Literature Review on Hybrid Composite Beam

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Abstract— The use of "Hybrid-Composite Beam" or HCB, in the field of bridge engineering, gained a lot of attention The HCB is made up of three main sub-components that are a composite shell, compression reinforcement, and tension reinforcement. The basic principle of HCB is it combines the strength and stiffness of conventional concrete and steel with the corrosion resistant and lightweight characteristics of advanced composite materials. Only a limited number of researchers have studied in HCB for its essential design methodologies and long-term performance.

Key words: Hybrid composite beam, Compression reinforcement, Tension reinforcement

I. INTRODUCTION

FRP composites play a major role in bridge engineering which significantly shows the increase in lifetimes of bridges. These composites favorable characteristics like(e.g. Good durability, transparency to electromagnetic radiation, and low-to-moderate tool costs high strength-to-weight ratio, corrosion resistance, dimensional stability) making them a solution for rectifying a number of problems like corrosion and deterioration of structures. The high initial cost of FRP when compared to traditional concrete and steel members can be solved only by its large manufacturing.

The underlying concept behind HCB was first introduced by Hillman[1996], supposed that if a scc arch tied at the ends and incorporated into a composite shell, then the resulting structural system would become lightweight , strong and corrosion resistant. The HCB is made up of three main sub-components that are a composite shell, compression reinforcement, and tension reinforcement. The shell mainly comprises a glass fiber reinforced polymer (FRP) box beam. The compression reinforcement consists of concrete which is pumped into a profiled conduit (generally an arch) within the beam shell. The tension reinforcement of HCB consists of carbon, glass or more typically, steel fibers anchored at the ends of the compression reinforcement. The concrete and steel are inserted into a gfrp shell which is durable and protect the materials from the effect of the environment. The void space between the components are filled by a polyisocyanurate foam.

As noted previously the classical arch profile of the compression reinforcement requires only less quantity of concrete thereby reducing production of greenhouse gasses and the arch profile as a structural frame giving an opportunity for carrying to shear. This unique configuration of HCB that combines conventional materials into FRP components creates a new structural member that utilizes the advantages of each material employed in HCB in such a manner as to making a new structural solution to bridge engineering.

II. LITERATURE SURVEY

A. Mohamed A. Aboelseoud, and John J. Myers, "Durability of Hybrid Composite Beam Bridges Subjected to Various Environmental Conditioning", American Society of Civil Engineers, ISSN 1090-0268, April 25, 2016

This study examined the durability of a commercial glass FRP (GFRP) laminate that was used to encase the HCB elements in a recently constructed HCB bridge. The E-glass/vinyl ester laminate was subjected to five aging regimes. The durability of the E-glass/vinyl ester laminate was examined in terms of changes that occurred in the ultimate tensile strength. A microstructural analysis was performed on both unconditioned and conditioned specimens via optical microscopy (OM), scanning electron microscopy (SEM), energy-dispersive X-ray (EDX) analysis and Fourier transform infrared (FTIR) spectroscopy. The microstructural analysis revealed that the hydroxide and chloride ions penetrated the laminate through the existing voids and cracks without causing hydrolysis to the vinyl ester resin. The mechanical testing and the microstructural analysis provided fundamental insight into the durability and stress corrosion mechanisms of the examined GFRP shell under different environmental effects. This information is valuable to enhance the GFRP shell's durability. [1]

B. Mohamed A. Aboelseoud1 and John J. Myers, "Finite-Element Modeling of Hybrid Composite Beam Bridges in Missouri", American Society of Civil Engineers, May 5, 2014, ISSN 1084-0702.

FE modeling of the superstructure of one of the recently constructed HCB bridges, using two commercial FEA packages is focussed on this paper. A field load test that produces several load cases were applied to the bridge, and the deflections of the HCBs were founded at different locations. Then the measured deflections and predicted deflections compared which show that the FEA can predict the HCB bridge behavior with acceptable accuracy, whereas the theoretical procedure of HCB significantly overestimates the beams deflections. Finally, the two FE models are used to analyze the behavior of the HCBs.

