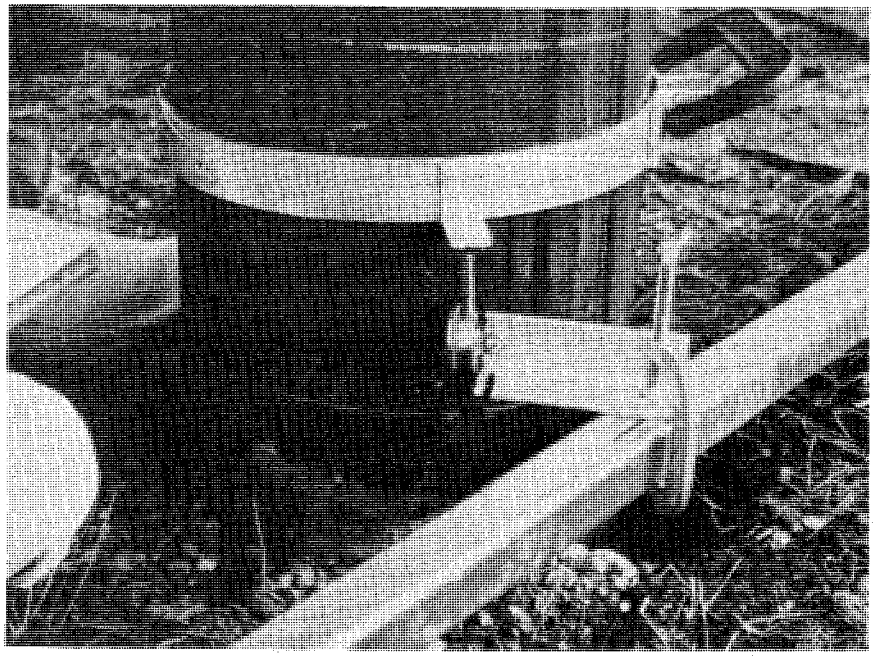


Figure 12. Dial Indicator Support System for a Metal Shell Pile Load Test

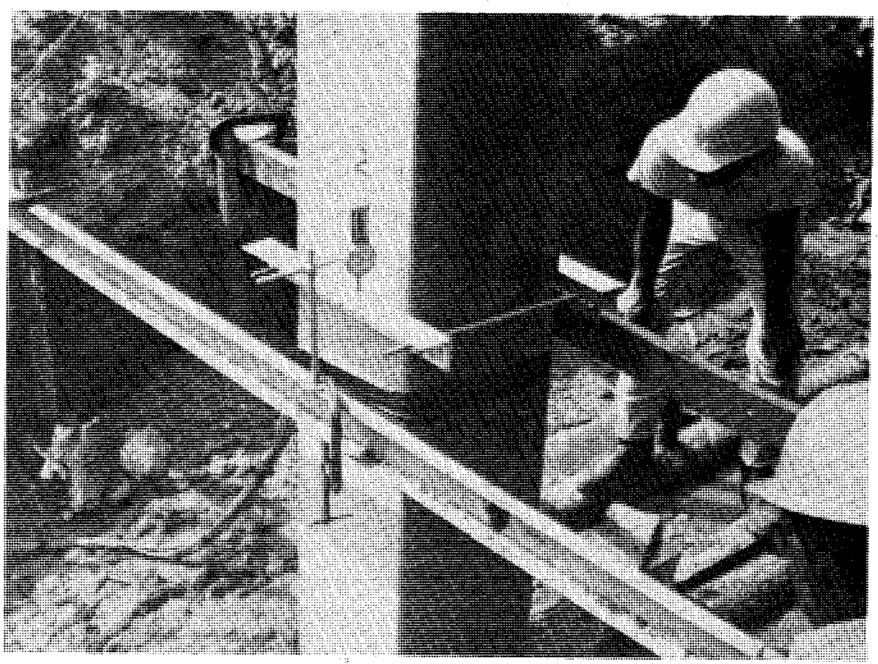


Figure 13. Dial Indicator Support System for a Prestressed Concrete Pile Load Test

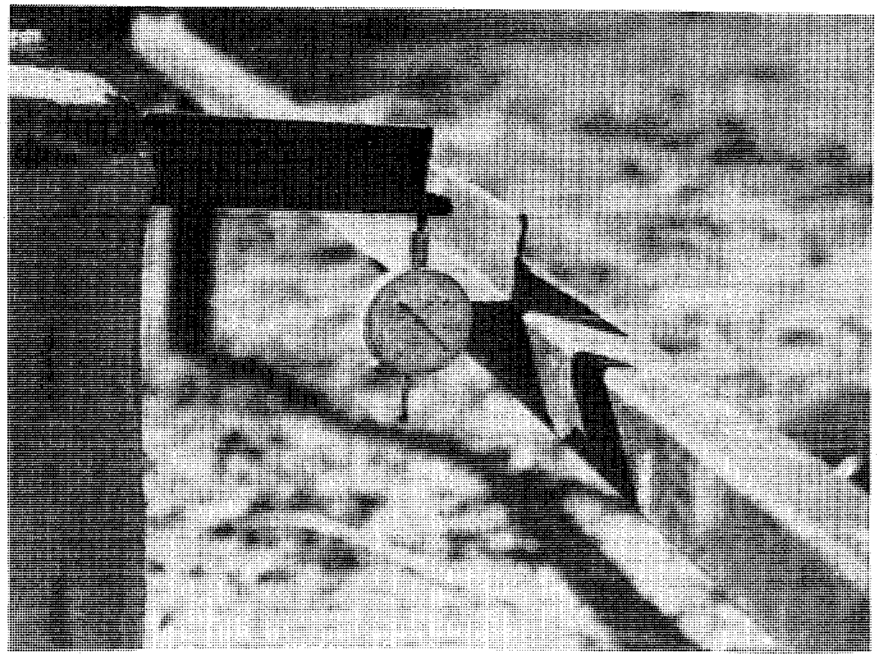


Figure 14. Dial Indicator Support System for an Anchor Pile

should have at least a two-inch travel with dial graduations of 0.001-in. (0.025 mm) for measuring settlement of a test pile or shaft, and dial graduations of 0.0001-in. (0.0025 mm) for measuring movements of anchor piles or shafts that are to be part of the permanent foundation. Provisions should be made to protect the instrumentation and support system from extreme variations in temperature and accidental disturbance.

