Transportation Consortium of South-Central States (Tran-SET)

Cost-Effective Methods to Retrofit Metal Culvert Using Composites

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Project No. 17STUNM03

PI: Dr. Mahmoud Taha, Dr. Susan Bogus (UNM)

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Developing a technique to retrofit corroded metal culverts using glass fiber reinforced polymers (GFRP)

Limited research has been conducted on strengthening existing corrugated metal culverts using Glass Fiber Reinforced Polymers (GFRP). It has been recognized that typically a concrete liner is provided on the inside surface of the corroded corrugated metal culvert to prolong the life. However, this technique will not be useful for culvert sections that have damage all along the surface of the culvert section. Hence, this project focuses on developing a comprehensive technique to use a fit in GFRP pipe section for existing corroded metal culverts. It has been reported that one of the sag water pipe repaired using GFRP liner has failed within 12 years of repair. Prior research outlined that the reason for such failure is accelerated aging and improper grout between the steel and GFRP substrates. This project recognized that the bond between the metal surface and the GFRP is critical for complete composite action of the repaired culvert.

Problem Statement

Corrosion of metal culverts has been a considerable challenge as it excessively lowered their life expectancy and significantly affected their serviceability. The expected life expectancy for metal culverts is around 50 years. However, heavy corrosion has dropped this life expectancy to lower than 30 years, creating a significant financial burden. Failure of metal culverts is a relatively expensive event. The high cost of rebuilding metal culverts is not only related to materials and construction cost, but also to costs associated with closure of roads to reconstruct failed culverts and related to traffic delay. For this reason, this project focuses on developing cost-effective methods to retrofit metal culvert using composites.

Summary

The research team has conducted double lap shear test to determine the bond strength between GFRP and steel using epoxy. It is to be noted that the bond shear strength and shear modulus are critical parameters for developing the design of the composite culvert section for experimental investigations and to develop a Finite Element Model of the complete composite strengthening system. The experimental setup is shown in Figure 1.

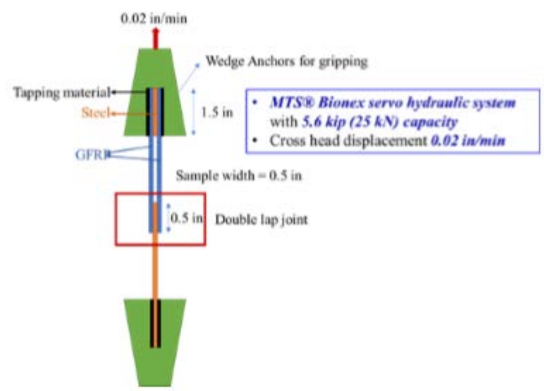

Figure 1. Double lap joint bond test schematic.

Though GFRP as a material is corrosion resistant, it has potential durability issues. Prior investigations show that GFRP exhibits a premature tensile failure due to weak interfacial bond between the glass fibers and the polymeric matrix. This weak bond results in many other potential limitations of GFRP including relatively low creep rupture strength and limited fatigue strength. The limited shear strength of GFRP profiles is a potential problem and governs the design in many cases. GFRP in the form of pipe sections are typically manufactured using filament winding technique. Other GFRP profiles are produced using pultrusion.

To prove the value of using nanomaterials in GFRP production, we developed a pultrusion setup which has been used as a fabrication technique for produce GFRP profiles for experimental investigation as shown in Figure 2. While the pipe sections that will be used for metal culvert retrofit will be fabricated using filament winding technique, the proposed material dispersion approach will be used in both methods. In an attempt to overcome the GFRP limitations, Multi-Walled Carbon Nanotubes (MWCNTs) were first dispersed into the polymeric matrix prior to fabrication of GFRP to fabricate nano-modified GFRP. The GFRP has been fabricated using 700 vinyl ester resin as used by industry. GFRP circular bars were fabricated with a 3/8 in diameter.

These GFRP bars were then tested under direct tension and short beam shear test for preliminary mechanical characterization.

