TECHSUMMARY March 2022

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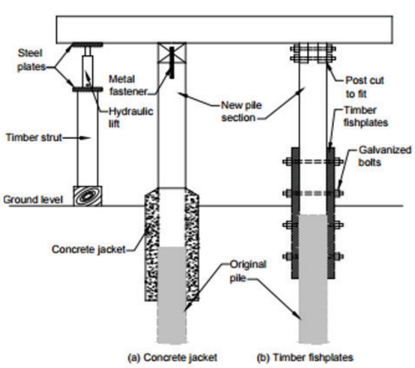
Rehabilitation of Deteriorated Timber Piles using Fiber Reinforced Polymer (FRP) Composites

INTRODUCTION

Timber bridge piles are susceptible to decay in the vicinity of the waterline. Upon corrosion and degradation of the pile brought about by the presence of water, replacement of the damaged pile section is done with new, treated wood through splicing as given in the figure below. The code-approved splicing methodology features stringent design and installation guidelines. Difficulties arise as a successful splice is difficult to accomplish in the field and is not a long-term solution as the exposed heart wood tends to rot.

Splicing



FRP-wrapped pile

Using glass fiber reinforced polymer (GFRP) wraps to reinforce the decayed timber pile area with filler materials to arrest further decay and simultaneously enhance the pile strength is a relatively new method of rehabilitation. It is a cost-effective and longer-lasting method to repair timber bridge piles. However, the installation methods and design guidelines for FRP wrapped piles are yet to be developed.

This study has evaluated both the bond, bending, and shear and compressive strengths of five FRP wrap systems on creosote treated timber piles. Low-viscosity epoxy systems with better resin penetration are evaluated for strengths in addition to testing polymeric crack fillers to repair section loss in a timber pile. This study also evaluated shear, flexure, and axial compression strengths for timber pile splicing (legacy) methods in addition to the FRP wrap splicing method.

OBJECTIVE

The objectives of this research project were to:

1. Determine the best FRP wrap and filler materials and in-situ rehabilitation techniques to be used for repair through literature review and laboratory testing.
2. Test and evaluate the strengths of both the legacy splice and FRP wrap mechanisms to determine the design adequacy of FRP wrapping for field implementation.
3. Develop a simplified design methodology for the rehabilitation of timber piles.

SCOPE

This study focused on:

1. Evaluating bond, pull-off, shear, bending, and axial strength capacities of pile systems using the FRP wraps and comparing to pile systems with traditional (legacy) splice mechanisms. All the test data were obtained after wrapping or splicing the cut pieces of creosote-treated timber piles.
2. Identifying fillers that are suitable to repair the decayed sections in timber piles.
3. Developing procedures for repairing timber piles with FRP wraps including repair guidelines, load rating methods, field inspection techniques.
4. Conducting workshops to train DOTD personnel for field implementation.

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METHODOLOGY

Timber piles are repaired using traditional methods (steel plate, C-channel, and wood plate splicing) and tested under bond, pull-off, shear, and axial compression before analyzing and comparing the test results with those obtained by utilizing the FRP wrap based data. The steel C-channel system proved to be the strongest in terms of stress to failure, but similar to the failure stress of FRP wrapped piles.

Full-size creosote-treated timber specimens are tested also to evaluate for bond, pull-off, and compression and bending strengths. Timber piles were provided in 8- and 15-ft. lengths and treated with creosote before shipping. Pile diameters varied from 10 in. to 12 in. On a few timber specimens, surfaces are often nonorthogonal to the pile's longitudinal axis due to cutting with hand saw, but influence of nonorthogonality on test results is negligible.

For this study, FRP systems using glass fibers and epoxy-based resins were selected as they are less expensive than carbon or aramid. Also, glass composite has elastic modulus that is similar to that of timber. Furthermore, FRP wrap systems have been previously used to rehab timber piles and showed excellent strength and durability.

CONCLUSIONS

Design methodologies and rating equations were based on the testing program developed through this effort and the following conclusions were drawn:

1. Epoxy-based FRP wrap systems had the highest pull-off, bond, and axial compressive strengths while phenolic and polyurethane systems had lower strengths.
2. Polyurethane systems exhibited the lowest bond and compressive strengths, compared with the bond and compressive strengths of specimens prepared with other resins such as epoxy.
3. Bond tests under wet/dry cyclic conditions showed higher bond strength than the FRP-wrapped samples without wet/dry cycles because of post curing of the resin. The test samples were prepared under dry conditions and no moisture ingress was found during wetting process.
4. Increasing the number of wraps increased the capacity of the pile although an increase in compressive strength in terms of load resistance per unit area did not increase proportionately.
5. Full-scale test specimens with total cross sectional cut after rehabilitating with FRP wrap failed at stresses similar to those without cuts for bond and axial compression, i.e., indicating tests replicate field conditions.
6. Paste-like crack fillers were shown to seal external cracks well, while sand was shown to be an effective means to increase the yield of bulk fillers.
7. Bulk fillers that foam are best at filling voids. However, their strength is lower than the non-foaming fillers.
8. Visual inspection can be conducted on FRP-wrapped timber piles with infrared thermography (IRT) or digital tap hammer offering more objective inspection data.
9. Based on the laboratory and field experiences, traditional (legacy) splicing methods are more cumbersome to rehabilitate than FRP wrapping techniques.
10. Traditional (legacy) splicing methods are more expensive than the FRP wrap techniques in terms of material, transportation, durability, and labor costs.
11. FRP-wrapped timber piles provide a strong, cost efficient, and durable solution as compared to traditional (legacy) splicing methods.

RECOMMENDATIONS

1. The strength of the fillers should be determined to reflect any need for the pile to withstand extra load beyond the original design load.
2. Longer samples should be made to conduct combined axial and bending.
3. Field evaluations of FRP-wrapped systems should be conducted to establish the durability of the proposed methods and to nondestructively evaluate for voids underneath the wraps.
4. Additional testing should be completed for piles repaired with a FRP wrap splice mechanism with extra layers of fabric to reinforce the hoop fiber direction to improve shear and bending capacity.
5. Design and field splicing specifications need to be developed using FRP wraps to rehabilitate deteriorated timber piles.
6. Develop a training program for construction workers on installation of FRP wrap systems for timber piles.