Each pile or shaft to be tested requires two dial indicator support beams, one on each side of the test pile or shaft oriented perpendicular to the reaction beam (Figures 11 through 13). One or more dial indicators are mounted on each beam approximately equidistant from the center and on opposite sides of the test pile or shaft. Locating dial indicators in this manner will compensate for any tilting or lateral movement during testing. Dial indicators should be attached to the support beams with stems mounted parallel to the direction of load application and against lugs clamped or welded to the side of the pile or shaft. For the anchors, dial indicators should be attached to the pile or shaft with stems bearing against the support beams. (Figure 14).

Test Procedure. Load testing using the Quick-Load method consists of applying a prescribed increment of load in a prescribed time and measuring the resultant settlement of the pile or drilled shaft. Application of load is continued until either a plunging failure occurs or the capacity of the test equipment is reached.

Increments of load should equal 10 to 15 percent of the design load (5 to 10 tons (4536-9072 kg) for piling and 25 to 50 tons (22,680-45,360 kg) for drilled shafts and high capacity piles); however, these may be increased up to 100% at the beginning of the test but should be decreased to the minimum increment as plunging failure approaches. This procedure will help to define the ultimate load and point of failure. A constant time interval of two and one-half minutes is used throughout the test.

When using the Quick-Load method for testing, the following data are recorded immediately preceding and immediately following the application of an increment of load: actual time, time interval, load added, total load, dial indicator readings, and total gross settlement. Recording of these data is considerably simplified if a form similar to the one shown in Appendix C is used.

Increments of load are added and data recorded every two and one-half minutes until plunging failure of the pile or drilled shaft occurs, or the capacity of the test equipment is reached. A plunging failure is considered to have occurred whenever continuous pumping of the hydraulic jack is required to maintain load or when the settlement becomes disproportionate to the load being applied. When a plunging failure occurs, stop pumping and immediately make data readings. Without pumping, allow the load and settlement to stabilize, making data readings at two and one-half and five minutes after pumping is stopped. Then, quickly and smoothly remove all load and immediately make data readings. Wait two and one-half minutes and make a set of data readings then wait another two and one-half minutes and make the final data readings.

A plot of load versus gross settlement after each two and one-half minute period should be made while the test is being conducted so that the person in charge of the test can follow its progress at all times. As the pile or drilled shaft approaches plunging failure it is often desirable to have more data to help define the point of failure. By following the load-settlement graph the responsible person can determine when to reduce the load increment and how much it should be reduced.

INTERPRETATION OF LOAD TEST DATA

When analyzing data from a foundation load test all pertinent factors should be considered and the method of interpretation should provide values that are reproducible and independent of the judgment of the interpreter. A "double tangent" method generally satisfies these requirements and has been adopted as the primary method for interpreting the load-settlement data obtained from the Quick-Load test. Interpretation by this method is as follows (refer to Figure 16):

1. Plot a graph of load versus gross settlement using any convenient scale.
2. Draw one line originating at the point of zero load and settlement and tangent to the initial flat portion of the gross settlement curve. (The slope of this line will be approximately the same as the slope of the recovery line.)
3. Draw a second line tangent to the steep portion of the gross settlement curve with a slope 0.05-in. of settlement per ton (1.4mm/100kg) of load for a pile test and a slope of 0.01-in. per ton (0.3mm/100kg) of load for a drilled shaft test.
4. The load at the intersection of the two tangents drawn in steps 2 and 3 is defined as the ultimate bearing capacity of the pile or drilled shaft and will be used to establish a proven "maximum safe static" load.
5. The proven maximum safe static load for <u>piling</u> is defined as one-half of the ultimate bearing capacity obtained in step 4. The proven maximum safe static load for a <u>drilled shaft</u> is defined

