# Pile Load Tests Including Quick-Load Test Method, Conventional Methods, and Interpretations

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This paper covers the general principles of pile load testing, including objectives of pile testing, importance of planning, various types and methods of testing, instrumentation, data to be obtained, and interpretation and use of the test results. Also included are some typical case histories together with correlative data between standard test methods and the constant rate of penetration test method.

•THE PURPOSE of pile load testing can be either to prove the adequacy of the pile-soil system for the proposed pile design load or to develop criteria to be used for the design and installation of the pile foundation. Tests in the first category are generally routine, are carried to twice the proposed working load, and are conducted at the start of the job. Tests to develop design and installation criteria involve more elaborate programs, and piles are usually tested to failure.

Pile load tests are expensive and can be quite time consuming. For small projects the cost of pile testing can represent a considerable portion of the overall foundation cost. In many cases, prior experience combined with adequate subsoil data and sound judgment can preclude the need for pile testing, especially if the pile design load is relatively low.

Routine pile load testing is often the decision of the foundation engineer, but may be required by the general specification or building code having jurisdiction over that type of construction. The decision to embark on an advance test program to develop design criteria is usually made by the owner and the foundation engineer and is based on the scope of the project and the complexities of the foundation conditions. Such test programs can often result in substantial savings in foundation costs, and these can more than offset the investment in the test program.

The prime objective of a test program is to produce data to determine the most economical and suitable pile foundation, including the pile types to be used, the most efficient or highest working load for each type of pile, the required length for each type of pile, and the installation methods necessary to achieve the desired results.

## PLANNING THE TEST PROGRAM

Proper planning for any type of pile testing is necessary, but it is absolutely essential for the test program conducted to develop design criteria. Planning starts with a detailed review of the subsoil data in conjunction with the design requirements of the proposed structure. This analysis leads to the following decisions:

1. Final test data to be developed;
2. Type or types of testing to be performed;
3. Extent of the testing that will be required;

Paper sponsored by Committee on Foundations of Bridges and Other Structures and presented at the 49th Annual Meeting.

4. Special testing procedures necessary to achieve the desired results;
5. Selection of test locations;
6. Effects of soil conditions on test results, and the need for any additional subsoil data;
7. Selection of the different types of piles to be tested;
8. Determination of approximate pile lengths;
9. Outline of possible installation methods to be used; and
10. Preparation of the technical specifications.

Although thorough planning of a test program is essential, the overall plan must be flexible enough to permit modifications that might be necessary as the driving and testing data are produced.

The technical specifications for the pile test program cover the following points:

1. Prequalification of the pile contractor—This is necessary if the contract for the pile test program is to be awarded on the basis of competitive bidding. However, the complexities and importance of a pile test program require that serious consideration be given to negotiating the contract with a carefully selected contractor.
2. Types of piles to be tested and maximum lengths to be furnished—It should be noted that where a proprietary type of pile is to be included in a test program, any special equipment or material necessary to properly install this type of pile must be made available to the test pile contractor. This problem of proprietary types of piles may be handled by subcontract or separate negotiation with the pile contractor specializing in that piling system.
3. Size and capacity of basic pile-driving equipment to be furnished—This is to eliminate the problem of starting the test program with inadequate pile-driving equipment that might preclude any extension of the test program beyond that originally contemplated or even the proper execution of the original program. Proprietary types of piles may have special equipment requirements.
4. Driving criteria and special installation methods that may be required.
5. Types of tests and maximum testing capacity to be furnished—This will permit the contractor to properly plan for the necessary equipment and to build into the test program some degree of flexibility.
6. Required testing equipment and instrumentation including calibration.
7. Testing procedures to be followed.
8. Data to be recorded and reported.
9. Payment method and schedule of bid items—The flexibility mentioned earlier should be reflected in the pricing and payment method for the test work, for example, lump sum for mobilization and demobilization, unit price for materials, and hourly rates for various types of operations such as pile driving, moving, testing, or standing by.

## TEST TYPES AND METHODS

Pile load testing usually involves the application of a direct axial load to a single vertical pile. However, load testing can involve uplift or axial tension tests; lateral tests applied either horizontally or perpendicular to the pile axis (e.g., if battered); group tests; combined axial and lateral tests; any of these tests applied to batter piles; or any of these tests applied to pile groups consisting of vertical piles, batter piles, or a combination of such.