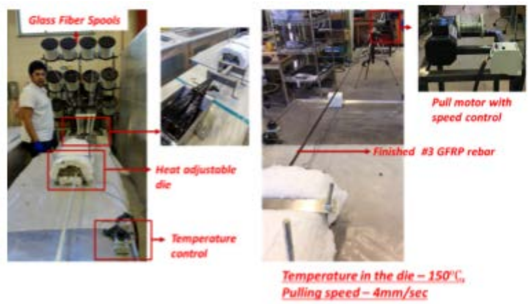

Figure 2. Pultrusion fabrication setup developed at UNM structural lab for examining the significance of nanomaterials on new class of GFRP sections.

Findings

The results from direction tension tests are presented in Figure 3. The tensile test results indicated a 20% increase in strength when using a low concentration of MWCNTs (0.5% by weight) is used in the polymeric matrix for fabrication of GFRP. A change in the mode of failure from a typical broom-like failure to a limited broom failure was observed. This indicates an improvement in the bond between glass fibers and epoxy matrix when MWCNTs are used.

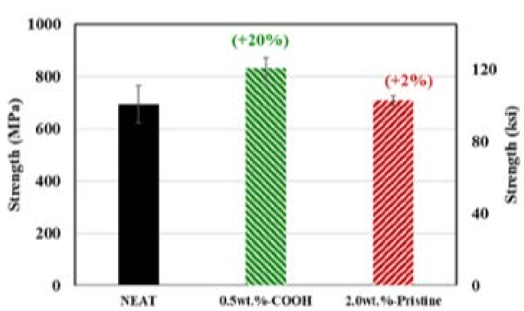

Figure 3. Direct tensile strength results of GFRP samples with and without MWCNTs.

It is evident that the strengthening scheme is completely dependent on the composite action of the composite strengthened section. To test the composite action, the team will conduct a full scale three-point bending test to examine the beam action for the composite section made from corrugated steel pipe, polymer grout and GFRP section. Upon working closely with the NMDOT engineers, a pipe with 14" in diameter was selected. The selected dimension of pipe was fabricated using filament winding using industrial partners Sewer Shields Composites as a cost share to the project. The GFRP pipes have an outer diameter of 14 in, a length of 7 ft, and a thickness of 0.5 in.

The team has fabricated a GFRP plate using wet layup technique with three layers of GFRP bidirectional plies. These samples were then cut into dog bone shaped samples and tested under direct tension as shown in Figure 4. Five samples have been tested under direct tension with fibers orientation in 0° and 45° direction following ASTM D3039.

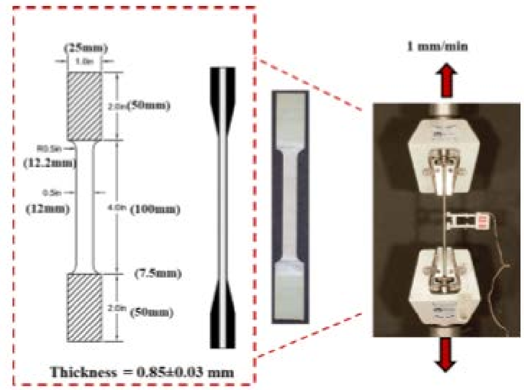

Figure 4. Experimental setup and sample dimensions for direct tension test.

Impacts

This study aims to develop and design a cost-effective technique for retrofitting corroded metal culverts using GFRP material. The proposed retrofitting technique shall enable extending the life expectancy of retrofitted metal culverts beyond 75 years. This current study will provide a detailed procedure for using GFRP to retrofit existing corroded metal culverts which can be implemented when necessary by other engineers. This research shall open ways of using GFRP material for the cost-efficient, reliable and durable system to repair and rehabilitate existing culverts. The results obtained from the study shall be reported to reputable academic journals which are accessible to industry and academic professionals

Tran-SET

Tran-SET is Region 6's University Transportation Center. It is a collaborative partnership between 11 institutions (see below) across 5 states (AR, LA, NM, OK, and TX). Tran-SET is led by Louisiana State University. It was established in late November 2016 "to address the accelerated deterioration of transportation infrastructure through the development, evaluation, and implementation of cutting-edge technologies, novel materials, and innovative construction management processes".

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