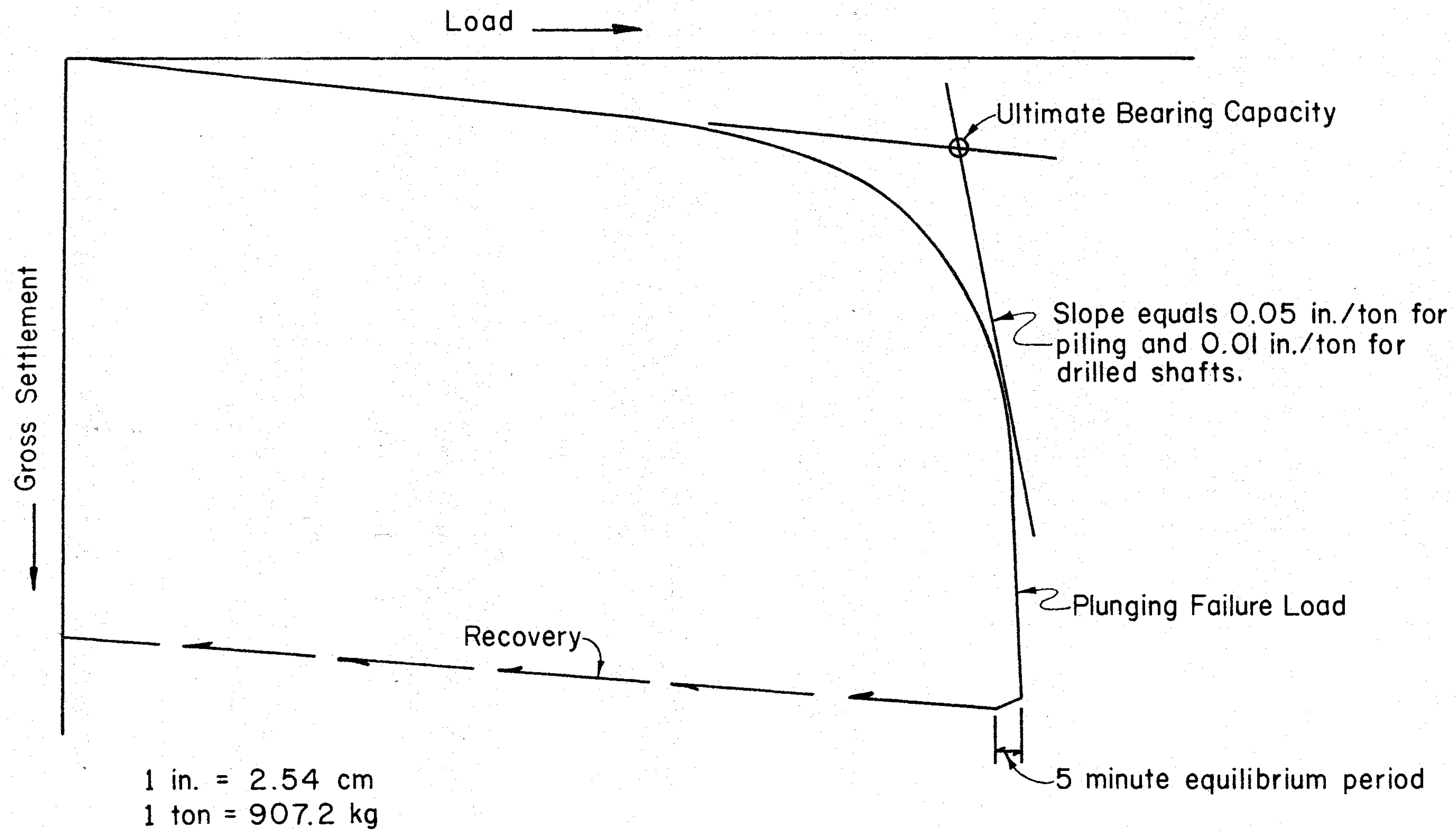


Figure 16. Typical Load Settlement Graph

as one-half the ultimate bearing capacity obtained in step 4 provided the gross settlement at the proposed design load is not more than one-half inch (1.3 cm).

APPLICATION OF LOAD TEST RESULTS

Piling. The maximum safe static load determined from the load test is used to establish a relationship between the proven static load and the dynamic resistance determined by hammer formula or wave equation analysis. This relationship, generally referred to as a "K" factor, is defined as follows:

K = L/P where:

K = Piling "K" factor

L = Maximum safe static load proven by load test

P = Dynamic driving resistance as determined by the appropriate hammer or wave equation formula.

The hammer or wave equation formula modified by the "K" factor yields load capacities that conform to the proven maximum safe static load and are used to determine the driving resistance of all regular piling in the structure or within the limits of influence of the load test.

Figure 17 is a plot of the load and settlement data shown tabulated in Appendix A. These data were taken during the load testing of an 18 inch (45.7 cm) square prestressed concrete pile tested using the Quick-Load method. Interpretation of Figure 17 by the double tangent method gives an ultimate bearing capacity of 150 tons (136,080 kg) and a proven maximum safe static load of 75 tons (68,040 kg). The dynamic resistance of this pile-soil system was determined by the Engineering News Record formula and found to be 29 tons (26,309 kg) (these and other pertinent data are shown in Appendix A).

Drilled Shaft. Results of a recent comprehensive research study of the load transfer characteristics of drilled shafts showed that substantial economic benefits could be realized through the utilization of the ability of a drilled shaft to transfer load to the surrounding soil by skin friction as well as through point bearing. In addition to establishing a safe load capacity for a particular shaft-soil system, the maximum safe static load can be used to determine the amount of load carried by skin friction. A relationship, "K" factor, can then be established between this load and one determined by an acceptable static analysis procedure and this "K" factor applied to other soils of this type.

Strain gages installed in the test drilled shaft provide the best means of obtaining the amount of load carried by skin friction; however, it is not generally feasible to instrument all test shafts. In the absence of strain gage instrumentation, the "K" factor can be determined as follows:

