Load-Deflection Behaviour of Frp Concrete Composite Deck

Payam Sarir, Omid Monshi Toussi

Department of Civil Engineering, University KEBANGSAAN Malaysia (UKM), Malaysia
Department of Civil Engineering, University KEBANGSAAN Malaysia (UKM), Malaysia

ABSTRACT

Nowadays, Fiber Reinforced Polymer (FRP) concrete composite bridge deck system has been introduced because of its light-weight and durability. Strong composition is needed between FRP and concrete to acquire the structural composite behavior of FRP concrete composite deck. FRP has unique properties that, if disregarded, can lead to failure during operation. However, when these same unique properties are taken into advantages, they can provide the engineers with a system superior to traditional metallic materials. This study investigates analytically the deflection behavior of FRP concrete composite deck using shear connectors under flexural loading. Finite element software (LUSAS) is used to model FRP composite deck. For this purpose, LUSAS has introduced some elements. Volume elements are utilized to model concrete and Glass Fiber Reinforced Polymer (GFRP) section. Meshing elements are necessary in finite element in order to act as a member in modeling. 3D solid continuum elements are used to mesh the sample. Five GFRP module having different thicknesses of 8mm, 9.6mm, 11.2mm, 12.8mm and 16mm are taken to analyze. Results show that the thicknesses of GFRP module have significant effect on the ultimate load and deflection of the deck. Once the thickness of GFRP section increased, the deflection at mid span decreased and the ultimate load increased accordingly. Furthermore, results revealed the appropriate interface material between FRP and concrete in finite element modeling. In order to get an effective interface element, about 40 numerical models have been analyzed. The results were compared with experimental study. Inserted data for verified model in LUSAS were demonstrated as an appropriate interface element between FRP and concrete.

Keywords: *GFRP concrete composite bridge deck, durability, shear connection system, finite element modeling, interface*

INTRODUCTION

Fiber Reinforced Polymer- concrete composite deck is a structure which is concrete place over FRP panel. This panel act as main member of deck during service Cho et al. (2010) [1]. Recently to overcome the corrosion-related problems, the steel reinforcement must be protected from corrosion, chemical agents or to be replaced with alternative non-corrosive materials in new structures. One of these alternatives is the Fiber Reinforced Polymers (FRP) which recently has been introduced as concrete reinforcement in bridge decks and other structural elements such as precast constructions. FRP material solves the durability problem due to corrosion of steel reinforcement [2]. A lightweight modular FRP composite deck weighs approximately 80% less than the conventional concrete deck. This low dead load of the deck allows an increase to the allowable live load capacity of the bridge [3]. The main constituents of FRP are the fibers and matrix [4]. Fiber Reinforced Polymer composites are materials that consist of two constituents. The constituents are combined at a macroscopic level and are not soluble in each other. One constituent is the reinforcement, which is embedded in the second constituent, a continuous polymer called the matrix [5]. The reinforcing material is in the form of fibers, i.e. carbon and glass, which are typically stiffer and stronger than the matrix. Kachlakev et al. (2001) [6] stated that FRP composites are anisotropic materials; that is, their properties are not the same in all directions. Figure 1 shows a schematic of FRP composites [5, 7].

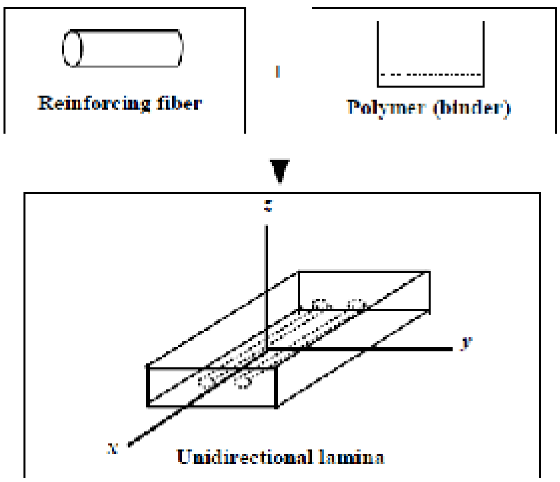

Figure 1 Schematic of FRP Composites

Gibson 1994; Kaw 1997 [5, 7]

OBJECTIVES:

The objectives of this case study are to estimate deflection and determine appropriate interface element between FRP and concrete. For this approach using finite element software is needed to investigate the study and compare numerical and experimental results.

