Idea 134: Service Life and Performance Assessment of Bridge Decks with Corrosion-Resistant Reinforcement: Literature Search

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Resources searched: Transport Database, Research in Progress, ASCE Civil Engineering Database, MnDOT Library Catalog, Google.

Summary: Results are compiled from the databases named above. Links are provided for full-text, if applicable, or to the full record citation. I completed my searches using the following terminology: glass fiber reinforced polymer, glass fiber reinforced concrete, GFRP, bridge deck, service life, life span, life cycle. They are divided into most relevant and less relevant.

Most Relevant Results

Field Investigation of Bridge Deck Reinforced with Glass Fiber Reinforced Polymer Rebar.
http://rip.trb.org/view/1409277
Abstract: Minnesota Department of Transportation (MnDOT) is in the planning phases for its first glass fiber reinforced polymer (GFRP) reinforced bridge deck. Instead of using traditional steel rebar, the deck will be reinforced with GFRP rebar. The bridge deck is scheduled to be let in February 2016 with construction starting later in 2016. Successful implementation of GFRP reinforced bridge decks would eliminate the steel corrosion problems that often shorten the life of the deck.

Although there is wide use of GFRP reinforcement in bridge decks in Canada, there have been relatively few GFRP reinforced bridge decks built in the United States (US). The Canadian decks were primarily designed using the empirical design method in the Canadian Highway Bridge Design Code. This method differs significantly from the design guidelines produced by American Association of State Highway and Transportation Officials (AASHTO) and American Concrete Institute (ACI) Committee 440 on FRP Reinforcement.

To maximize the knowledge and experience gained in constructing this bridge deck, a research project should be undertaken to investigate the performance of this bridge deck. Some of the key issues to be studied include cracking and crack control, deck stiffness, and FRP bar strains. Design of these decks using the US guidelines is almost always controlled by the crack control provisions, so monitoring cracking and bar stresses may allow less conservative designs in the future. The modulus of elasticity of GFRP bars is about one quart of that of steel bars, so deck deflection may also be of interest.

Title: AASHTO LRFD bridge design guide specifications for GFRP-reinforced concrete bridge decks and traffic railings.
Title: Development length of GFRP reinforcement in concrete bridge decks / prepared by Joe P. Hanus, Carol K. Shield, Catherine W. French.

Publisher: St. Paul, Minn. : Minnesota Dept. of Transportation, Office of Research Services ; [Springfield, Va. : Available through the National Technical Information Services, 2000]


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**Title:** Life Cycle Comparison of Steel and GFRP Reinforced Concrete Bridge Deck Designs in the Context of Uncertainty.

**Author:** Christensen Paul N; Sparks Gordon A; Tadros Gamil; Lau Mike; Eden Ruth J

**Source:** Conference Title: 2008 Concrete Bridge Conference. Location: St. Louis. Sponsored by: Federal Highway Administration. Held: 20080504-20080507. 2008. 11p (5 Figs., 6 Refs., 1 Tabs.)

**Abstract:** Four competing bridge deck designs are compared on the basis of life cycle costs (LCC). Two of the designs are reinforced with steel. The remaining two are reinforced with glass fiber reinforced polymers (GFRP). Typical of Canadian prairie environments, the decks will face periodic exposure to deicing salts - a factor influencing both the designs and projected maintenance needs. Combining the resulting stream of costs over a 100-year service life and required rate of discount permits the computation of Present Worth LCC (PWLCC) for comparative purposes. Uncertainty in performance and other variables is captured through a systematic integration of sensitivity and risk analyses to produce expected value results and corresponding risk profiles. The results will aid the Manitoba Department of Infrastructure and Transportation select deck designs for two upcoming bridge projects.

**Publication Year:** 2008

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**Title:** Durability in a Salt Solution of Pultruded Composite Materials Used in Structural Sections for Bridge Deck Applications.