C. Mohamed Husain, Khaled Fawzy, and Ahmed Nada, "Performance of prestressed concrete beam with FRP tendons "International Journal of Engineering and Innovative Technology (IJEIT), Volume 5, Issue 2, August 2015, pp.22- 29

The purpose of this research study is to assess the effects of some structural parameters on the behavior of prestressed concrete bridges with FRP prestressing tendons by using Three-dimensional nonlinear finite element method (3D-NL-FEM). A certain number of models of prestressed concrete bridge tensioned with FRP cables subject to four-point load system have been modeled and structurally analyzed on (ANSYS, 2013). In order to examine the effects of prestressing reinforcement ratio, concrete compressive strength, and level of initial prestressing on the behavior a parametric study was conducted. carbon fiber (CFRP), aramid fiber (AFRP), and glass fiber (GFRP) were used as prestressing cables.It was concluded that all the studied parameters affect the strength capacity, ductility and failure modes of the FRP-prestressed beam models.

D. Mohamed a. Aboelseoud1 and john j. Myers," Effects of environmental exposure to hybrid composite beam (hcb) bridges", a 23rd Australasian conference on the mechanics of structures and materials (acmsm23) , vol. II,9-12 December 2014,pp. 651-656

This research work examined the durability of a commercial gfrp laminate used to encase the hcb elements in one of the recently constructed bridges. The thermal cycling consisted of 50 freeze-thaw cycles that simulated the winter season effects. Then, the summer season effects were simulated by alternating groups of 50 high-temperature cycles and 50 high relative humidity cycles for a total of 150 cycles each. The results of this study demonstrated that the gfrp shell, and subsequently the hcb as a whole, has excellent durability in relation to the expected weathering exposures in the midwest united states[4].

E. Devin K. Harris and Amir Gheitasi,"Field Testing And Numerical Modeling Of A Hybrid Composite Beam Bridge In Virginia".

This paper focuses on evaluating the in-service performance of a newly constructed HCB bridge superstructure located on Route 205 in Colonial Beach, Virginia. A live load test was conducted using tandem axle dump trucks under both quasi-static and dynamic conditions. Results obtained from the experimental study were used to find out three key behavior characteristics. Dynamic amplification and lateral load distribution were found from the investigation to be reasonable in comparison to the assumed design values. The testing program conducted also included internal and external measurement systems to help characterize the load sharing behavior of the HCB on an element level. The main load carrying elements of hcb are the deck in compression and the steel ties in tension, and the FRP shell did not act compositely with the internal components.

F. Amir Gheitasi Mark Saliba John M. Civitillo, "In-Service Performance, And Behavior Characterization of the Hybrid Composite Bridge System – A Case Study", 9th International Conference on Short and Medium Span Bridges, July 2014, pp.1-10

This paper focuses on evaluating the in-service performance of a newly constructed HCB bridge superstructure located on Route 205 in ColonialBeach, Virginia. By using tandem axle dump trucks under both quasi-static and dynamic conditions, a live load test was conducted. Results obtained from the experimental investigation were used to determine three key behavior characteristics. Dynamic amplification and lateral load distribution were found from the investigation to be reasonable in comparison to the assumed design values. The testing program conducted also included internal and external measurement systems to help characterize the load sharing behavior of the HCB on an element level. The main load carrying elements of hcb are the deck in compression and the steel ties in tension, and the FRP shell did not act compositely with the internal components.

G. C.R. Earley, M.A. Abeol Seoud, J.J. Myers," Early-Age Behavior and Construction Sequencing of Hybrid Composite Beam (HCB) Bridges in Missouri", USA, June 2013.

These research work objectives include the bridge in-situ structural behavior evaluation to confirm design assumptions, the development of a quality control/quality assurance testing of the bridge members, and the evaluation of potential serviceability and maintenance challenges[7]. To make easier this, beam elements had been instrumented with various sensors available.This paper focuses on the early-age behavior of the HCB elements during fabrication. it also describes the fabrication and construction process and sequencing.