Pile load testing also generally involves the application of a static load to the pile. However, other methods of load application have been used, such as dynamic, vibratory, and explosive. Neither dynamic nor explosive testing is too reliable, and these methods are infrequently used. Vibratory testing is only used where structure loading conditions warrant. The test load, whether it be for a bearing test, uplift test, or lateral test, is usually applied statically by a force acting directly on the pile either by direct weight or by hydraulic jacks in combination with some type of reaction system.

Where the test load is applied directly to the pile by means of a loaded platform (Fig. 1), the load must be capable of being applied and removed in increments of known weight. The test beam and platform are considered part of the test load and included in the first increment of loading.


Figure 1. Test load applied directly to pile by using loaded platform and water-filled interconnected steel tanks.

The load and platform must be kept balanced at all times. Usually timber cribs are placed under the platform edges to prevent tipping of the load in case the platform becomes unstable. Wedges between the timber crib and platform edge are tightened only while the load is being added or removed. These wedges must be kept loose as the pile settles under the direct load.

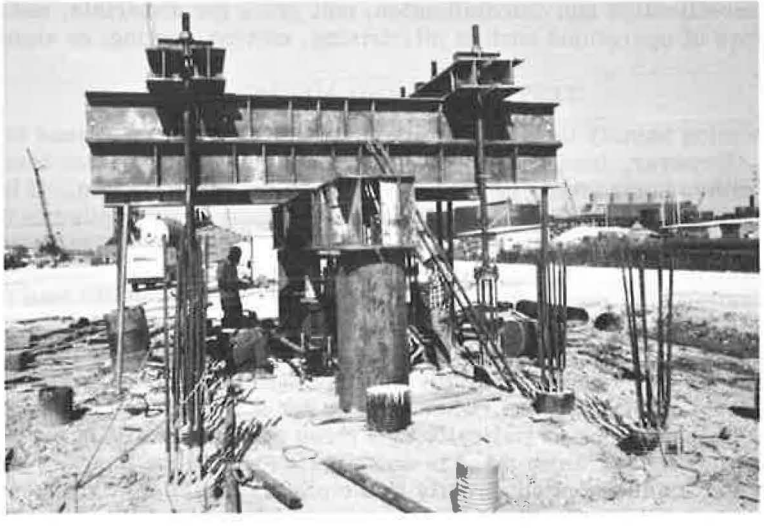

Figure 2. Test load applied to pile with hydraulic jack reacting against a test frame and anchor piles.

Most test loads are applied with hydraulic jacks reacting against either a stable loaded platform or a test frame anchored to reaction piles (Fig. 2); there may also be some other type of reaction. The use of hydraulic jacks has several advantages. For example, it is the only practical way to apply load-unload-reload cycles, and hydraulic jacks are more suitable for uplift tests, lateral tests, and tests on batter piles.

Regardless of the method of load application, the load should be kept constant under increasing pile deflection. For direct loading this presents no problem. When hydraulic jacks are used this can be accomplished by activating the jack pump with a compressed gas control system. Precautions should be taken to avoid eccentric loading by carefully centering test beams or jacks and maintaining a balanced load.

Anchor piles or the supports for a reaction load must be placed a sufficient distance from the test pile to avoid influencing its performance. This minimum distance will depend on such things as the magnitude of load to be applied and the subsoil conditions. Such influence could reflect a greater or lesser ultimate bearing capacity than actual.

It is recommended that, during a lateral load test, an axial compressive load equal to the minimum design dead load, be applied to the pile. This type of combined test loading would give a more accurate indication of the actual lateral load capacity of the pile under service conditions. When a vertical load is applied during a lateral load test, the pile butt should not be restrained from lateral movement. This can be accomplished by using a system of rollers between the vertical load and the pile. The point of application of the horizontal load should, if possible, simulate in-service conditions.

## INSTRUMENTATION

The basic information to be developed from the pile load test is usually the deflection of the pile butt under the test load. Probably the fundamental method of measuring the pile butt movement is by reading a target rod (or scale fixed to the pile) with an engineer's transit referenced to a fixed bench mark. In most cases, the degree of accuracy obtained with this type of instrumentation is sufficient. Quite often, measurements with the level and rod (or scale) are used as a secondary or backup system to check other measuring systems.

Direct readings of the pile butt movement (either vertically or horizontally) can be made by using the mirror, scale, and wire method. A measuring scale is fixed to a mirror, which in turn is attached directly to the pile or the test plate. A taut wire passing in front of the scale permits direct readings of pile movement. Consistent scale readings are obtained by aligning the wire and its image in the mirror. The wire can be kept taut by a weight and pulley system or by springs.