METHODOLOGY

The FE model will be loaded by single load according to the experimental documents and run properly. After validating the basic behavior of load-deflection response by comparing it to the experimental data; the study will focus on investigating the effect of composition behavior of different shear connectors. In fact the variety of shear connection element can be discussed in terms of difference in material properties, changing the space of shear studs and changing cross section area of shear connectors. Figure 2 shows dimension and other condition of sample deck.

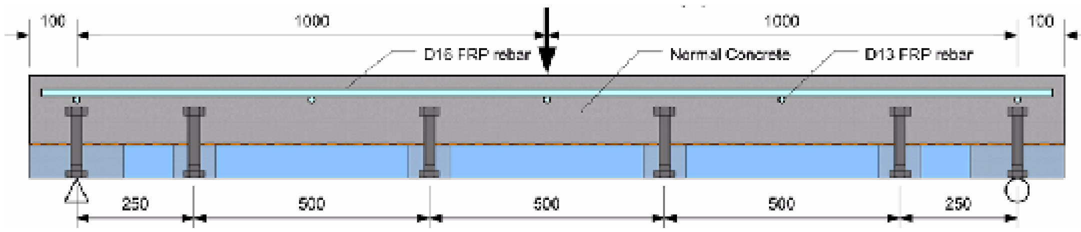

Figure 2 GFRP Deck

Cho et al 2010 [1]

Since Joshani in 2010 successfully used cohesive elements to model the shear bond mechanism between steel and concrete (Joshani 2010) [8], the Mode 3 of interface for this study is assumed. The specification of interface material has been shown in Table 1.

Table 1 Interface Material

	Mode 1	Mode 2	Mode 3
Fracture Energy	0,65 N/mm	0,65 N/mm	0,65 N/mm
Initiation Stress	1×10^{-4} MPa	1×10^{-4} MPa	1×10^{-4} MPa
Max. Relative Displacement	1×10^{-8} mm	1×10^{-8} mm	1×10^{-8} mm

For simulating loading, steel plate is used to dispread loads on the model according to the experimental investigation. Loading plate is a solid which used as loading distributor. FRP is an anisotropic material that the specification in all direction is different. Material specification which is used for GFRP module is indicated in Table 2.

Table 2 GFRP Modue

Properties	value
E_x	3500Mpa
E_y	2300 MPa
E_z	2300Mpa
G_{xy}	850Mpa
G_{yz}	1200Mpa
Gxz	850Mpa
υ_{xy}	0,26
υ_{yz}	0,3
υ_{xz}	0,26

THEORITICAL APPROACH

Cho et al (2010) [1] examined the deflection of FRP concrete composite deck, by sing flexural bending test. Loading was applied on the sample by displacement control at speed of 0.5 mm/min through a loading plate with dimensions of 230 mm (width) × 580 mm (length) disposed at the center of the beam. Roller bearings were adopted to reproduce the boundary condition of a simply supported beam. Universal Testing Machine (UTM) with capacity of 2,000 kN was used as loading device (Cho et al 2010) [1]. Figure 3 shows the experimental graph which is tested in laboratory and LUSAS analytical graph. It can be understood from the graph that analytical results agree with experimental results.

