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Experimental and Analytical Investigation of Fibre Reinforced Polymer (FRP) Bridge Deck Structures

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Abstract: FRP (Fiber Reinforced Polymer) bridge deck structure has more significance when they are compared with the conventional bridge structures. When these structures are compared with the conventional bridge structures it is found that FRP Structures perform better in various functions such as light weight, high durability, strength, high stiffness and can be easily install. As far as loading criteria is concerned, FRP bridge deck structures undergo two types of loading namely static and dynamic loading.

The construction of FRP bridges are on large scale nowadays in various countries, therefore it is necessary to construct such bridges in India. Although the initial cost of FRP bridges is high but their technical parameters are more beneficial as compared to conventional bridges. The aim is to investigate the behaviour of FRP bridge deck panel by using Finite Element Analysis (FEA). To calculate deflection by experimental analysis between FRP bridge deck panels by adding FRP and conventional deck panels. To compare stresses and deflections of FRP bridge deck panel and conventional panel.

Keywords: Fibre Reinforced Polymer (FRP), bridge deck panels, static loading, stress and deflection, Finite Element Analysis (FEA).

I. INTRODUCTION

Fibre Reinforced Polymers (FRP) applications in construction of bridge have firstly started for strengthening of existing concrete bridges (carbon fibre reinforced polymer lamellas). Subsequently, reinforcing bars of FRP were employed in production of „steel free‟ concrete decks in to avoid corrosion problems. The following move was to deliver connect decks made completely of fiber strengthened polymer composites.

The essential reason of FRP materials being advantageous for use in pedestrian decks has the qualities of light weight and high strength to protect it from corrosion. A major number of walker spans have been worked as 'every composite' connect where all the bridge segments are made of FRP materials. While the in all likelihood utilization of FRP materials in street spans is FRP decks over for the most part steel braces.

These days, various street spans are named fundamentally insufficient or practically out of date due to disintegrated basic parts or low load carrying capacity. Generally the fundamental load carrying capacity of individuals from these bridges is in great condition while the deck framework is deteriorated. Deterioration of bridges decks, which regularly are made of reinforced concrete, is for the most part brought about by corrosion of the support steel because of salts deposition. By and large, decay of concrete bridges happens before these bridges achieve their plan design service life.

II. FRP DECK IN STRUCTURAL PERFORMANCE

The properties and behaviour of FRP decks depend on several factors for example the constituent materials of the composite material, direction of the fibres, the method of manufacture, the cross-sectional geometry and the adhesives used for the deck component joints.

Fibres are usually aligned in $0/90^0$ to carry longitudinal and transverse loads respectively, and $\pm 45^0$ to carry shear loads. The optimization of fibre orientations in the design of financially available FRP decks is well done and modifications on the fibre directions would not result in extreme changes of the material properties.

On the other hand, the cross-section configuration can have a great effect on the decks‟ properties and behaviour. The unidirectional configuration of the pultruded decks gives the deck mainly unidirectional load-carrying behaviour (in the direction of the pultrusion), whereas sandwich decks display a bi-directional load-carrying behaviour. The bi-directional behaviour is more favourable with regard to concentrated wheel loads.

The concentrated wheel loads induce localized flexure of FRP decks, which need to be considered carefully in the design in order to avoid cracking of the wear surface.

III. METHODOLOGY

The method to realize the objectives is based on outcome of the literature study and analysis of upgrading a FRP model of bridge deck. Numerical analyses by means of finite element modeling were utilized to assess the overall structural behaviour and load carrying capacity of the bridge under different load effects. Some simple analytical analyses were done mostly to design the deck of FRP bridge. The general organization of the study is illustrated below.

