LOW STRAIN DYNAMIC TESTING OF WOOD PILES SUPPORTING AN EXISTING PIER

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ABSTRACT

Low strain dynamic testing is performed to evaluate pile structural integrity. Testing is simply done by affixing an accelerometer to the pile top and impacting the pile head with a small hand-held hammer. The resulting record of pile top motion is analyzed in either time, or frequency domains. The method was initially developed, and is now routinely applied, for evaluating integrity of concrete piles. Testing is commonly performed shortly after pile installation so that deficiencies can be detected early and corrective measures taken before construction of the superstructure. This paper presents a case history where low strain dynamic testing was performed to test wood piles supporting an existing structure. Under consideration is a 183 m long wooden pier constructed only two years ago, but using piles that had been used before and recovered from an old structure. The piles were installed at this site by jetting and spudding and without the use of a pile driving hammer. Differential settlements and lateral movements are adversely affecting the structure's functionality and risking its stability. Since pile installation records were not kept during construction, low strain dynamic testing was performed to assess piles' integrity and lengths. The data were of good quality assuring the applicability of low strain integrity testing to wood piles even under an existing structure. Results of the tests were useful in defining the structure's integrity and a rehabilitation program.

INTRODUCTION

A wooden fishing pier constructed approximately two years ago to replace an old one destroyed by hurricane winds and general deterioration is undergoing

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structural distress caused by foundation settlements and lateral movements. The 183 m long pier is carried on 51 bents supported by a total of 124 timber piles. The number of piles in each bent range between 2 to 4 piles. The pier deck is approximately 6 m above water level. Water depth increased to a maximum depth of 7 m at the pier head. Subsurface conditions at the site consist of mainly loose to firm fine to coarse sand and gravel to a depth of 3 m under which a deep layer of very hard clayey organic silt occurs. Figure 1 shows a general view of the pier and its piles. The timber piles used in the construction of this pier had been used before and recovered from an old structure. All piles were installed, large diameter down, by jetting and spudding and without the use of a pile driving hammer. Pile installation records were not kept during construction. Differential vertical settlements and lateral movements of the foundation piles are adversely affecting the structure's functionality and risking its stability. Since pile installation records were not available, it was not possible to determine pile lengths in-place and conclude penetrations in order to rationally evaluate the foundation system. Visual inspection of the pile shafts indicated some deterioration, particularly within the tidal zone. One pile was totally broken. Low strain dynamic pile testing was performed for the purpose of assessing pile structural integrity and lengths. The information obtained was essential for evaluating the overall integrity of the structure and for developing a rehabilitation program.

Low strain dynamic pile testing was initially developed, and is now widely used, for testing concrete piles for assessment of structural integrity (Rausche and Seitz 1983, Hussein and Garlanger 1992). Testing is usually performed shortly after pile installation (either by driving, or casting-in-place) so that deficient piles can be recognized early and corrective measures taken before construction of the superstructure. The application of the method was recently expanded to cover testing of concrete piles under existing structures for determination of unknown pile lengths (Hussein et al. 1992). A case history is presented here where low strain dynamic pile testing was performed on timber piles under an existing pier.

LOW STRAIN DYNAMIC PILE TESTING

One dimensional wave mechanics applies to a linear elastic pile that has a length an order of magnitude greater than its width. When a pile is impacted at its head, a compressive stress wave travels down the pile at a speed, c, which is a function of the material elastic modulus, E, and unit mass, ρ, i.e., $c = (E/\rho)^{1/2}$. For a pile with no soil resistance, the wave travels unimpeded (except for minor pile damping) and reaches the pile toe at a time L/c after impact (where L is pile length) and reflects as an upwards traveling tension wave which is registered at the pile head a time 2L/c after impact. Soil resistance and changes in pile impedance Z(=EA/c, where A is pile area) cause wave reflections that reach the pile top before time 2L/c after impact. Low strain dynamic pile testing is based

Figure 1: General View of Pier and Piles

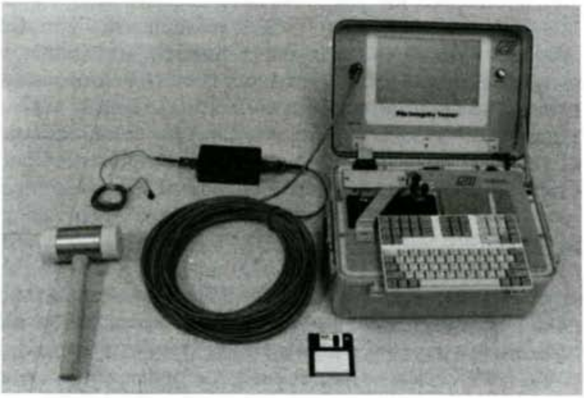

Figure 2: Pile Integrity Tester (P.I.T.) Equipment

on one dimensional wave propagation mechanics and the premise that changes in pile impedance and soil resistance produce predictable wave reflections at the pile top. The time after impact at which the reflections reach the pile top are directly proportional to the distance of the origin of the reflected waves.

Stress waves at the pile head are commonly monitored with an accelerometer. Field testing is conveniently performed using the Pile Integrity Tester (P.I.T.) system which consists of an accelerometer, a hand held hammer and a field data acquisition system capable of digitizing analog signals and processing digital data. The P.I.T. equipment is shown in Figure 2.