**Author:** Fam Amir; Boles Raouf; Robert Mathieu

**Source:** Journal of Bridge Engineering. 2015/5. Content ID 04015032 (Refs.)

**URL:** [http://dx.doi.org/10.1061/(ASCE)BE.1943-5592.0000768](http://dx.doi.org/10.1061/(ASCE)BE.1943-5592.0000768)

**Abstract:** This study addresses the durability of glass fiber-reinforced polymer (GFRP) pultruded structural sections used in bridge-deck applications, namely, a flat plate with T-shaped ribs (R-GFRP) and a corrugated plate (C-GFRP). Standard coupons were aged for up to 224 days at 23, 40, and 55 degrees C in separate baths of 3% salt solutions simulating deicing conditions. The tensile-strength retentions and Young's moduli were measured periodically. Data were assessed using ANOVA. Microstructure assessments using differential scanning calorimetry, Fourier transform infrared spectroscopy, and scanning electron
microscopy were carried out to provide additional assessment of degradation. It was shown that after 224 days, the tensile strength retentions of the R-GFRP and C-GFRP were similar, and that they decreased from 77 to 63% as the temperature increased from 23 to 55 degrees C. The observed reductions were confirmed by micrographs showing some surface cracks and separations between the fibers and the matrix, but results also showed that the polymer matrix was not fully degraded by the hydrolysis because no significant changes occurred in the glass transition temperature after exposure. When data were fitted in the Arrhenius service-life model, it showed that after 100 years, R-GFRP will suffer more deterioration than C-GFRP because the strength retentions at a location with annual mean temperatures of 10 degrees C were 42 and 61%, respectively.

**Publication Year** 2015

**Title** GFRP Bridge Deck Panel.

**Author** Vovesny M; Rotter T

**Source** Conference Title: 23rd Czech and Slovak International Conference on Steel Structures and Bridges 2012. Location: Podbanske. Held: 20120926-20120928. Procedia Engineering. 2012. 40(0) pp 492-497 (Figs., Photos., Refs., Tabs.)

**URL** http://dx.doi.org/10.1016/j.proeng.2012.07.131

**Abstract** The aim of the research is design and analysis of new bridge deck panel made of glass fiber reinforced polymer (GFRP). Use of GFRP in construction is rapidly growing in the last few years. The reason for use GFRP is its low self weight in compare of strength and high resistance against weather influenced degradation resulting in long life. Using GFRP for the construction of the bridge deck leads to lightweight construction that can pass the required wheel load. Lightweight design is appreciated for a temporary bridge which is expected to be transported and assembled often on places of current need. Long durability and resistance against weather degradation also reduces maintenance costs of the bridge deck. Design of the deck panel will be done on the base of loading experiments and finite element method (FEM) analysis. The main use of GFRP bridge deck panel is for a temporary bridge but it is possible to extend its use on permanent or movable bridges.

**Publication Year** 2012

**Title** FRP Rebar in Bridge Decks for Greater Deck Longevity.

**Author** Gremel Doug; Koch Ryan
Abstract
A principle failure mechanism in bridge decks is corrosion of the steel reinforcing, caused by exposure to chlorides. GFRP (Glass Fiber Reinforced Polymer) rebar is inert to the chemical attack of the chlorides and therefore a perfect substitute for the steel rebar. The result will be a longer lasting, more durable bridge structure. GFRP Rebar continues to gain wider acceptance, due largely to the availability of standardized documents and the excellent performance of research bridges. ACI has developed guidelines for design (ACI 440.1R-06), test methods (ACI 440.3R-04), material specifications and construction specifications. ASTM standardized test methods (ASTM D7205 series) define guaranteed material properties for the designer. In Canada, the Canadian Highway Bridge Design Code includes provisions (section 16) for the standardized use of GFRP Rebar. As a result, many bridge structures are being routinely constructed with GFRP rebar in Canada. AASHTO committee T6 is currently working on documents of a similar nature. The use of GFRP rebar offers the benefit of an extended bridge service life using traditional design methodologies, based on consensus standards, verification of material properties, 'open' procurement methods with multiple bidders for the supply of the GFRP bars, and field installation and quality control oversight practices that are very similar to those used today at a first cost to the bridge owner that is something less than 5% of today's costs. Details of the largest GFRP reinforced bridge structure built to date will be described. The Floodway bridge, near Winnipeg Canada, is a two bridge structure with two lanes each consisting of eight spans of 142 feet each for a total length of bridge deck of 2272 feet.
instrumented with electrical resistance strain gauges and fiber-optic sensors at critical locations to record internal strain data. Also, the bridge was tested for service performance using calibrated truckloads. Design concepts, construction details, and results of the first series of live load field tests are presented.

