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Structural Polyurethane Foam Infill for Fiber Reinforced Polymer Bridge Deck Panels

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16. Abstract

Although still in their infancy, fiber reinforced polymer (FRP) bridges have shown great promise in eliminating corrosion concerns and providing bridges that meet or exceed the Federal Highway Administration's (FHWA) goal of 100-year life spans. Although cost effective in terms of life cycle analyses, first costs have limited the application of FRP bridges, as most state Departments of Transportation (DOTs) have limited funds to meet ever increasing demands. One area that has shown some headway is the use of FRP bridge decks, the location where the majority of corrosion-related damage normally occurs. However, first costs still hamper their widespread use. The ***objective*** of the proposed research was to develop, test, and evaluate fiber-reinforced, polyurethane foams to replace the costly honeycomb construction currently used to manufacture FRP bridge deck panels, thus making them more cost effective and a viable alternative to reinforced concrete.

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MRC Research Study

Structural Polyurethane Foam Infill for Fiber Reinforced Polymer Bridge Deck Panels

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Research Idea & Objective

Although still in their infancy, fiber reinforced polymer (FRP) bridges have shown great promise in eliminating corrosion concerns and providing bridges that meet or exceed the Federal Highway Administration's (FHWA) goal of 100-year life spans. Although cost effective in terms of life cycle analyses, first costs have limited the application of FRP bridges, as most state Departments of Transportation (DOTs) have limited funds to meet ever increasing demands. One area that has shown some headway is the use of FRP bridge decks, the location where the majority of corrosion-related damage normally occurs. However, first costs still hamper their widespread use.

The ***objective*** of the proposed research was to develop, test, and evaluate fiber-reinforced, polyurethane foams to replace the costly honeycomb construction currently used to manufacture FRP bridge deck panels, thus making them more cost effective and a viable alternative to reinforced concrete.

Brief Background

The deterioration of our nation's infrastructure is an almost daily news item that attracts passionate political, economic, and socio-economic discussions. One of the leading causes of this deterioration is the "bare roads policy" adopted by the majority of state highway agencies during the 1960's. This policy involves the application of deicing salts on state roads during winter months to reduce traffic accidents, injuries, and fatalities. Unfortunately, a negative side effect of this policy is that deicing salts attack the steel embedded in reinforced concrete bridges, leading to premature deterioration of the bridge. In 2001, an FHWA-sponsored study predicted that the U.S. will spend an estimated 8.3 billion dollars annually over the next ten years in an effort to repair or replace bridges exhibiting corrosion-related damage, with indirect costs exceeding 10 times that amount.

FRP composite bridge deck panels offer superior corrosion resistance at one-fifth the weight of reinforced concrete. However, current FRP bridge deck panels rely on an intricate geometric honeycomb system between the top and bottom layers of the sandwich panel. This labor-intensive honeycomb construction doubles the cost of FRP composite panels compared to reinforced concrete. Although cost effective in terms of longevity of the bridge and overall reductions in weight, the lower first cost of reinforced concrete precludes the use of FRP bridge decks in the majority of situations.

Closed-cell, high-density polyurethane foams offer a cost-effective alternative to the complex honeycomb construction currently used in FRP bridge deck panels. Structural sandwich panels with a polyurethane foam infill are commonly used in automobiles, aircraft, and prefabricated buildings. However, current foams do not possess the compressive strengths necessary to resist localized compressive stresses and fatigue loading beneath a truck wheel, even with a significant top layer of FRP.

Research Plan & Scope of Work

Broadly speaking, the ***research plan*** for this proposed study involved investigating alternative polyurethane foam formulations as potential candidates to replace the honeycomb construction currently used in FRP bridge deck panels. The purpose of this research was to serve as a proof-of-concept and to obtain preliminary data for proposals to both federal and state funding agencies including NSF, NCHRP, FHWA, and MoDOT.

The sandwich panels consisted of top and bottom structural surfaces separated by a polyurethane foam core. The structural surfaces were constructed from several layers of glass FRP with a total thickness of 3/8 in. Several polyurethane foam densities were tested. The research also examined glass fiber reinforcement for the polyurethane foams in order to increase compressive strength. The fibers measured either ¼- or ½-inch in length with application rates of 20 to 25 percent (by weight) based on preliminary testing. The target compressive strength for the project was 800 to 1000 psi at a deformation of 0.1 in.