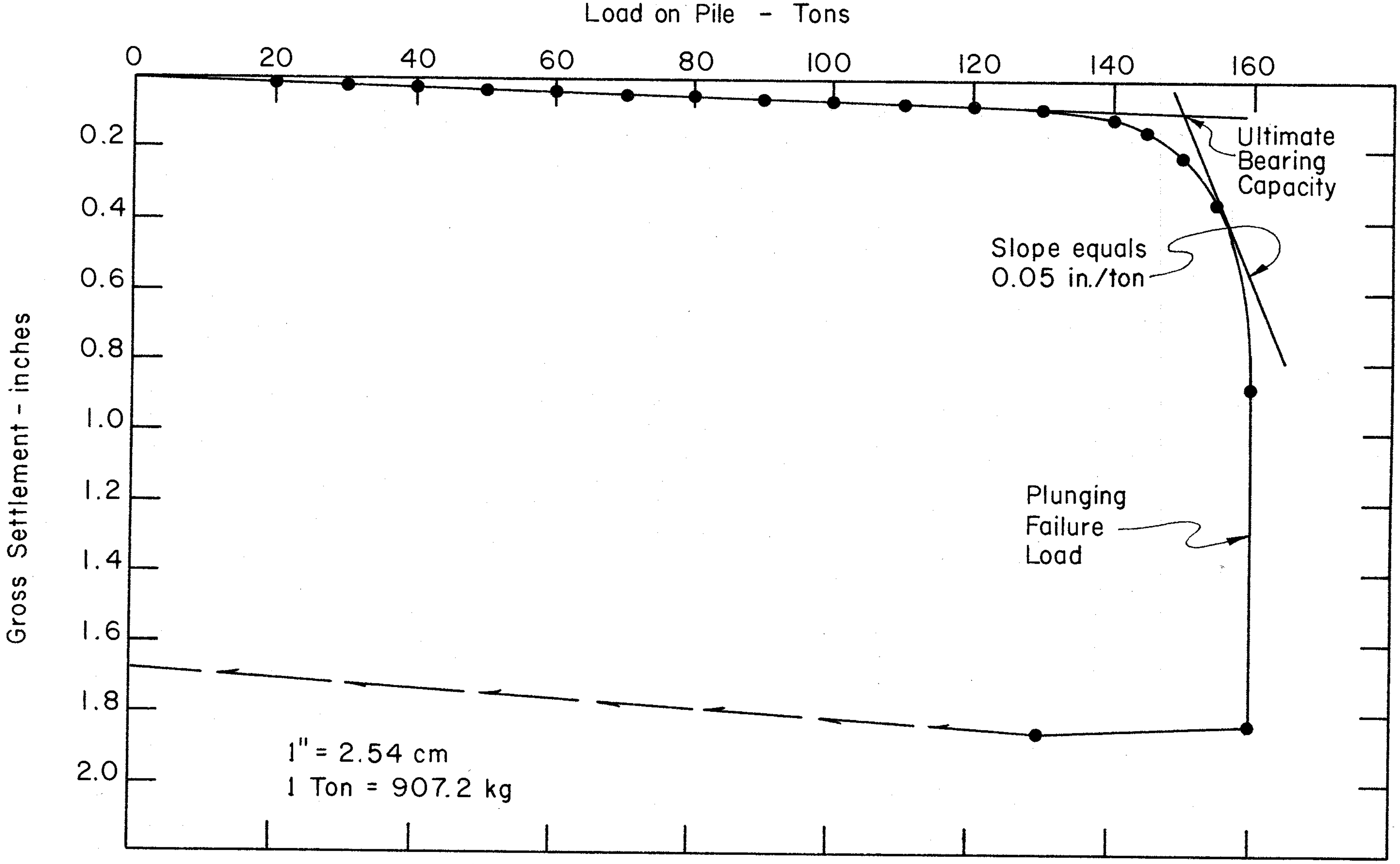


Figure 17. Load-Settlement Graph for a Pile Load Test

$K = (L-B)/R$, where:

K = Drilled shaft "K" factor

L = Maximum safe static load proven by load test

B = Allowable point bearing based on soils data and laboratory tests

R = Allowable frictional resistance determined by soils data and laboratory tests.

The frictional resistance determined by static analysis modified by this "K" factor will yield load capacities that conform to the proven maximum safe static load and are used to determine the load capacity of all shafts used in the structure or within the limits of influence of the load test. This "K" factor may also be used in the design of drilled shaft foundations at other locations having the same type of soil that has been load tested.

Figure 18 is a plot of the load and settlement data shown tabulated in Appendix B. These data were taken during the load testing of a 36 inch (91.4 cm) diameter drilled shaft tested using the Quick-Load method. Interpretation of Figure 18 by the double tangent method gives an ultimate bearing capacity of 732 tons (664,070 kg) and a proven maximum safe static load of 366 tons (332,035 kg). Based upon laboratory tests of the soil, the allowable loads in point bearing and friction were calculated to be 73 tons (66,226 kg) and 395 tons (358,344 kg) respectively (these and other pertinent data are shown in Appendix B). Using these data a drilled shaft "K" factor of 0.74 is calculated.