The most common method for measuring the pile movement is with dial extensometers mounted on an independent support system, and with gage stems bearing against the top of the test plate or on angle irons attached to the sides of the pile (Fig. 3). At least 2 dial gages mounted on opposite sides of the pile should be used to compensate for possible tilting or lateral movement of the pile under load. Sometimes a gage sensitivity of 0.001 in. is specified, but usually gages reading to 0.01 in. have sufficient accuracy to meet the normal settlement criteria. With ultra-sensitive dial gages, it is often impossible to satisfy some of the specification requirements such as "until settlement stops."

When the instrumentation for a compression test is set up, it is often advisable to mount dial gages to measure lateral movements of the pile under test. Such movement could be due to eccentric loading and contribute to the apparent vertical movement of the pile butt.

The instrumentation system must be supported independently from the loading system with supports protected from extreme temperature variations, effects of the test load, and accidental disturbance by test personnel. It is advisable to have a secondary or backup instrumentation system in case of an accidental disturbance of the primary system or the necessity to reset dial gages so that continuity of data is maintained.

Data on load distribution and the elastic behavior of the pile can be obtained with displacement (or so-called "strain") rods or strain gages. This type of instrumentation can be installed in almost all types of conventional piling but more readily in cast-in-place

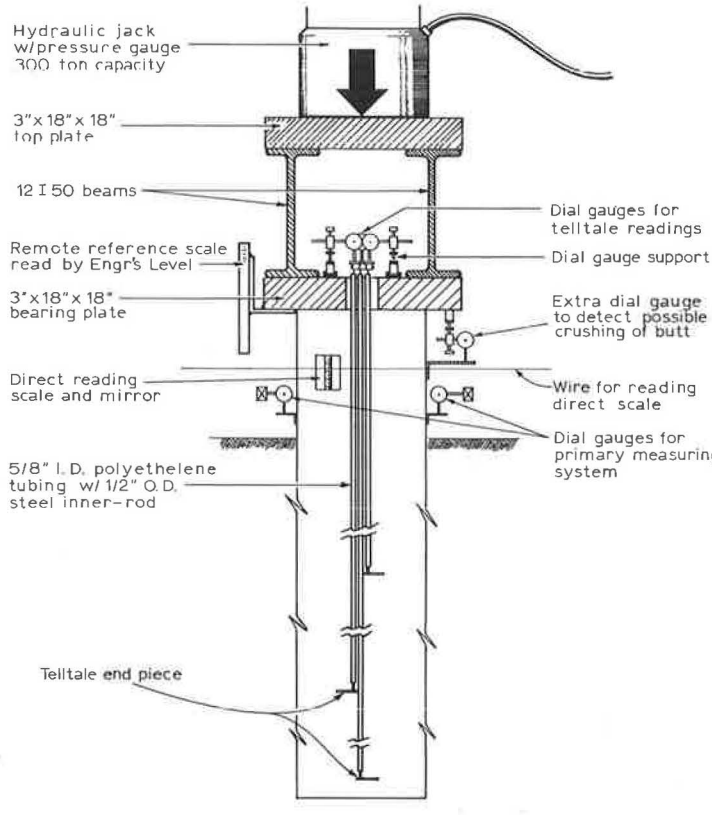


Figure 3. Instrumentation of test pile.

concrete piles. Strain gages or the terminal points of "strain" rods can be located at various positions along the pile.

In general, strain rods are less complicated, are less subject to malfunction, are more easily handled by field personnel, and produce direct elastic shortening data over a long gage length between the terminal point and the pile butt. The proper installation of strain gages, so as to avoid malfunction and produce reliable data, is an extremely sensitive operation.

The installation of strain rods or gages results in a physical change in the cross section of the pile and thus its elastic properties. Although data at frequent intervals along the pile shaft are desirable, it is sometimes advisable to sacrifice some data in the interest of practicality. Often a single strain rod to the pile tip is sufficient to provide the essential information on the elastic behavior of the pile and the basic load distribution.

## TEST PROCEDURES

Most routine tests are carried to one and one-half or twice the proposed design load for a single pile, or one and one-half times the design load for a pile group. Carrying the test load any higher merely wastes job time and money. Rarely can such additional data be used advantageously, such as for redesign, without seriously affecting the job schedule.

Most test programs that are specifically executed to produce design data should include testing piles to failure in order to develop the most efficient design. However, this is not always essential, and definite design decisions can be reached if sufficient routine testing is done on piles of different types, sizes, shapes, and lengths.

