Axial Load Test Procedures for Pile Foundations

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INTRODUCTION

Because of the non-availability of reliable procedures for assessing the load transfer mechanisms between piles and surrounding soil, or for determining the ultimate capacity of piles, full-scale load tests are conducted. It is a standard practice to conduct load tests in large projects either in the design phase or during construction. The significance of a properly conducted load test is that it furnishes the actual soil resistance at the site upon which design can be based reliably.

In practice, load tests are more commonly conducted to determine that the foundation is capable of sustaining working loads with sufficient factor of safety. In other instances, load transfer characteristics are required to identify the mechanism by which load is transferred to the soil.

Load tests vary in their procedure, equipment, instrumentation, and load application method. There are two types of tests conducted for axial types of loading, namely compression tests and pullout (tension) tests. For compression tests, the load can be applied either by adding dead weight or by hydraulic jacking. Direct application of dead weight can be done with concrete or steel blocks, water tanks, sand bags or any other type of weights. However, the use of this method has decreased considerably, and it became more common to use hydraulic jacks to vary the load on the test pile, especially for high loading conditions.

EQUIPMENT AND INSTRUMENTATION

The arrangement for an axial compression test is generally done using either a dead load platform, or a hydraulic jack with reaction (or anchor) piles. The hydraulic jack with reaction piles arrangement (Figure 1) is used routinely in load testing. In order to minimize the effect of stresses transferred from the reaction piles to the soil near the test shaft, a minimum distance is required between the reaction piles and the test pile. It is generally accepted to allow for a minimum spacing of 3 reaction pile diameters between each reaction pile and the test pile, provided that this distance is greater than 5 ft (Hirany and Kulhawy, 1988).

A reaction beam is installed on top of the reaction piles. The test pile is loaded by utilizing a hydraulic jack that is placed on the center of the test pile. The applied load is measured with a load cell placed between the hydraulic jack and the pile or by a pressure gauge installed between the pump and the jack.

Instruments are primarily employed to record two types of movement in load tests. First is the pile head (butt) movement and second are the incremental strain measurements along the pile length. Measurements of the pile head movement is essential in all load tests and is done by the use of dial gauges and/or surveying systems. The incremental strain measurements along the pile length are taken only if load transfer distribution needs to be determined. Instruments that can be installed for such measurements are the telltales (strain rods) and electric strain gauges.

Several arrangements are possible for conducting pullout tests (Hirany and Kulhawy, 1988). However, two arrangements are more common than others. In the first setup as indicated in Figure 2(a), a hydraulic jack is located between a beam and a reaction frame that is anchored to the pile by a tension connection (or longitudinal steel rebars). The reaction supports can be reaction piles or cribbing placed at each side of the test pile.

An alternative arrangement is shown in Figure 2(b) and is different in that the load is applied by two hydraulic jacks acting on top of the reaction supports. In this setup, the load on the test pile is taken as twice the jacking load. The instruments and measurements for the pullout tests are similar to those for compression load tests.

TESTING PROCEDURES

Details of different testing procedures can be found in many publications (e.g. ASTM Dl 143-81, Fuller and Hoy, 1970, Crowther, 1988, Joshi and Sharma, 1987, Hirany and Kulhawy, 1988). All methods cited in the literature are either stress-controlled or strain-controlled.

Controlled-Stress Methods

Variations of the controlled-stress methods are described below.

Slow Maintained Load Test (SML)

In this method, the pile is loaded in equal increments of 25% of the design load up to twice the design load. Each increment is maintained until a settlement of 0.01 in/hr is reached. The maximum load is then held typically for 24 hours and then removed in similar decrements. This kind of test is the ASTM standard procedure and the most common test, especially in large projects. A typical test lasts between 1.5 to 3 days.

Quick Maintained Load Test (QML)

In this procedure, 15% of the design load is added at a time and held for 5 minutes. The maximum load is equal to 3 times the design load. When the total load is reached, unloading is then done with four equal decrements allowing 5 minutes between each two decrements. Typical time of a load test can be between 3 to 5 hours.

This method has the advantage of being fast but it cannot be used where the pile is installed in strata with significant creep properties because load may be shed from the sides to the base without changes in the applied load (O'Neill and Hawkins, 1982).

Incremental Equilibrium Test (IE)

This test is a modification of the SML test and takes only about one-third of the SML test duration. Although the test is faster, the IE test was reported to provide similar correlations to the SML test (Fellenius, 1975). The IE test is conducted by applying increments of 15% to 25% of the design load and maintaining that load for about 10 minutes. The load then is allowed to drop (with the increase in settlement) until it becomes constant. At this point, equilibrium between the load and displacement is reached and the next increment is applied.

Constant-Time Interval Test (CTI)

Loading using this method is the same as that for the SML procedure. However, each load is maintained for exactly one hour. This procedure has a typical duration of about 10 hours.