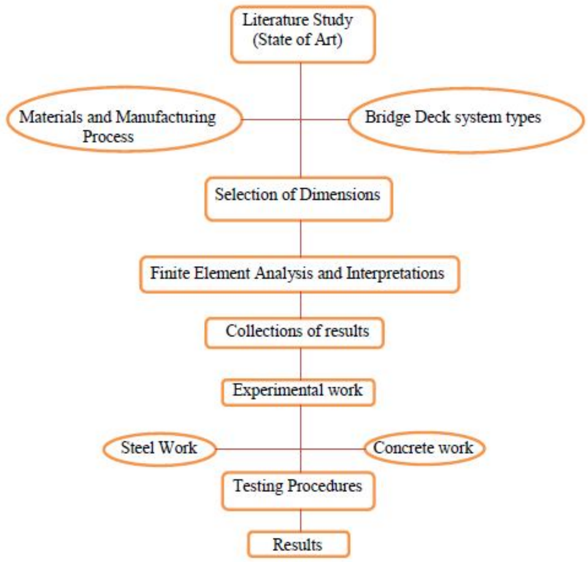

Fig.1. Organization and method of study

IV. EXPERIMENTAL SETUP

The dimensions of the panels are 625 x 167 x 75(mm). Six deck panels are casted out of which three panels are of conventional type and other three are of FRP type. After casting of deck panels they are allowed to cure in water for 28 days to ensure strength. All the salt depositions and foreign particles are removed or cleaned and are tested for static loading to find the deflection in Universal Testing Machine (UTM). Three decks are coated with Glass Fiber Reinforced Polymer (GFRP) on the layer which is exposed to vehicles with proper adhesives. Proper reinforcement and specific cover will be provided to the deck panels to ensure safety and strength criteria. Laying of FRP sheet layer over the deck panel will help to increase the strength, ductility, resistance to corrosion, stiffness and other mechanical properties. Analytical finding of forces and moments, stresses and strains are calculated by using software. Cubes are also casted to check the strength for M-40 concrete mix design proportion by using IS code 10262:2009 and 456:2000.

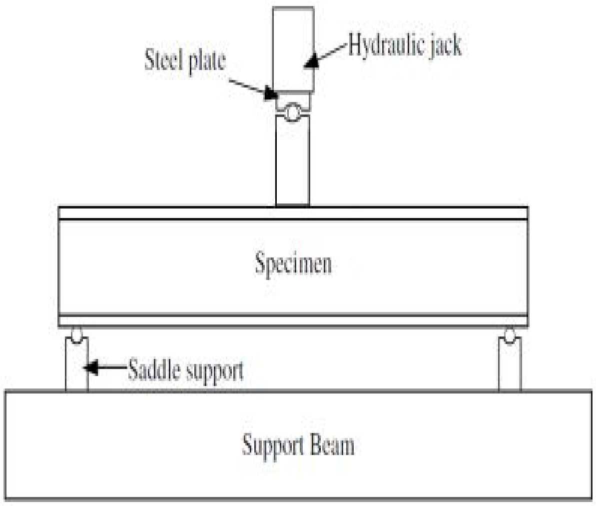

Fig.2. Schematic Single Point Bending Setup

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V. FIBER REINFORCED POLYMER (FRP) USED

Fibre reinforced polymer material is a combination of polymer resins, acting as a binder, with strong and stiff fibres which act as a reinforcement. The FRP used is glass FRP (GFRP) which is made up of glass particles weaven in proper pattern. The diameter of the GFRP is in microns which do not allow water to enter to the concrete specimen so far. GFRP is first in the mat form which also has the flexibility so that it can be wrapped on the specimen and later after the chemical process it is hardened. To make the glass mat strong and stiff it is reinforced with fibre under certain chemical process. When the chemical process is undergoing, the glass fibre achieved enough strength. GFRP can be transparent and also available in green, red and other colour.

After the process the glass mat gets combined with the fibre forming GFRP. The thickness of glass FRP varies from 1mm to 4mm. The thickness of GFRP used for the laying up process was 2mm having an angle of ±45o. As long as the thickness of GFRP increases it also help to increase the strength and make it stiff.