The time interval between pile driving and testing depends on the type of pile and subsoil conditions. For example, sufficient time should be permitted for the proper curing of cast-in-place concrete piles before they are tested. Where test piles are driven into cohesive soils, it is advisable to wait several days for the soil to regain its shear strength, which in all probability was reduced because of the remolding effects of pile driving.

The test load can be applied in various increments and time intervals. In general, the load should be applied over an extended period of time, with increments equal to about 25 percent of the proposed or assumed design load. However, in the interest of saving time, the increments can be larger during the early stages of the test and, in the interest of obtaining accuracy, they should be smaller as the total load is increased.

A normal time interval between load increments is from 1 to 2 hours. Frequently, specifications will require that the load be held until the rate of settlement is less than some fixed value such as 0.01 in. per hour, but in most cases a maximum time interval between increments will also be specified. Providing that the pile-soil system has not failed, the full test load should be held for some period of time, such as 24 or 48 hours. Specifications will often establish a maximum rate of settlement under full load that cannot be exceeded over a certain period of time in order for the test to be considered satisfactory. Where specifications use language such as "until settlement has stopped," the impracticality of using highly sensitive dial gages is obvious.

Instrumentation readings should be taken before and after each increment of load and at sufficient intermediate intervals in order to define the load-time-deflection curves. When piles are not tested to failure, and after the full test load has been applied, readings are taken at least every 30 minutes for the first 12 hours and every hour thereafter. During removal of the test load, readings should also be taken before and after each load decrement, and a final rebound reading should be taken about 12 hours after the full load has been removed.

Among the several special testing techniques available are cycle loading and the constant rate of penetration (CRP) method. When piles are tested to establish the design load, cycle loading can help determine more accurately the load that satisfies the allowable deflection criteria. Also, cycle loading can provide some indication as to the distribution of load between friction and end-bearing. Van Weele (1) has suggested a method by which a plot of the elastic recovery at each unloading cycle versus load applied at that cycle is used to separate friction from point-bearing. The curve usually becomes a straight line soon after the early load increments (Fig. 4). The distance between the plotted curve and a line drawn through the origin and parallel to the straight part of the curve represents the portion of the load carried by friction. At best, this is only an approximation.

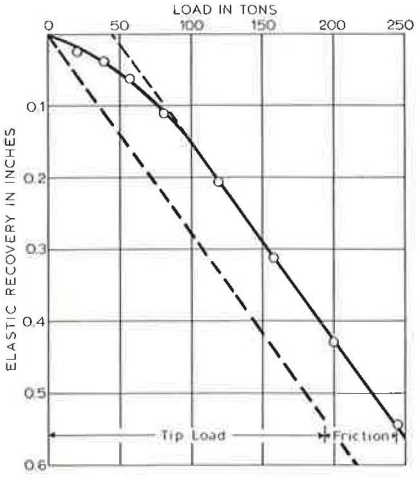


Figure 4. Approximate distribution of test load between point-bearing and friction (1).

Cycle loading should not be mandatory for routine testing because it could add unnecessary expense without contributing significant additional data. Such special procedures should be included at the engineer's option.

The constant rate of penetration method was first experimented with in 1957 by Whitaker but did not receive wide publicity until after 1961 (2). Under favorable conditions, this method has shown reasonably good correlation with standard test methods. For the CRP test, a force or load of sufficient magnitude is applied to the pile to maintain a constant penetration rate into the ground. This means that the applied load might have to be adjusted as the test proceeds. In general, the recommended penetration rate is about 0.03 in. per minute for cohesive soils and about 0.06 in. per minute for granular soils. However, the

penetration rate could vary over a rather wide range and still produce satisfactory results.

The CRP method is applicable to friction types of piles, and sufficient testing capacity of the pile-soil system.

Special testing procedures can be used to produce specific data. For example, the distribution of applied load between friction and point-bearing can be approximated by driving and testing piles of different lengths. Some would be driven just short of the end-bearing stratum, while others would be driven to full embedment. An uplift test might also produce approximate data on the amount of load carried by friction.

Another special test procedure would be the casing off of that portion of the test pile that extends through soils offering temporary support so as to determine the capacity of the pile-soil system within the permanent bearing strata.

## INTERPRETATION OF RESULTS

The basic purpose of the pile test is to determine or verify the safe working load for the pile-soil system. In most cases, tests are not carried to failure, and some arbitrary criterion is applied to determine if the test results are satisfactory. Some of these criteria are rather vague, such as "where the settlement is disproportionate to the load" or "where the load-settlement curve breaks." Others are based on a maximum allowable gross or net settlement that can either be a fixed number, such as 1 in. or related to the amount of test load applied, such as 0.01 in. per ton.