**Publication Year** 2007

**Title** CONCRETE BRIDGE DECKS REINFORCED WITH FIBER-REINFORCED POLYMER BARS (WITH DISCUSSION AND CLOSURE).

**Author** Bradberry T E

**Source** Transportation Research Record. 2001. (1770) p. 94-104 (2 Phot., 23 Refs., 5 Tabs.)

**URL** [http://dx.doi.org/10.3141/1770-13](http://dx.doi.org/10.3141/1770-13)

**Abstract** Corrosion of metallic reinforcement is a primary cause of reinforced concrete bridge deck deterioration. A potential innovative solution to this problem is to eliminate this corrosion by using nonmetallic fiber-reinforced polymer (FRP) bars. FRP bars consist of continuous fibers of glass (GFRP), aramid (AFRP), carbon (CFRP), or a combination of these (hybrid FRP), impregnated with and bound by a resin matrix through a pultrusion, braiding, or weaving manufacturing process. Each of these fiber types is linearly elastic to failure. Characteristics of FRP bars include electrochemical inertness, high tensile strength, low weight, low elastic modulus (primarily GFRP and AFRP), and low shear strength. For increased bridge deck service life, electrochemical inertness is the most important characteristic of FRP bars. The structural design of a concrete bridge deck with FRP top mat reinforcement is presented. The deck is supported on five prestressed concrete Type C beams. The 200-mm (8-in.) nominal-depth deck is designed for self-weight, bridge rails, overlay, MS18 (HS20) wheel loads, and bridge rail impact loads. The continuous beam analysis with distribution of force effect is based on AASHTO distribution formulas. The discussion includes required flexural strength, limits on calculated crack width, FRP bar bond stress characteristics, durability, and shear strength of the concrete deck reinforced with embedded FRP bars.

**Publication Year** 2001

**Least Relevant Results**

**Title** Health Monitoring of Precast Bridge Deck Panels Reinforced with Glass Fiber Reinforced Polymer Bars.

**Author** Pantelides Chris P; Holden Korin M; Ries James

**Source** Title on cover page reads: Health Monitoring of Precast Bridge Deck Panels Reinforced with Glass Fiber Reinforced Polymer (GFRP) Bars
The present research project investigates monitoring concrete precast panels for bridge decks that are reinforced with Glass Fiber Reinforced Polymer (GFRP) bars. Due to the lack of long term research on concrete members reinforced with GFRP bars, long term health monitoring is important to record the performance and limit states of the GFRP decks and bridge as a whole. In this research, data is collected on concrete strains, bridge deflections, vertical girder accelerations, as well as initial truck load testing and lifting strains.

Publication Year 2012

Title Evaluation of FRP Posttensioned Slab Bridge Strips Using AASHTO-LRFD Bridge Design Specifications.

Author Noel Martin; Soudki Khaled

Source Journal of Bridge Engineering. 2011/11/1. 16(6) pp 839-846 (5 Figs., 4 Photos., 15 Refs., 6 Tabs.)

URL http://dx.doi.org/10.1061/(ASCE)BE.1943-5592.0000226

Abstract Deterioration of concrete structures caused by corrosion of steel reinforcement requires large capital investments in order to repair or replace existing structures which may or may not be nearing the end of their expected service lives. Fiber-reinforced polymer (FRP) reinforcement has emerged as a viable alternative to conventional reinforcement with lower life cycle costs. Serviceability typically governs the design of FRP structures because of the inherent low stiffness of FRP materials. As a result, concrete members tend to exhibit high deflections, large crack widths, and a reduction in shear capacity compared to similar steel-reinforced members. This study focuses on glass fiber-reinforced polymer (GFRP) reinforced slab strips cast with self-consolidating concrete (SCC) and posttensioned with carbon fiber-reinforced polymer (CFRP) tendons to improve the serviceability, shear capacity, and deformability of slab bridges. The flexural performance of five FRP slabs and one steel-reinforced control slab are compared to the design provisions of the AASHTO Load and Resistance Factor Design (LRFD) Bridge Design Specifications.

Publication Year 2011

Title EVALUATION OF THE MAGAZINE DITCH BRIDGE.

Author Chajes M J; Shenton H W; Gillespie J W; Mertz D R; Fagan P

Source 2001/4. 105 p. (2 Apps.)