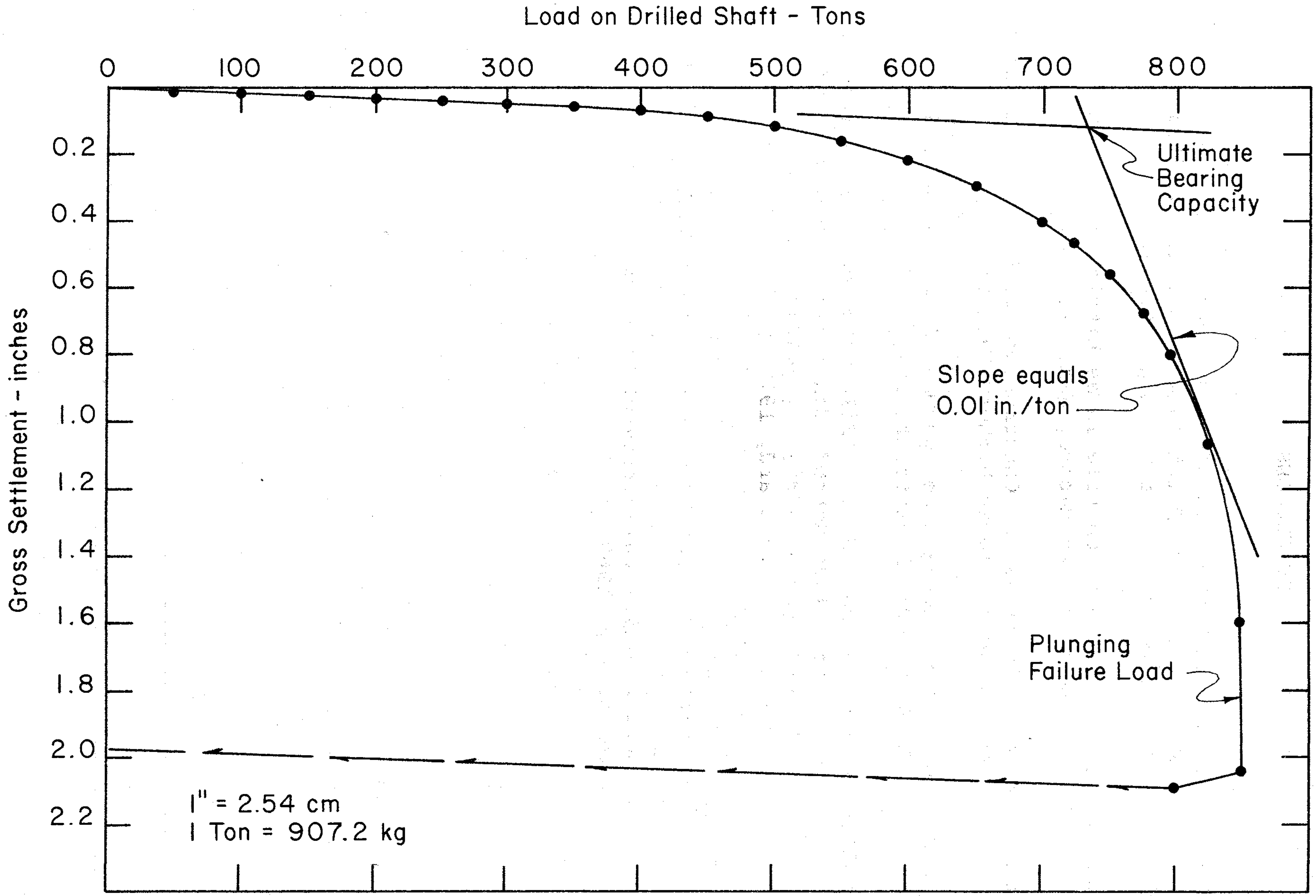


Figure 18. Load-Settlement Graph for a Drilled Shaft Load Test

REFERENCES

1. Whitaker, T., and Cooke, R.W. "A New Approach to Pile Testing". Proc. Fifth Internat. Conf. on Soil Mechanics and Foundation Eng., Paris, 1961

2. Esrig, M. I. "Load Test on Pile in as Little as Ten Minutes". Engineering News-Record, Jan. 31, 1963.

3. Standard Specifications for Construction of Highways, Streets and Bridges. Texas Highway Department, 1972.

4. Foundation Exploration and Design Manual, Bridge Division, Texas Highway Department, July, 1972.

5. Fuller, F. M., and Hoy, H. E. "Pile Load Tests Including Quick-Load Test Method, Conventional Methods, and Interpretations". Highway Research Record 333, Highway Research Board, 1970, pp 74-86.

6. Chuang, J. W., and Reese, L. C. "Studies of Shearing Resistance Between Cement Mortar and Soil", Research Report 89-3, Center for Highway Research, The University of Texas of Austin, Texas, May, 1969.

APPENDIX A

LOAD TEST DATA FOR 18" SQ. PRESTRESSED CONCRETE PILE TESTED BY THE TEXAS QUICK-LOAD METHOD

STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION
FORM 1302 REVISED
8/76

RECORD OF FOUNDATION TEST LOAD

Loading No. 7 Day

TEXAS QUICK TEST LOAD METHOD

County Gale Control 376-3-48 Structure Intracoastal Canal Bridge
Highway No. State 124 Project BRF 729(6) Structure No. ______
Bent No. 29 Foundation No. 1 Sta. 187+84 Rt. 9' Lt. ______
Foundation Size & Type 18"Sq.Prestr.Conc. Total Length 65' Design Load 60 Tons
Foundation Tip Elevation -59' Effective Penetration 59' Ground Elevation 0.00
Hammer Type & Size Delmag D46-02 Dynamic Resistance 28.86 Tons
Time Test Began 11:00 A.M. Date Aug.6,1976 Resident Engineer J. W. Hunter

Time	Time Interval	Load Added	Total Load	Extensometer Readings		Total Gross Settlement - Inches		
Min.	Min.	Tons	Tons	Dial 1	Dial 2	Dial 1	Dial 2	Average
0	0	0	0	2.000	2.000	0	0	0.0000
0	0	10	10	1.998	1.998	.002	.002	0.0020
2.5	2.5		10	1.997	1.998	.003	.002	0.0025
	0	10	20	1.991	1.994	.009	.006	0.0075
5.0	2.5		20	1.991	1.995	.009	.005	0.0070
	0	10	30	1.985	1.990	.015	.010	0.0125
7.5	2.5		30	1.985	1.991	.015	.009	0.0120
	0	10	40	1.978	1.986	.022	.014	0.0180
10.0	2.5		40	1.978	1.986	.022	.014	0.0180
	0	10	50	1.971	1.980	.029	.020	0.0245
12.5	2.5		50	1.970	1.980	.030	.020	0.0250
	0	10	60	1.963	1.975	.037	.025	0.0310
15.0	2.5		60	1.962	1.975	.038	.025	0.0315
	0	10	70	1.956	1.968	.044	.032	0.0380
17.5	2.5		70	1.955	1.968	.045	.032	0.0385
	0	10	80	1.948	1.962	.052	.038	0.0450
20.0	2.5		80	1.947	1.962	.053	.038	0.0455
	0	10	90	1.941	1.957	.059	.043	0.0510
22.5	2.5		90	1.938	1.953	.062	.047	0.0545
	0	10	100	1.932	1.948	.068	.052	0.0600
25.0	2.5		100	1.929	1.944	.071	.056	0.0635
	0	10	110	1.923	1.938	.077	.062	0.0695
27.5	2.5		110	1.920	1.936	.080	.064	0.0720
	0	10	120	1.912	1.928	.088	.072	0.0800
30.0	2.5		120	1.908	1.924	.092	.076	0.0840
	0	10	130	1.900	1.919	.100	.081	0.0905
32.5	2.5		130	1.895	1.915	.105	.085	0.0950
	0	10	140	1.888	1.908	.112	.092	0.1020
35.0	2.5		140	1.882	1.897	.118	.103	0.1105

