Florida Department of Transportation
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STRENGTH OF REPAIRED PILES

PROBLEM STATEMENT

Corrosion damaged piles are commonly repaired by jacketing the pile. These jackets consist of removable or stay-in-place forms that are installed around the pile and subsequently filled with concrete, mortar or epoxy. Jackets can be flexible *(constructed of industrial strength fabric)* or rigid, although semi-rigid fiberglass jackets have become popular because of their light weight.

Pile jackets are widely used in Florida: a survey completed in 1996 showed that the state had 279 bridges with jacketed piles with a cumulative jacket length of 83,068 feet. The Florida Department of Transportation (FDOT) uses six different fiberglass jackets designated as Type I through Type VI. Use by type varies with extent and position of damage. Types I-IV are *non-structural* and are used to repair minor damage. Types V and VI are *structural* and are used in cases of severe damage where there is a need to provide reinforcing steel to replace prestressing strands that have corroded. The vast majority of the repairs carried out, however, are minor repairs. Structural repairs constitute a tiny fraction of the total number.

Although much information is available on the manner in which repairs are to be carried out and on the performance of repair materials, relatively little information is available on the structural efficiency of the repaired piles. Without information on the strength of repaired piles, rational decisions that potentially could lead to savings are more difficult to justify.

OBJECTIVES

When a pile corrodes, the load it supports is re-directed through the reduced corroded cross-section, thereby increasing its stress. Because the load path is already set, the extent of increase in capacity arising out of a repair is uncertain. Therefore, the first objective was to study the capacity increase resulting from the repair of corroded piles.

The critical parameter for efficient load transfer to the repair material is the interface bond between the pile core and the repair material. Efficiency would improve if the bond could be improved. Some FDOT districts have already instituted measures to enhance bond. For example, District IV has a repair option that utilizes powder activated nails as shear connectors. Confinement provided by steel ties is known to improve the material properties of concrete. Advances in concrete technology can also lead to enhanced bond. However, the extent of improvement achieved by such measures in piling applications is not known. Thus, the second objective was to determine whether this repair efficiency can be improved.

Non-structural jackets are intended simply to restore appearance and protect reinforcement against subsequent chloride attack. Structural repairs, on the other hand, are intended to restore the ultimate capacity of the cross-section. In the original scope of this project, the goal was to examine only structural (Type V) repairs. However, as there are far more non-structural repairs than structural ones, the experimental investigation was expanded to include non-structural (Type II) repairs as well.

To meet these objectives, the study was divided into two phases. In Phase I, simulated repairs were carried out on model piles and their ultimate capacities were assessed under concentric and eccentric loads. The results of Phase I were used to establish a test program for Phase II, in which the effect of shear connectors and a new material were evaluated.

FINDINGS AND CONCLUSIONS

The focus of Phase I one testing was to determine the extent to which currently used pile jacketing methods restored pile capacity. Seven series of axial load tests were conducted, three of which were used as controls; the remaining investigated the effects of structural (Type V) and non-structural (Type II) repairs for two distinct damage surfaces--formed and chipped.

The following conclusions may be drawn from the test results:

- Structural repairs provide higher increase in axial capacity. Non-structural repairs on formed surfaces led to practically no increase in capacity.

- The roughness of the interface contributes significantly to composite action. Chipped surfaces resulted in composite action practically to failure. The repair material debonded more readily in the case of formed specimens and was the same for structural and non-structural repairs.

- None of the repairs led to full restoration of the original strength. The highest increase was 80.7% (Type V - formed); the lowest was *56.6%* (Type II - chipped).

Seven series of eccentrically loaded compression tests were conducted. Three were used as controls, and the remaining investigated the effects of structural (Type V) and nonstructural (Type II) repairs. As with the axial testing series, two distinct damage surfaces were evaluated, formed and chipped. All "bending" tests used a 1.2 inch off-center load line producing an eccentricity (e/h = 0.2).

The following conclusions may be drawn from the test results:

- Structural repairs are very efficient and lead to significant increases in ultimate capacity. Non-structural repairs on formed surfaces are much more efficient under eccentric loading than under axial loading, where there was practically no increase in capacity.

- The bond between the old concrete and the repair material is less important under eccentric load than with concentric loading.

- None of the repairs led to a full restoration of the original strength. The highest increase was 93.1% (Type V - formed); the lowest was 64.3% (Type II - chipped). These are, however, higher than those for axial loads.

The focus of Phase II was to identify measures that could lead to improved ultimate capacity. As axial tests on formed piles provided the least improvement, only axial loads were considered in this phase. Five systems--four powder activated nail systems and a chemically-based proprietary repair system--were tested in this phase.

The following conclusions may be drawn from the test results:

- Improvement in capacity as a result of the use of powder activated nails was disappointing. When installed only above the water line (District IV's original scheme), increases in capacity over Phase I were only 3.3%. However, when these nails were used both above and below the waterline there was a 6.3% decrease, due to the damage induced in the core during the installation of the nails.

- The best results were obtained when enhanced bond did not result in damage to the core. Capacity increases of 12.1% were recorded for the cases where dowels were epoxied into pre-drilled holes.

- The chemically based proprietary system provided a greater increase (7.7%) than powder activated nails. This system is simple to use and may provide the most cost effective solution.

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