Properties	Glass FRP
Density (kg/m3)	2500
Modulus of elasticity (GPa)	90
Tensile Strength (MPa)	4500
Safety factor for static design	1.4
Thickness	2mm

Fig.3. Glass mat and Glass Fibre Reinforced Polymer (GFRP)

VI. PAGE STYLE EPOXY ADHESIVE USED

Araldite standard epoxy adhesive is used for placing to GFRP sheet over the deck panels. It consists of two tubes i.e. one is resin which is water clear liquid and another is hardener which is in Light yellow liquid. These adhesive are allowed to mix with one another and applied on the GFRP sheets to have better bonding with the deck panels. To get better bonding strength the epoxy adhesive is allowed to dry.

Fig.4. Standard epoxy adhesive

VII. MODELLING AND VALIDATION OF SOFTWARE

In this chapter, finite element modeling of FRP deck along with the conventional deck panels in ANSYS APDL R17.1 software is explained. Important points in FEA are discussed and steps for modeling are illustrated in brief. The detailed procedure of FEA of FRP deck along with the conventional deck panels by ANSYS APDL R17.1 is given below. Results are obtained for displacement at ultimate load of FRP deck panels and conventional deck panels.

ANSYS APDL R17.1 is finite-element analysis software. ANSYS APDL R17.1 provides a pre-processing and post processing environment for the analysis of models. It is used in a wide range of industries like automotive, aerospace etc., and is extensively used in academic and research institutions due to its capability to address non-linear problems. The ANSYS APDL R17.1 interface is show below.