Remarks: ______ District ______
Date ______
By ______

STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION
FORM 1302 REVISED
8/76

RECORD OF FOUNDATION TEST LOAD

Loading No. ____

TEXAS QUICK TEST LOAD METHOD

County ____ Control ____ Structure ____
Highway No. ____ Project ____ Structure No. ____
Bent No. ____ Foundation No. ____ Sta. ____ Rt. ____ Lt. ____
Foundation Size & Type ____ Total Length ____ Design Load ____
Foundation Tip Elevation ____ Effective Penetration ____ Ground Elevation ____
Hammer Type & Size ____ Dynamic Resistance ____
Time Test Began ____ Date ____ Resident Engineer ____

Time	Time Inter-val	Load Added	Total Load	Extensometer Readings		Total Gross Settlement - Inches		
Min.	Min.	Tons	Tons	Dial 1	Dial 2	Dial 1	Dial 2	Average
	0	5	145	1.871	1.887	.129	.113	0.1210
37.5	2.5		145	1.857	1.873	.143	.127	0.1350
	0	5	150	1.841	1.857	.159	.143	0.1510
40.0	2.5		150	1.805	1.822	.195	.178	0.1865
	0	5	155	1.800	1.817	.200	.183	0.1915
42.5	2.5		155	1.619	1.660	.381	.340	0.3605
	0	5	160	1.439	1.518	.561	.482	0.5215
45.0	2.5		160	1.128	1.150	.872	.850	0.8610
47.5	2.5		*160	0.153	0.175	1.847	1.825	1.8360
50.0	2.5	-30	130	0.148	0.173	1.852	1.827	1.8395
52.5	2.5		130	0.147	0.167	1.853	1.833	1.8430
	0	-130	0	0.349	0.271	1.651	1.729	1.6900
55.0	2.5		0	0.354	0.279	1.646	1.721	1.6835
57.5	2.5		0	0.359	0.281	1.641	1.719	1.6800

Remarks: * Plunge Failure - would not take additional load. Stopped pumping.

District 21
Date Aug. 6, 1976
By Walter M. Lane

SUMMARY OF DATA

FOUNDATION TEST LOADING

TEXAS QUICK LOAD TEST METHOD

County Gale Structure Intracoastal Canal Bridge

Highway No. State 124 Control 376-3-48 Project BRF 729(6)

Date of Test Load		Aug. 6, 1976
Bent No.		Bent 29
Location (Station)		187+84
Description of Pile		18" Sq. Prestr. Conc.
Total Length		65'
Ground Elevation		0.00'
Btm. of Ftg. Elev.		-0.97'
Pilot Hole Elev.		0.00'
Pile Tip Elev.		-59.00'
Effective Pen.		59'
Soil Type (General)		Silt, Sand & Clay
Design Load per Pile		60 Tons
Type & Size of Hammer		Delmag D46-02
Dynamic Resistance (ENR)		29 Tons
Penetration per Blow		2.0"
Description of Cushion		Cap Block
Type	Green Oak	Pine Plywood
Size	26"Ø	23" Sq.
Thickness	6"	3"
		7 Day Test
Duration of Quick Test Load		57.5 Min.
Maximum Load on Pile		160 Tons
Gross Settlement		1.843"
Net Settlement		1.680"
Plunging Failure Load		160 Tons
Ultimate Static Bearing Capacity		150 Tons
Maximum Safe Static Load (Proven)		75 Tons
"K" Factor (Proven)		2.6

Remarks:

State Department of Highways
and Public Transportation
District 21
Date 8/7/76

APPENDIX B

LOAD TEST DATA FOR 36" Ø DRILLED SHAFT TESTED BY THE TEXAS QUICK-LOAD METHOD

STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION
FORM 1302 REVISED
8/76

RECORD OF FOUNDATION TEST LOAD

Loading No. ____

TEXAS QUICK TEST LOAD METHOD

County Morton Control 37-13-2 Structure HB&T RR Overpass
Highway No. IH 45 Project I 45-1(151)037 Structure No. ____
Bent No. 20 Foundation No. ____ Sta. 137+10 Rt. 10' Lt. ____
Foundation Size & Type 36" Ø Drilled Shaft Total Length 60' Design Load 300 Tons
Foundation Tip Elevation +6' Effective Penetration 50' Ground Elevation +66.2'
Hammer Type & Size ____ Dynamic Resistance ____
Time Test Began 10:00 A.M. Date 8-18-76 Resident Engineer J. B. Thomas