When definite failure does not occur, such as plunging of the pile into the ground, some arbitrary definition of "failure" must be used. Such criteria should be realistic—neither too conservative nor too liberal. The important factors to be considered are the permissible differential settlement under the design load and safety.

Settlement usually governs and requires consideration of the elastic shortening of the pile under the design load. Assuming that all the piles are of the same material, of approximately equal length, and driven into substantially similar soils, the elastic shortening will be approximately equal for all piles and thus will not contribute to differential settlement.

Many methods have been suggested for determining the safe allowable pile load or for defining the "failure" of the pile-soil system. The application of these various criteria can produce a wide range of "safe" pile loads from the same test data.

Unless failure actually occurs, it would appear reasonable to define the point of "failure" by a maximum slope of the load-settlement curve. For example, the failure load could be defined as the load that results in a slope greater than 0.05 in. per ton on the gross load-settlement curve or a slope greater than 0.03 in. per ton on the plastic load-settlement curve, whichever is smaller (Fig. 5). This is still an arbitrary definition of failure, but is a more generalized approach. The total criterion would include a maximum allowable gross settlement under the design load, with consideration given to elastic shortening of the pile and to safety.

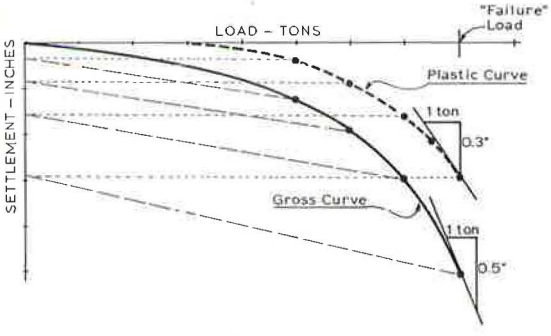


Figure 5. Slope criteria for determining "failure" load from load-settlement curves.

Where failure results from some arbitrary criterion, the factor of safety could range from one and one-half to two. Where actual failure of the pile-soil system is determined by a plunging of the pile into the ground, this factor of safety could range from two to two and one-half.

The complete analysis of the test results should include consideration of all factors, such as the elastic behavior of the pile (from instrumentation or cycle loading) and an evaluation of the long-term performance. This

could involve an analysis and evaluation of the subsoil data in conjunction with the test results.

It should be noted that observed settlements made at the top of the pile may not necessarily indicate downward movement of the pile into the ground. Where high load tests are performed, the possibility of local failure of the pile above ground surface, or crushing of the grout under the test plate, should be recognized as possible factors contributing toward observed "settlements."

## APPLICATION OF RESULTS

Because it is impractical to test every pile on a project, the results of the testing must be applicable to other piles to be driven. This is a reasonable and accepted procedure, providing that the following conditions exist:

1. The other piles are of the same type, material, and size as the test piles;
2. Subsoil conditions are comparable to those at the test pile locations;
3. Installation methods and equipment used are the same as or comparable to those used for the test piles; and
4. Piles are driven to the same penetration depth or resistance or both as the test piles to compensate for variations in the vertical position and density of the bearing strata.

The results of tests on single piles can usually be applied to pile groups, especially in granular soils. The group effect, if any, depends a great deal on the subsoil profile to some depth below the pile tips. Unless the bearing stratum is relatively thin and underlain by deep deposits of soft compressible soils, there should be no detrimental effects from group loading. However, where the piles receive their principal support in cohesive soil, group action should be analyzed.

The application of the results of the advance test program to the foundation design and specification can often produce substantial savings in foundation costs. Although, as a practical measure, the test results would lead to the selection of a single design load, the requirements for various types of piles as to size, length, shape, weight per foot (stiffness), installation methods, and driving requirements could vary over a rather wide range. These differences should be reflected in the specifications and, in turn, will be reflected in the alternative costs to produce the most economical foundation for the conditions involved.

## LOAD TESTING BY THE TEXAS HIGHWAY DEPARTMENT

In 1963, correlative pile load test field studies were initiated by the Texas Highway Department between the standard 48-24 hour test method (3) versus a quick test method (4) that was modified after the constant rate of penetration method described by Whitaker and Cooke (2).

### Purpose of Pile Load Test as Used by the Texas Highway Department

Design values, construction procedures, and anticipated performance of a piling or drilled shaft foundation should be substantiated by load tests in certain cases.