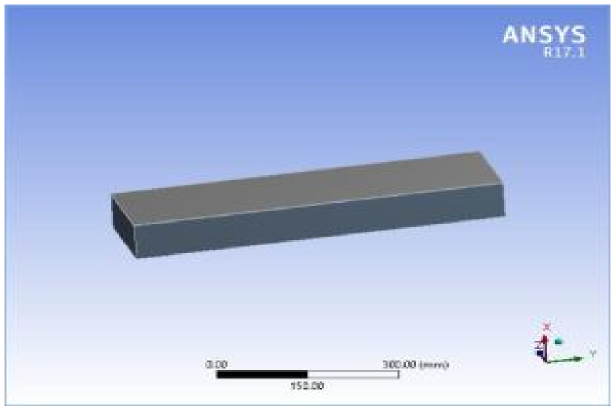

Fig.5. Sample of deck panels in ANSYS

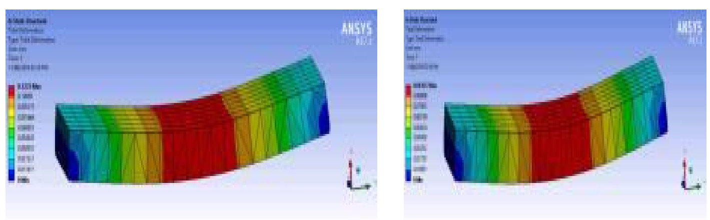

Fig.6. Analysis of FRP Panel-1and 2 in ANSYS

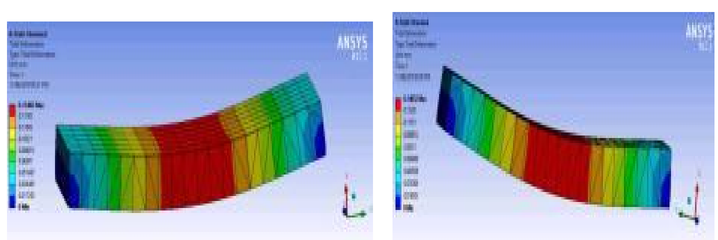

Fig.7. Analysis of FRP Panel-3 and Conventional Panel-1 in ANSYS

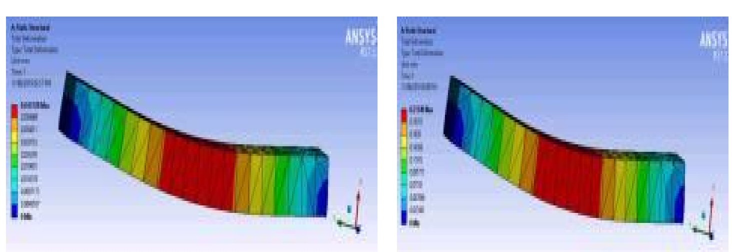

Fig.8. Analysis of Conventional Panel-2 and 3 in ANSYS

VIII. RESULTS

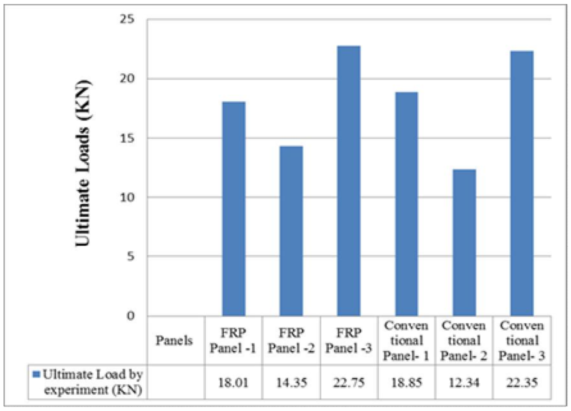

Fig.9. Ultimate loads on all panels

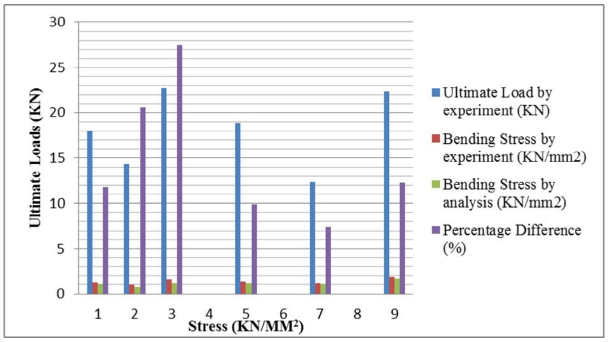

Fig.10. Comparison of bending stress by experiment and analysis of all panels

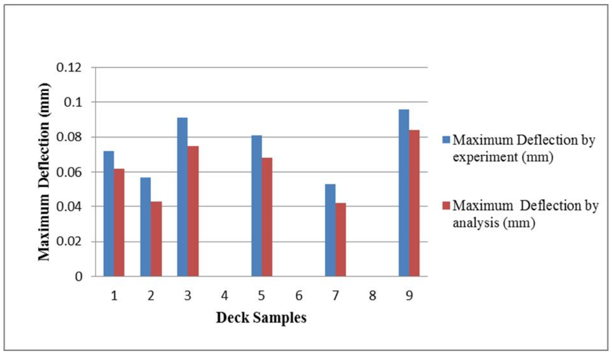

Fig.10. Comparison of maximum deflection by experiment and analysis of all panels

IX. CONCLUSION

After studying all the related papers, experimental and analytical results, we can conclude that experimental results and Finite element analysis results are approximately equal and FEA validate results for the Experimental work.

Based on the results obtained the following conclusion can be made:-

1) The Finite Element Analysis (FEA) using ANSYS (R17.1) software has been done to check the behaviour of GFRP bridge deck panels and conventional bridge deck panel.
2) The average deflection of GFRP deck panels are 0.073 mm by experimental and 0.060 mm by analytical whereas the average deflection of conventional deck panels are 0.076 mm by experimental and 0.064 mm by analytical.
3) The average bending stresses in GFRP bridge deck panels are 1.265 (KN/mm2) by experimental and 1.004 (KN/mm2) by analytical whereas the average bending stresses in conventional bridge deck panels are 1.454 (KN/mm2) by experimental and 1.305 (KN/mm2) by analytical.

This conclude that even after the heavy applications of loading, the deflection in GFRP bridge deck panels is 3.94% less than that conventional bridge deck panels by experimental work and 6.25% less by analytical work whereas the bending stress in GFRP bridge deck panels is 12.99% less than that conventional bridge deck panels by experimental work and 23.06% less by analytical work. This proves that GFRP bridge deck panels are the effective panels.