Time	Time Interval	Load Added	Total Load	Extensometer Readings		Total Gross Settlement - Inches		
Min.	Min.	Tons	Tons	Dial 1	Dial 2	Dial 1	Dial 2	Average
0	0	0	0	2.000	2.000	0.000	0.000	0.0000
0	0	50	50	1.995	1.995	0.005	0.005	0.0050
2.5	2.5		50	1.995	1.995	0.005	0.005	0.0050
	0	50	100	1.991	1.989	0.009	0.011	0.0100
5.0	2.5		100	1.990	1.988	0.010	0.012	0.0110
	0	50	150	1.984	1.982	0.016	0.018	0.0170
7.5	2.5		150	1.982	1.980	0.018	0.020	0.0190
	0	50	200	1.977	1.975	0.023	0.025	0.0240
10.0	2.5		200	1.974	1.972	0.026	0.028	0.0270
	0	50	250	1.966	1.964	0.034	0.036	0.0350
12.5	2.5		250	1.963	1.961	0.037	0.039	0.0380
	0	50	300	1.957	1.955	0.043	0.045	0.0440
15.0	2.5		300	1.954	1.952	0.046	0.048	0.0470
	0	50	350	1.946	1.945	0.054	0.055	0.0545
17.5	2.5		350	1.943	1.942	0.057	0.058	0.0575
	0	50	400	1.928	1.927	0.072	0.073	0.0725
20.0	2.5		400	1.924	1.923	0.076	0.077	0.0765
	0	50	450	1.907	1.905	0.093	0.095	0.0940
22.5	2.5		450	1.902	1.900	0.098	0.100	0.0990
	0	50	500	1.880	1.877	0.120	0.123	0.1215
25.0	2.5		500	1.874	1.871	0.126	0.129	0.1275
	0	50	550	1.844	1.841	0.156	0.159	0.1575
27.5	2.5		550	1.837	1.834	0.163	0.166	0.1645
	0	50	600	1.783	1.779	0.217	0.221	0.2190
30.0	2.5		600	1.776	1.772	0.224	0.228	0.2260
	0	50	650	1.721	1.715	0.279	0.285	0.2820
32.5	2.5		650	1.713	1.707	0.287	0.293	0.2900
	0	50	700	1.603	1.597	0.397	0.403	0.4000
35.0	2.5		700	1.593	1.587	0.407	0.413	0.4100

Remarks: ____ District ____
Date ____
By ____

STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION
FORM 1302 REVISED
8/76

RECORD OF FOUNDATION TEST LOAD

Loading No. ____

TEXAS QUICK TEST LOAD METHOD

County ____ Control ____ Structure ____
Highway No. ____ Project ____ Structure No. ____
Bent No. ____ Foundation No. ____ Sta. ____ Rt. ____ Lt. ____
Foundation Size & Type ____ Total Length ____ Design Load ____
Foundation Tip Elevation ____ Effective Penetration ____ Ground Elevation ____
Hammer Type & Size ____ Dynamic Resistance ____
Time Test Began ____ Date ____ Resident Engineer ____

Time	Time Inter-val	Load Added	Total Load	Extensometer Readings		Total Gross Settlement - Inches		
Min.	Min.	Tons	Tons	Dial 1	Dial 2	Dial 1	Dial 2	Average
	0	2.5	725	1.544	1.534	0.456	0.466	0.4610
37.5	2.5	0	725	1.534	1.524	0.466	0.476	0.4710
	0	2.5	750	1.451	1.441	0.549	0.559	0.5540
40.0	2.5	0	750	1.441	1.431	0.559	0.569	0.5640
	0	2.5	775	1.334	1.322	0.666	0.678	0.6720
42.5	2.5	0	775	1.325	1.313	0.675	0.687	0.6810
	0	2.5	800	1.194	1.176	0.806	0.824	0.8150
45.0	2.5	0	800	1.179	1.161	0.821	0.839	0.8300
	0	2.5	825	0.977	0.956	1.023	1.044	1.0335
47.5	2.5	0	825	0.958	0.937	1.042	1.063	1.0525
	0	2.5	850	0.710	0.699	1.290	1.301	1.2955
50.0	2.5	0	850	0.410	0.388	1.590	1.612	1.601
*50.0	0	0	850	1.410	1.388	1.590	1.612	1.601
52.5	2.5	0	**850	0.968	0.946	2.032	2.054	2.043
55.0	2.5	-50	800	0.923	0.901	2.077	2.099	2.088
57.5	2.5		800	0.920	0.898	2.080	2.102	2.0910
	0	-800	0	1.008	0.986	1.992	2.014	2.0030
60.0	2.5		0	1.038	1.020	1.962	1.980	1.9710
62.5	2.5		0	1.042	1.034	1.958	1.966	1.9620

Remarks: * Extensometers reset with 1" spacers immediately after reading.
** Plunge failure load at 850 tons.

District ____
Date 8-18-76
By H. M. Lott

SUMMARY OF DATA

FOUNDATION TEST LOADING

TEXAS QUICK LOAD TEST METHOD

County Morton Structure HB&T RR Overpass

Highway No. IH 45 Control 37-13-2 Project I45-1(151)037

Date of Test Load	8/18/76
Bent No.	20
Location (Station)	137+10 (10' Rt.)
Description of Shaft	36"Ø Drilled Shaft
Total Length	60'
Ground Elevation	+66.2
Shaft Top Elev.	+65.0'
Shaft Tip Elev.	+6.0'
Effective Pen.	50.0'
Soil Type (General)	Clay, Silt, Sand
Method of Installation	Casing w/slurry
Design Load per Shaft	300 Tons
Allowable Point Bearing Load (Lab. Tests)	73 Tons
Allowable Frictional Load (Lab. Tests)	395 Tons

Duration of Quick Test Load	62.5 Min.
Maximum Load on Shaft	850 Tons
Gross Settlement	2.200"
Net Settlement	1.962"
Plunging Failure Load	850 Tons
Ultimate Static Bearing Capacity	732 Tons
Maximum Safe Static Load (Proven)	366 Tons
"K" Factor (Proven)	0.74

Remarks:

Date 8/19/76

APPENDIX C

SAMPLE DATA FORM FOR A FOUNDATION
TEST LOAD USING THE
TEXAS QUICK-LOAD METHOD

STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION
FORM 1302 REVISED
8/76

RECORD OF FOUNDATION TEST LOAD

Loading No. ____

TEXAS QUICK TEST LOAD METHOD

County ______________ Control ______________ Structure ______________

Highway No. ______________ Project ______________ Structure No. ______________

Bent No. __________ Foundation No. __________ Sta. __________ Rt. ______ Lt. ______

Foundation Size & Type ______________ Total Length __________ Design Load __________