Load testing of piling is especially recommended when it has been established by soil studies that static resistance (design load as indicated on the plans) will be obtained at specified plan tip elevation but dynamic resistance by hammer formula will not be reached. If it is apparent that considerable savings may be attained by load testing, this procedure should be used and specified on the plans.

For design purposes, a static loading test is performed for the following reasons:

1. To prove the piling adequate for the proposed design load at the selected pile tip elevation; and
2. To determine the true relationship between static and dynamic capacity of the piling in a particular soil condition and thereby to obtain a K-factor that is applied to the dynamic formula. The K-factor is determined by the following formula:

$$K = \frac{L}{P}$$

where

L = maximum proven design load as indicated by pile load test, and
P = "safe" load capacity determined by the dynamic hammer formula used on the test-loaded piling before the K-factor is applied.

The specification hammer formula is then modified, to conform to the maximum proven design load as determined by the load test. For the Engineering-News formula, this modification would be

$$P = K \frac{2WH}{s + 0.1}$$

Standard 48-24 Hour Test Method

Prior to January 1963, the Texas Highway Department (THD) used the basic AASHO 48-24 hour test method as modified by the THD specifications (3). This method consists of first loading the pile to approximately the design load with successive load increments (in multiples of 5 tons) equal to about one-third the design load (Fig. 6). Gross settlement readings, loads, and other data are recorded immediately before and after the application of each increment of load and at 15-minute intervals between load application. Load increments are not added until 2 hours have elapsed without measurable settlement, which is considered to be 0.005 in. or more.

If the estimated net settlement exceeds 0.25 in. before the application of twice the proposed design load, the pile is unloaded and the rebound recorded. If the actual net settlement is more than 0.25 in., the pile is driven to a greater resistance.

When the estimated net settlement (gross settlement minus estimated elastic rebound) has reached a value of 0.25 in. (Fig. 7), or when a minimum of two times the design load is on the pile and an estimated net settlement does not exceed 0.25 in. the addition of load is discontinued and a standard AASHO 48-24 hour test is run.

The 48-24 hour test consists of holding the load on the pile constant for a minimum of 48 hours and for 24 hours of no measurable settlement. Readings for gross settlement are made every 15 minutes during this period. If the gross settlement at the end of a successful 48-24 hour test is less than 0.3 in., additional load is applied until the estimated net settlement is about 0.25 in., and the standard 48-24 hour test is run again. At the conclusion of the standard 48-24 hour test, all load is removed and rebound readings are taken every 15 minutes for 4 hours. If the recorded net settlement is less than 0.25 in., the pile is reloaded to twice the proposed design load, and this load is held for 4 hours without measurable settlement. Following this the load is increased until the anticipated net settlement is 0.25 in., and the standard 48-24 hour test is repeated. Such testing is continued until the actual net settlement equals or exceeds 0.25 in. or until the testing capacity is reached.

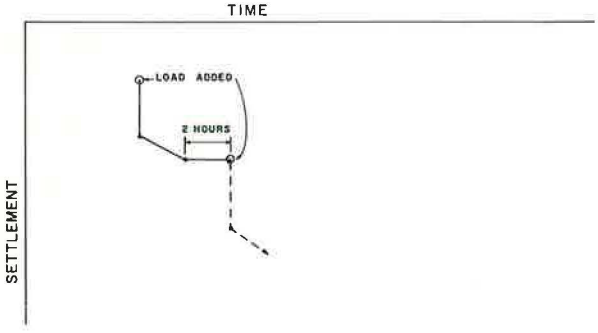


Figure 6. Load-settlement-time relationship for one load increment (48-24 hour test method).

The theoretical "failure" load is considered to be the load that results in a net settlement (gross minus rebound) of 0.25 in. The maximum proven design load is interpreted to be 50 percent of the load that, after a minimum of 48 hours, causes a permanent net settlement of not more than 0.25 in., measured at the top of the pile. If the test load causes

a permanent net settlement of more than 0.25 in., then the allowable design load is 50 percent of the load obtained by interpolation from the computed net settlement line value of 0.25 in. This line is obtained by calculation based on the actual recorded recovery.