The ***scope of work*** consisted of the following four tasks.

Task 1: Construct Specimens. This task involved construction of the sandwich panel specimens. The investigators first construct a steel mold to act as a form for the specimens. This mold helped maintain consistent specimens with parallel top and bottom surfaces. The mold also held the structural surfaces stationary during the foam injection process. The investigators then constructed specimens with different polyurethane foam densities and glass fiber reinforcements as discussed previously.

Task 2: Test Specimens in Compression. This task involved testing the sandwich panels in compression to failure. Testing was accomplished with the 200,000-lb servo-controlled Tinius-Olsen universal compression/tension machine located in Butler-Carlton Hall. This machine accommodated the necessary specimen size, which measured 6-inches-square in plan with a thickness of 6 inches. The loading rate was set at 3 psi/s, with failure based on a deformation of 0.1 inches.

Task 3: Test Specimens in Fatigue under Compression. This task was used to determine the fatigue compression properties of the polyurethane foam sandwich panels. Bridges are subjected to millions of cycles of loading during their lifetime. The polyurethane foam infill must be capable of resisting repeated loadings in compression without developing excessive permanent deformation. The American Association of State Highway Transportation Officials (AASHTO) specifies the design tire pressure as 125 psi. The composite panels were tested at a fatigue loading of four times that value, or 500 psi, which is consistent with load testing normally done for composite bridge members. Also based on AASHTO, the loading was based on a total of 2,000,000 cycles.

Task 4: Evaluate Performance of Polyurethane Foam Cores. This last task compared the results of the different formulations. In addition, the investigators forensically examined the specimens to determine the behavior of the foam core under both the compression and fatigue loadings.

Results

Results of the study indicated that polyurethane foam formulations can develop the necessary compressive strength properties to serve as replacement for the costly honeycomb structure currently used to construct FRP bridge decks. A foam density of 24 pcf and glass fiber content of 6% achieved a compressive strength of 1000 psi prior to cell wall collapse and 2,000,000 cycle fatigue loading without degradation. A photograph of the current honeycomb system and the successful polyurethane foam are shown in Fig. 1. The stress-indentation plot for the foam is shown in Fig. 2. A summary presentation slide submitted to MRC is shown on the following page.

(a) Current Honeycomb Structure (b) Polyurethane Foam Core Alternative

Fig. 1 FRP Bridge Deck Construction

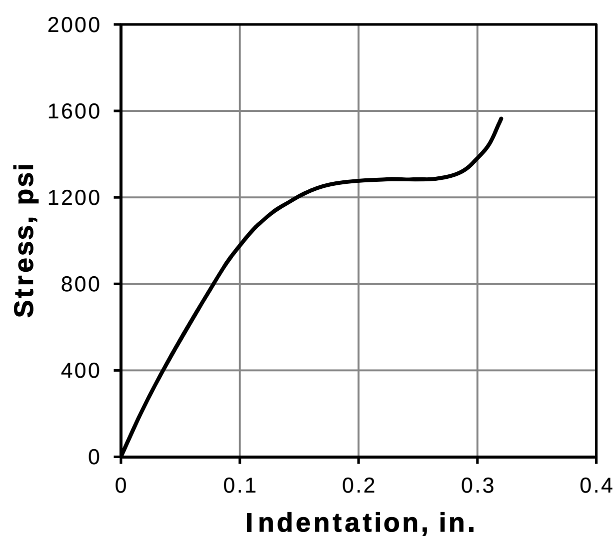

Fig. 2 Stress-Indentation Plot for Successful Polyurethane Foam

Structural Polyurethane Foam Infill for FRP Bridge Deck Panels

Research Objective –
Develop a polyurethane foam to replace the costly honeycomb structure currently used in FRP bridge decks.

Findings –
Foam density of 24 pcf and glass fiber content of 6% achieved compressive strength of 1000 psi prior to cell wall collapse and 2,000,000 cycle fatigue loading without degradation.

External Funding –
Successful MRC pilot study lead to a research statement submittal to MoDOT. MoDOT selected research idea for RFP release later this year with anticipated funding level of $180,000. NCHRP IDEA submittal planned for 2012 funding cycle.

Current Honeycomb System

Polyurethane Foam Alternative