Foundation Tip Elevation ______________ Effective Penetration __________ Ground Elevation __________

Hammer Type & Size ______________ Dynamic Resistance ______________

Time Test Began ______________ Date __________ Resident Engineer ______________

Time	Time Inter-val	Load Added	Total Load	Extensometer Readings		Total Gross Settlement - Inches		
Min.	Min.	Tons	Tons	Dial 1	Dial 2	Dial 1	Dial 2	Average

Remarks: ______________________________ District ______________

______________________________ Date ______________

______________ By ______________

APPENDIX D

SAMPLE SPECIFICATION AND ESTIMATED MATERIALS COST FOR FOUNDATION LOAD TEST

Adopted by the State Highway Department of Texas, January 3, 1972

ITEM 405

FOUNDATION TEST LOAD

405.1. Description. This item shall govern for the material and equipment to be furnished and the work to be performed for the test loading of piling or drilled shaft foundations.

405.2. General. The piling or shaft to be test loaded shall be as specified on the plans or as designated by the Engineer. A complete record of the driving resistance on the anchor and test piling, or drilling data on the anchor and test shafts, shall be made under the supervision of the Engineer.

The test load shall not be applied to the foundation until 5 days after driving the test piling, or 7 days after placing concrete in the test shaft. (Concrete in the shaft must have reached design strength.)

Unless otherwise specified, the Department will furnish the jacking equipment, suitable jacking beams and extensometers.

The Contractor shall furnish and drive the piling or place the shaft to be test loaded and such appropriate anchors that may be necessary, and shall furnish all necessary material, labor, work, tools, equipment in addition to that furnished by the State, shelter to protect the test load equipment from sun and rain, and incidentals necessary for the proper installation of the complete test load. After the test has been completed, the test set-up shall be dismantled by the Contractor in a manner satisfactory to the Engineer.

Piling or shafts to be test loaded and any anchor piling or shafts required, which are not a part of the permanent structure, shall be included as a part of the "Foundation Test Load".

The method of test loading and the location of piling and/or shafts shall be as shown on the plans, or as designated by the Engineer.

405.3. Construction Methods. The test piling shall be of the same type and cross section as the piling to be used in the structure. When precast concrete piling are to be test loaded, prestressed concrete piling of the same size and section may be used.

A permanent piling or shaft may be used as an anchor or for test loading when shown on the plans or when directed by the Engineer. Piling or shafts, not a part of the structure, shall be removed or cut off at least one foot below the bottom of the footing or finished elevation of the ground upon completion of the test load. Permanent piling used as anchor piling which are raised during the test load shall be redriven to original grade and bearing.

The driving of piling to be test loaded shall be in accordance with the Item, "Driving Piling".

The drilling and placing of shafts to be test loaded shall be in accordance with the Item, "Drilled Shaft Foundations".

405.4. Method of Loading. Test loading shall consist of the application of incremental static loads to a pile or shaft and measuring the resultant settlement. The loads shall be applied by a hydraulic jack acting against suitable anchorage, transmitting the load directly to the pile or shaft, or other methods designated by the plans or approved by the Engineer.

The load shall be applied in increments of 5 or 10 tons as directed by the Engineer. Gross settlement readings, loads and other data shall be recorded by the Engineer immediately before and after the application of each load increment.

Each load increment shall be held for an interval of 2-1/2 minutes. Each succeeding increment shall be as directed by the Engineer or as shown on the plans and shall be applied immediately after the 2-1/2 minute interval readings have been made.

When the load-settlement curve obtained from these test data shows that the pile or shaft .has failed; i.e., the load can be held only by constant pumping and the pile or shaft is being driven into the ground, pumping shall cease. Gross settlement reading, loads and other data shall be recorded immediately after pumping has ceased and again after an interval of 2-1/2 minutes for a total period of 5 minutes. All load shall then be removed and the member allowed to recover. Gross settlement readings shall be made immediately after all loads have been removed and at each interval of 2-1/2 minutes for a total period of 5 minutes.

All test loads shall be carried to failure or to the capacity of the equipment, unless otherwise noted on the plans.

405.5. Evaluation of Tests. Interpretation of the results will be in accordance with the 'Quick Test Load' requirements of the Bridge Foundation Exploration and Design Manual.

405.6. Measurement. Measurement will be made for each complete test load, satisfactorily performed and accepted.

Anchor and test piling, or anchor and test shafts, which are a part of the permanent structure, will be measured by the linear foot before cutting them to final plan grade.

Anchor and test piling or anchor and test shafts, which are not a part of the permanent structure, will not be measured for payment but will be included in the price bid for "Test Load".

If subsequent test loads are required on a previously loaded test piling or test shaft after the Engineer has directed the Contractor to dismantle the test equipment, any additional build up and driving of the test pile and/or reinstallation of the test equipment shall be considered as a separate test load.

405.7. Payment. The load tests provided under this item will be paid for at the unit price bid for each "Test Load", which price shall be considered full compensation for furnishing all material, labor, work, tools, equipment and incidentals necessary for the proper installation and completion of the test load. Anchor and test piling or anchor and test shafts, which are not a part of the permanent structure, will be included in the unit price bid for each "Test Load". Anchor and test piling or anchor and test shafts, which are a part of the permanent structure, will be paid for under the appropriate item.

If a subsequent test load is required, as described above under Article 405.6, such test will be paid for at the rate of one-half the price bid for each "Test Load".

ESTIMATED MATERIALS COST FOR QUICK-LOAD TEST

Structural Steel*	$ 0.65/lb.
Dial Indicators (2 required)	130.00
Hydraulic Jack	1,800.00
Miscellaneous (support beams, stakes, etc.)	100.00

*Quantity of structural steel is dependent upon design load. The reaction system shown in Figure 4 contains 40,700 lbs. of high strength steel.

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