Cyclic Test (CYC)

The cyclic test is conducted by a series of loading and unloading to the maximum test load. The rate of loading can be similar to that of the SML or CTI procedures. This test can be used where there is a need to determine the load at which creep displacements exceed certain limits. This procedure is time-consuming and is not typically used for routine load testing.

Controlled-Strain Methods

The controlled-strain methods are divided into two categories:

Constant-Rate Penetration Test (CRP)

In this test, the pile is made to penetrate the soil at a pre-determined constant rate, while the load applied is measured continuously. Average rates are 0.03 in/min for cohesive soils and 0.06 in/min for granular soils. The test can be performed in less than one hour, but it requires special equipment and trained personnel.

Constant Settlement Increment Test (CSI)

In this procedure, the load increments are determined from the load necessary to produce uniform increments of settlement of the pile head. Typical settlements are of the magnitude of 1% of the pile diameter. The load increment is varied in order to maintain the settlement magnitude.

Even though the slow maintained-load test is considered the standard procedure, other methods of testing such as the QML and CRP have been increasingly used where allowed in the local building codes and generally yield consistent results with the standard SML test method. These other testing procedures are recommended as adequate testing procedures by Fuller and Hoy, 1970 and Reese and O'Neill, 1988.

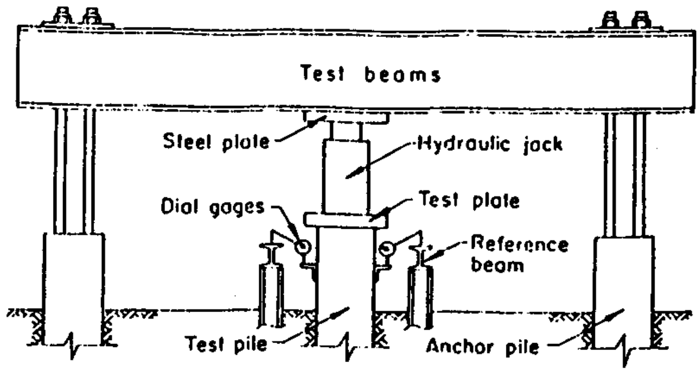

FIGURE 1

Test arrangement for compression loading (ASTM-D1143, 1987)

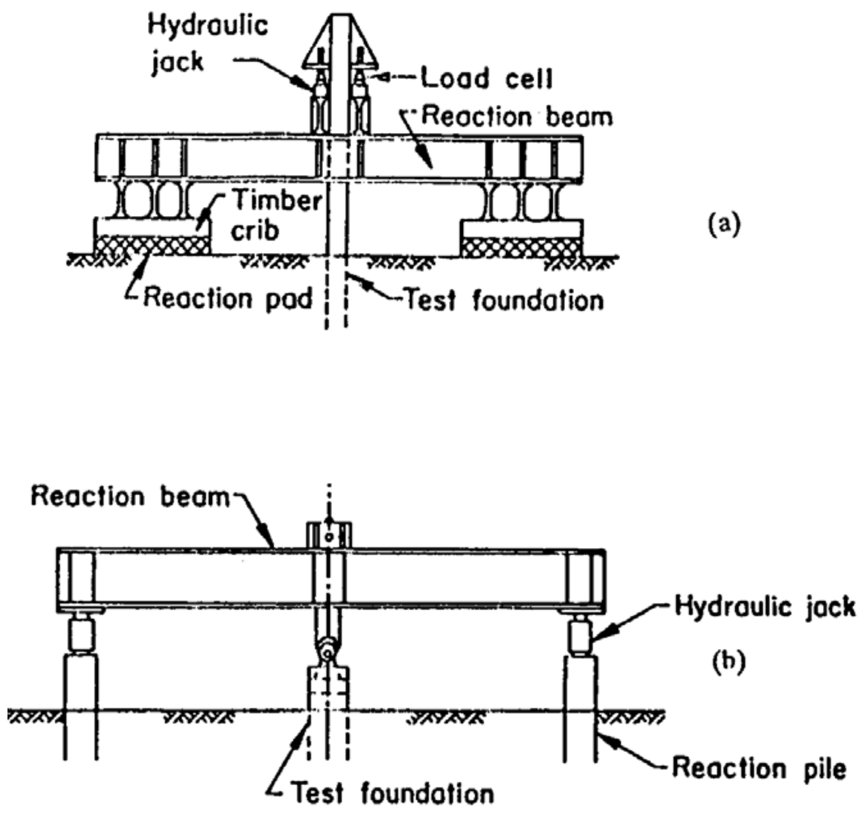

FIGURE 2

Two schemes for uplift loading testing (O'Rourke and Kulhawy, 1985)

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