Abstract In June of 1997, the Delaware River and Bay Authority (DRBA) built a revolutionary bridge made using advanced polymer composites. The 70-foot
long, single-span bridge spans Magazine Ditch and replaces an existing two span concrete box-beam structure. The superstructure of the bridge consists of a high strength, lightweight, glass fiber reinforced polymer (GFRP) composite deck that is supported by two post-tensioned concrete edge girders. Because of the unique nature of this structure, the University of Delaware was contracted to perform field load tests of the bridge in order to assess its as-built condition, and to establish a baseline against which future performance can be compared in order to evaluate long-term performance and durability. The University also was responsible for developing and installing a long-term "health" monitoring system that will permit ongoing monitoring of the bridge well into the future. The report presents the results of the field load testing and the details and performance of the long-term monitoring system. Based on the load tests, the performance of the bridge has been found to be excellent. The inventory load rating for the bridge deck when carrying only one lane of traffic is around 5 for either heavily loaded DRBA dump trucks that cross the bridge or the standard HS20-44 highway design truck (an inventory rating of 1 means adequate, i.e., an acceptable factor of safety against failure). Overall, the bridge is performing as designed, and is expected to meet the 75-year service life criteria.

Publication Year 2001

Title Manitoba's FRP Experiences.

Author EDEN,R; ELKHOLY,I; HAMILTON,G


Abstract Many Canadian jurisdictions are faced with the challenge of managing an aging and deteriorating infrastructure with limited funding. As a means of providing optimal service for the user, not only in the present but also in the future, many are investigating the potential use of new and innovative designs and technologies. The Province of Manitoba, the City of Winnipeg, consulting engineering firms, and contractors have partnered with ISIS Canada, Intelligent Sensing for Innovative Structures - A Canadian Network of Centers of Excellence, to develop and take advantage of this emerging technology for application in bridges and structures. The Province of Manitoba has been actively involved with ISIS Canada through the sponsorship of research and demonstration projects for several bridges (Taylor Bridge, Shell River Bridge, Red River Bridge on the North Perimeter Highway, Tourond Creek Bridge). For example, the Taylor Bridge, constructed in 1997, incorporated fibre reinforced polymers (FRP) as pre-stressing strand and reinforcement in four of the forty concrete I-girders, and as reinforcement in a portion of the concrete deck and concrete barrier wall. Fibre optic sensors were also cast into the structure, which led to the nickname The Smart Bridge. Furthermore, the use of FRP reinforcement has been planned for a number of concrete deck reconstruction projects and the strengthening of concrete pier columns. In addition, the
Province of Manitoba, with an inventory of over 720 timber bridges, requires an effective and economical method to strengthen the timber bridges and extend their service life rather than costly replacement. Current research is focusing on developing a methodology to strengthen timber bridge stringers using glass fibre reinforced polymers (GFRP). Another area of research, currently under consideration, is the application of steel-free concrete bridge deck technology.

For the covering abstract of this conference see ITRD number E211271.

Publication Year

2002

Title

ADVANCED COMPOSITE MATERIALS IN THE HEADINGLEY BRIDGE.

Author

STEWART,D; HALLDANE WILSONE,R

Source


Abstract

This paper was presented at the 'Advanced Materials' session. The implementation of advanced composite materials (ACM) for use in the construction of prestressed concrete highway bridges is currently being applied to the design of a new prestressed concrete highway bridge over the Assiniboine River on Provincial Road No. 334 at the Town of Headingley, Manitoba. The Headingley Bridge project includes the introduction of new design and material concepts to the construction of precast concrete highway bridges. These concepts are summarized below: use of CFRP prestressing strands, instead of conventional steel strands, in four girders; use of CFRP reinforcement as stirrups for the shear reinforcement for two girders as the shear connectors for the interface shear between the girders and the bridge deck; use of GFRP reinforcing rods to reinforce a portion of the concrete shoulder traffic barrier; and implementation of the latest in laser/fibre-optic sensing technology to monitor the performance of the bridge during construction and throughout its service life, essentially making the bridge a "smart" structure. This will be the first bridge in Canada to use ACM's for the prestressing strands, as well as the shear reinforcement. The overall objective of this project is to study the durability of a concrete bridge utilizing ACM reinforcement and to monitor effects of overload vehicles on the bridge. For the covering abstract of this conference see IRRD number 872812. (A)

Publication Year

1996