H. Renee Earley, M.A. Abeol Seoud, J.J. Myers," In-Situ Load Testing Results Of Hybrid Composite Beam Bridges In Missouri, USA," The 7th International Conference on FRP Composites in Civil Engineering International Institute for FRP in Construction, August 2014.

This research studies the structural behavior and the flexural design assumptions and methodology of this new type of beams. The filler material (polyiso foam) that is used to fill the voids of the HCB are found to produce partial composite action between its different elements and cause differential displacement between them. Consequently, the assumption of this current study that, the different components of HCB at the same level have equal strains, is not valid. However, the current design methodology overestimates significantly the tensile stresses in the different elements of the girder and leads always to very conservative design due to ignoring some factors.For future developing a new design algorithm that overcomes the flaws in the existing procedure is recommended.

I. Ying Shan and Kin Liao,"Environmental fatigue behavior and life prediction of unidirectional glass–carbon/epoxy hybrid composites", International Journal of Fatigue, *August 2002*, Volume 24, Issue 8, *pp.847–859*

In this study unidirectional glass fiber reinforced and glass–carbon fiber reinforced epoxy matrix composite specimens were subjected to tension–tension fatigue in the air and in distilled water at 25 °c. While no significant change in fatigue life was observed for both types of specimens tested in the air and in water when cyclically tested at 85% of average ultimate tensile strength (us), the detrimental effect of water becomes apparent to lower stress levels of 65 and 45% cuts. Compared to specimens tested in the air, cyclic loading with water results from shorter fatigue lives for both glass and hybrid specimens. While all of the glass fiber specimens did not survive to 106 cycles when cyclically loaded in water, hybrid specimens (with 25% carbon fiber (by volume), 75% glass fiber (by volume), 30% total fiber volume fraction) showed better retention in structural integrity under environmental fatigue, for fatigue lives up to 107 cycles, a consequence of the corrosion resistant of carbon fiber. Thus it is shown, by incorporating appropriate amount of carbon fibers in glass fiber composite, a much better performance in fatigue can be achieved for glass–carbon hybrid composite [9] .

J. Keller and Thomas,"Overview of Fibre-Reinforced Polymers in Bridge Construction", Structural Engineering International, *Volume 12, May 2002, pp. 66-70.*

The use of fibre-reinforced polymers (FRP) as structural elements in bridge construction has been a marked increase recent years .The main reason behind this are the advantageous properties of these materials, such as the possibility of producing any shape, their high resistance to corrosion and fatigue, and easy maintenance, low self-weight combined with high strength. With this background the Swiss Federal Roads Authority commissioned the Composite Construction Laboratory (CCLab) of the Swiss Federal Institute of Technology in Lausanne, with the preparation of a state-of-the-art report on the use of fibre-reinforced polymers in bridge construction and also to elaborate recommendations for application and research[10]. This paper summarizes the review which explains the improvement until the end of the year 2000.

III. Findings

The use of "Hybrid-Composite Beam" or HCB, in the field of bridge engineering, gained lots of attention The HCB is made up of three main sub-components that are a composite shell, compression reinforcement, and tension reinforcement.The shell mainly comprises a glass fiber reinforced polymer (FRP) box beam. The compression reinforcement consists of concrete which is pumped into a profiled conduit (generally an arch) within the beam shell. The tension reinforcement of HCB consists of carbon, glass or more typically, steel fibers anchored at the ends of the compression reinforcement. The basic principle of HCB is it combines the strength and stiffness of conventional concrete and steel with the corrosion resistant and lightweight characteristics of advanced composite materials. Only a limited number of researchers have studied in HCB. For its essential design methodologies and long-term performance

IV. Conclusion

From this literature survey of of HCB, we can can conclude that HCB 's contributions as a structural system to bridge engineering allows the bridge construction professionals to build stable structures which is costing favourable .

HCB combines the strength and stiffness of traditional concrete and steel with the lightweight and corrosion resistant advantages of fiber reinforced polymers (FRP).

Since HCB makes a different configuration of composite shell, tension reinforcement, compression reinforcement which in turn results less amount of carbon foot print required for the production of these materials.

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