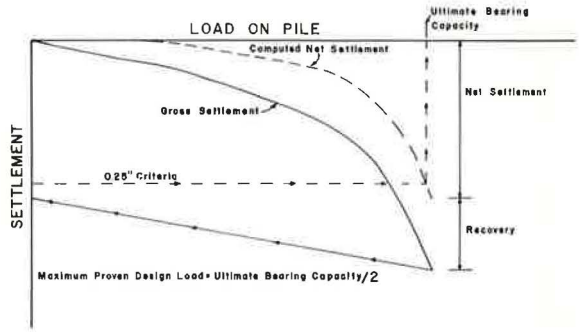


Figure 7. Interpretation of results (48-24 hour test method).

## Constant Rate of Penetration Method

In January 1963, Engineering News-Record published an article by Esrig (5) in which he discussed a new pile-testing procedure developed by Whitaker and Cooke (2). Whitaker termed the new testing procedure the constant rate of penetration (CRP) test. This method requires that the test-loaded pile be forced into the ground at a constant rate with the loads corresponding to specific penetrations being measured.

## Quick Test Method

After publication of Esrig's article, plans were immediately made to perform load tests not only in accordance with the Texas Highway Department standard specifications but also by a modification of the constant rate of penetration (CRP) test.

The CRP test calls for records of time and jacking force to be made at equal intervals of movements of the pile head with the rate of jacking being adjusted so that readings occur at equal intervals of time. For convenience and simplicity, the CRP test was modified by the Texas Highway Department to produce the quick test method. Essentially, it requires that loads be added in increments of 5 or 10 tons with gross settlement readings, loads, and other data recorded immediately before and after the application of each increment of load. Each increment is held for 2½ minutes, and the next increment is then applied.

When the load-settlement curve obtained from these test data (Fig. 8) shows that the pile is definitely being failed (i.e., the load on the pile can be held only by constant pumping of the hydraulic jack and the pile is being driven into the ground), pumping is stopped. Gross settlement readings, loads, and other data are recorded immediately after pumping has ceased and again after intervals of 2½ minutes and 5 minutes. The load on the pile in the case of constant pumping is called plunging failure load. Then all load is removed, and the pile is allowed to recover. Net settlement readings are made immediately after all load has been removed and at intervals of 2½ minutes for a total period of 5 minutes.

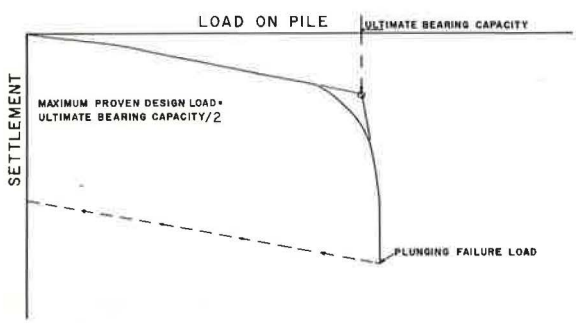


Figure 8. Interpretation of results (Texas Highway Department quick test method).

All test loads are carried to plunging failure or to the capacity of the equipment. The maximum proven design load is considered to be 50 percent of the ultimate bearing capacity, which is indicated by the intersection of lines drawn tangent to the 2 basic portions of the load-settlement curve as shown in Figure 8.

For this method of interpretation, the scale to be used for plotting the load-settlement curve should be 1 in. for each 10-ton load increment and

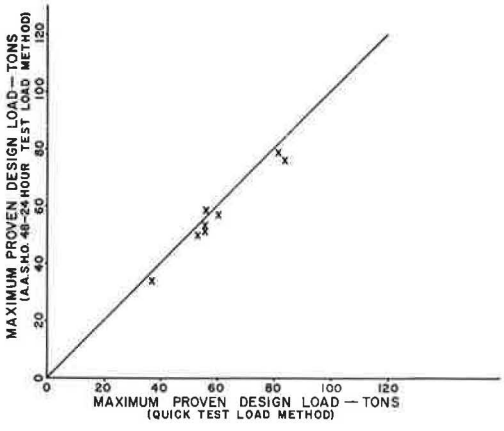


Figure 9. Correlation of proven design load between standard 48-24 hour and quick test methods.

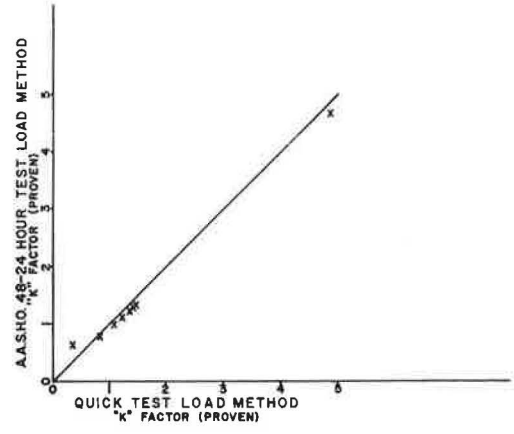


Figure 10. Correlation of proven K-factor between standard 48-24 hour and quick test methods.