The acceleration record created by hammer impact and wave reflections is integrated and the resulting velocity is displayed as either a function of pile length, or in the frequency domain. Time to length conversion is done using the wave speed. Usually data from several blows are averaged. Another data enhancement feature of the P.I.T. is amplification over time which allows for detection of wave reflection that may be too weak to recognize otherwise. In addition to visual inspection of the velocity records for wave reflections, additional rigorous dynamic analysis of the measured data can yield pile impedance profile as a function of length (Rausche et al. 1992).

TESTING RESULTS AND DATA INTERPRETATION

For meaningful application of low strain dynamic testing for determination of pile lengths at this project, two major issues had to be resolved. The first was pile top accessibility since for the most part the pier deck rested directly on top of the piles. There were, however, some piles that were separated from the pile deck by a distance of up to 30 cm. In cases where pile tops were not accessible, the accelerometer was attached to the side of the pile, approximately 0.5 to 1.0 m below its top, and hammer impacts were applied to the deck axially with the pile shaft. Piles that were separated from the bottom of the deck were tested by affixing the accelerometer to either the pile head, or to its side, but always impacting the pile head. A total of 21 piles were tested. Field work was accomplished in a few hours. The other issue of concern was the interpretation of testing results for determination of pile length from times of wave reflections with an unknown wave speed. Since the time 2L/c is measured, it is necessary to know (c) in order to compute L. A method was proposed by Hussein and Morgano (1993) for simultaneous determination of both c and L for piles of an unknown length by measuring pile motion at two locations along pile shaft. For this case, wave speed was determined to be 4000 m/s by testing a visibly broken pile that was not embedded in the ground since pile length could be measured with a tape. The same wave speed was then used in evaluating the data for all other piles tested. Generally, the data was of good quality. Figure 3 presents a typical test result showing pile top acceleration and corresponding velocity

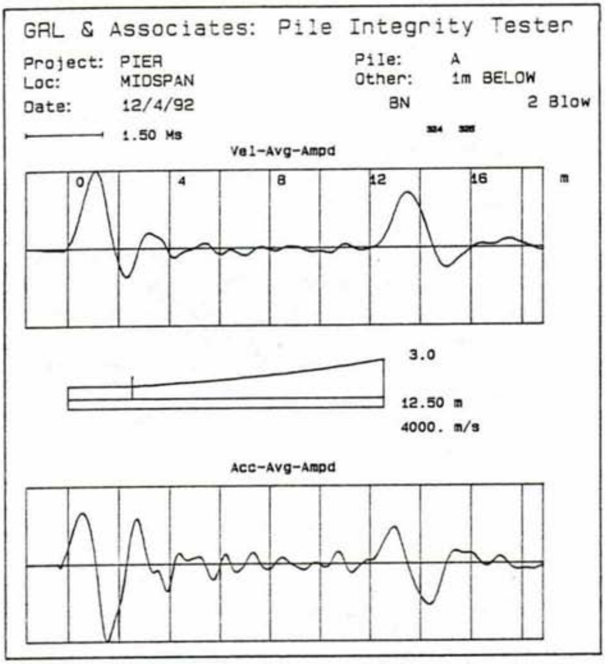

Figure 3: Typical Test Result

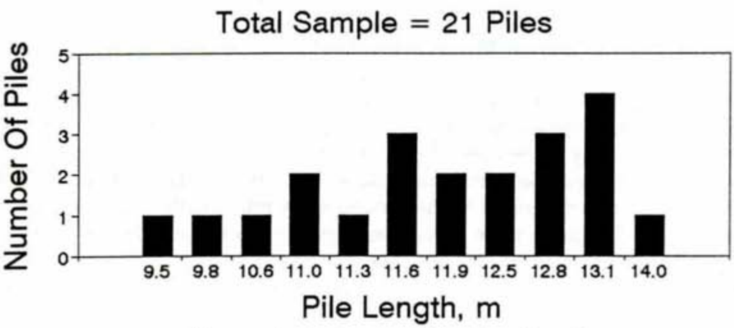

Figure 4: Summary of Testing Results

records as a function of length (time scale also indicated) for one pile under two hammer blows along with amplification factor used and data interpretation of length (12.5 m) assuming wave speed (4000 m/s). For the 21 piles tested, pile lengths ranged from 9.5 to 14.0 m. Figure 4 presents a summary of testing results. Data from some of the piles tested contained early wave reflections indicating reduction of pile impedance from locations coinciding with the water level. Visual inspection of the piles confirmed pile deterioration of suspected piles. Considering the distance between mud line, pile tops and lengths determined by dynamic testing for each pile, it was concluded that pile embedments were generally less than one meter into the ground.

CONCLUSION

The functionality and stability of a relatively new fishing pier structure were adversely compromised by pile foundation differential settlements and lateral movements. Pile installation records were not kept during construction making it virtually impossible to rationally analyze the foundation system without knowledge of pile lengths and embedments. Low strain dynamic testing was innovatively applied for testing the timber piles and determination of pile lengths under the existing structure. The data was of good quality confirming the applicability of the method for testing timber piles. Testing results were useful in defining the integrity of the structure and a rehabilitation program by yielding data on pile lengths and penetrations.

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