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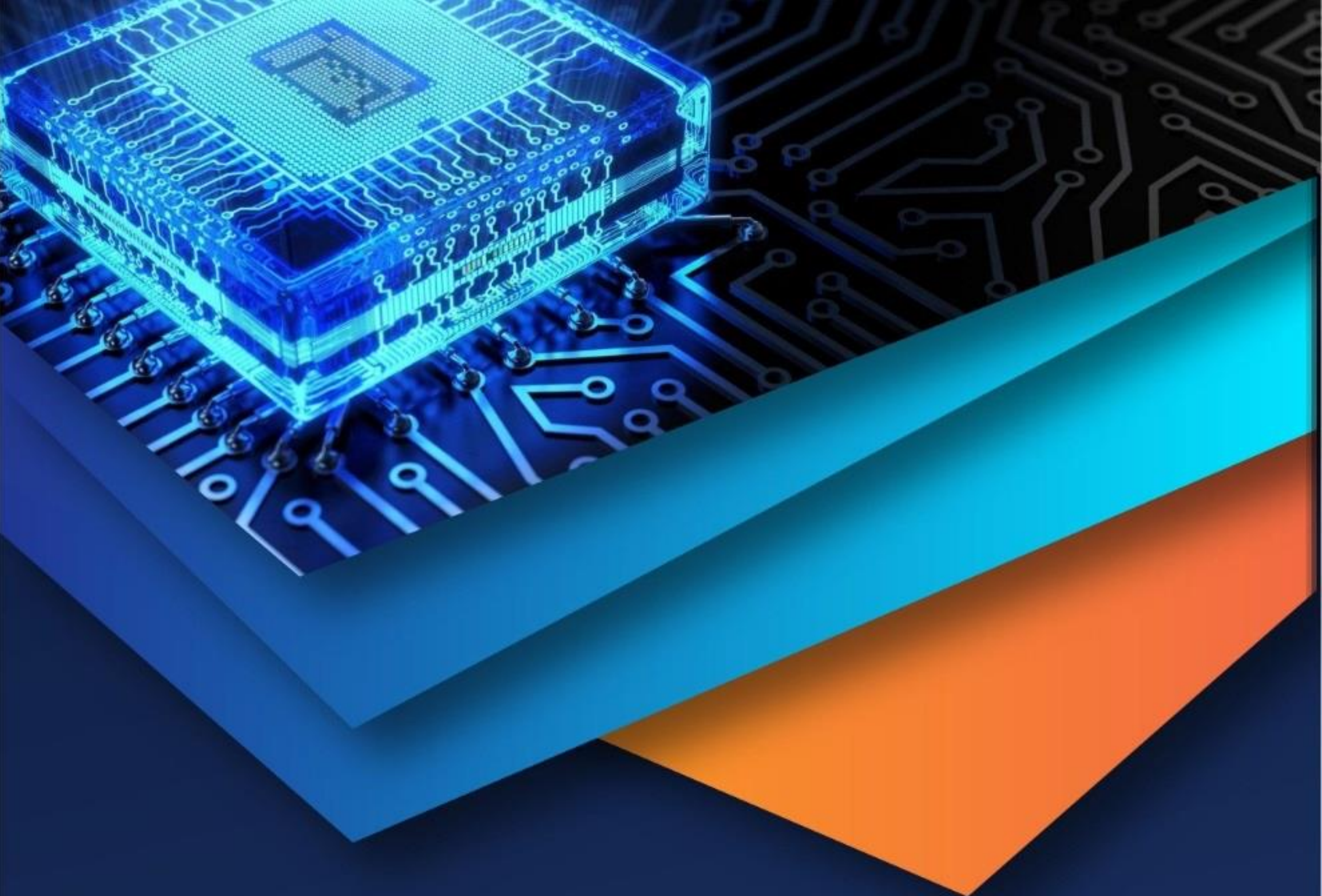

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