0.10-in. settlement respectively. The maximum proven design load is the value used to establish a K-factor for use with the dynamic hammer formula as stated earlier.

## Correlation Studies

From January 1963 until March 1965, 11 pile load tests were performed by the Texas Highway Department by using both the standard 48-24 hour and the quick test methods. Out of this number of tests, eight were test-loaded to theoretical failure by the 48-24 hour test method. All of the tests were taken to plunging failure with the quick test method. A summary of the data for these tests is given in Tables 1, 2, 3, and 4. The maximum proven design load obtained by the quick test method and the 48-24 hour test method are shown in Figure 9. The average deviation of maximum proven design load values obtained from the quick test method versus the standard 48-24 hour test method was about 4 percent.

The K-factors given in Tables 3 and 4 for both load test methods are shown in Figure 10. Agreement is considered to be very good in all ranges of value.

TABLE 1

LOCATION OF PILES TESTED FROM FEBRUARY 1963 TO NOVEMBER 1964

| Test Number | County | Structure | Bent and Test Pile |
|---|---|---|---|
| 1 | Brazoria | Chocolate Bayou | Bent 6, C |
| 2 | Wharton | Colorado River | Bent 4 |
| 3 | Arkansas | Copano Bay | Pile 1 |
| 4 | Victoria | MP RR OP | Pile 1 |
| 5 | Harris | Ramp F | Bent 9 |
| 6 | Jefferson | US-69 and FM-365 | Pile 1 |
| 7 | Harris | Pierce | Bent 94 |
| 8 | Harris | 183 | Bent 3 |
| 9 | Harris | SP RR UP | Bent 2 |
| 10 | Galveston | GC and SR RR UP | Bent 24 |
| 11 | Harris | SP RR UP | Bent 2 |

## CONCLUSIONS

Based on the results of these tests, the Texas Highway Department began using the quick test method as the standard testing method in April 1965. A special provision to Item 405, Test Loading Piling, was prepared for this test method and has been in use by the department since that time (4).

From the 1963-1965 study as well as from the department's experience to date, the following observations and conclusions have been reached relative to the quick test method:

1. A pile load test can be expeditiously performed in about 1 hour with resultant savings in money and time;
2. Construction delay to the project caused by load testing is greatly reduced;

TABLE 2

DESCRIPTION OF PILES, SOIL, AND HAMMER

| Test Number | Pile Type | Total Pile Length (ft - in.) | Effective Pile Length (ft - in.) | General Soil Type | Pile Design Load (tons) | Type of Hammer | ENF 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 |

TABLE 3

AASHO 48-24 HOUR TEST METHOD

| Test Number | Duration of Test (hr) | Maximum Load on Pile (tons) | Maximum Load Held 48 Hours (tons) | Gross Settlement (in.) | Net Settlement (in.) | Proven Design Load (tons) | K-Factor |
|---|---|---|---|---|---|---|---|
| 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.

TABLE 4

QUICK TEST METHOD

| Test Number | Duration of Test (min) | Plunging Failure Load (tons) | Ultimate Bearing Capacity (tons) | Gross Settlement (in.) | Net Settlement (in.) | Proven Design Load (tons) | K-Factor |
|---|---|---|---|---|---|---|---|
| 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 |

3. Substantial decrease in bid price of load test setup ensures feasibility of testing on small projects;
4. Simplicity of the testing procedure ensures standardization of the test and easy interpretation and utilization of results without reliance on arbitrary definitions; and
5. Load-settlement curves can be easily duplicated by repeated tests.

## REFERENCES

1. Van Weele, A. F. A Method of Separating the Bearing Capacity of a Test Pile Into Skin-Friction and Point-Resistance. Proc. Fourth Internat. Conf. on Soil Mechanics and Foundation Eng., London, 1957.
2. Whitaker, T., and Cooke, R. W. A New Approach to Pile Testing. Proc. Fifth Internat. Conf. on Soil Mechanics and Foundation Eng., Paris, 1961.
3. Standard Specifications for Road and Bridge Construction. Texas Highway Department, 1962.
4. Special Provisions to Item 405 of 1962 Standard Specifications. Texas Highway Department.
5. Esrig, M. I. Load Test on Pile in as Little as Ten Minutes. Engineering News-Record, Jan. 31, 1963.