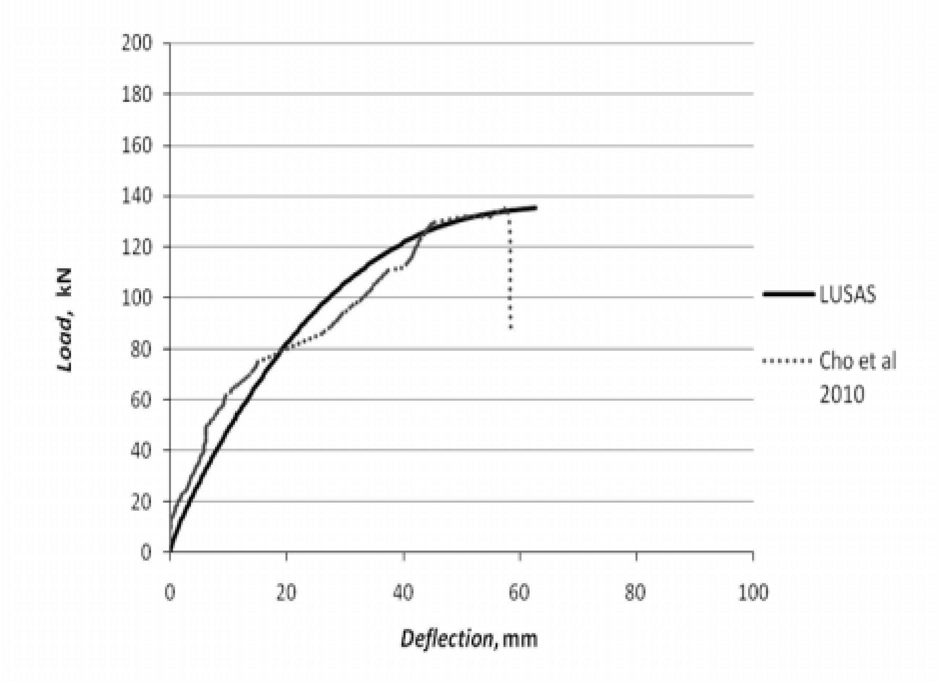

Figure 3 Load- Deflection Curve of Experimental and Analytical Results

Thicknesses of GFRP module take into consideration as a variable of this study. It is due to major effect on the ultimate load and deflection. The thickness of model changed to 8 mm, 9.6 mm, 11.2 mm, 12.8 mm and 16 mm which is more than 2 times of the actual thickness of model. The outcome was predictable. Results show that whatever the thickness of the section added up, the deflection of deck decreased. As a result, the ultimate load of section increased accordingly. For instance the ultimate load for 6.4 mm is 135 kN while for 16mm it is 317.5 kN. Maximum deflection in model of 6.4 mm is 62 mm and in model of 16 mm is 23 mm. For model 8 mm, 9.6 mm and 11.2 mm the difference is not as much as the 16 mm model.

As it has been indicated in the Figure 4, the maximum deflection occurred at the center of the deck. Deformed mesh showing the deflection of whole structure under loading up to failure.

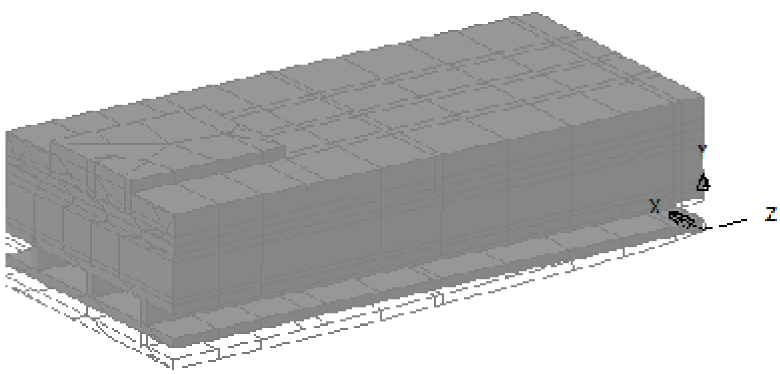

Figure 4 Deformed Mesh

An undimensional equation can be created to predict deflection of FRP module under loading.

$$\delta = \left| \frac{t - 1.28}{6t + 0.1} \right| P \quad (1)$$

Where:
δ: deflection
P: vertical load
t: thickness ; $t \geq 6.4$

CONCLUSION

In this study the deflection of FRP concrete composite deck under flexural loading has been evaluated. The results shown that the GFRP module has specific effect on the deflection. The study shows whatever the thickness of GFRP increased the deflection of deck decreased and consequently the ultimate loading has been increased. Objectives in this study are discussed in the following paragraph:

a) In this case of study, the proposed model by Cho et al. (2010) [1] numerically developed by using FE programmable software. The deflection of the composite slab was evaluated by LUSAS software and the Finite Element result was compared with experimental test. Moreover, five composite slabs with different GFRP module was modelled with different thicknesses of the slab which are 8 mm, 9.6 mm, 11.2 mm, 12.8 mm and 16 mm. Deflections of these five slabs were compared with each other. Finally, results revealed that whatever the thickness of GFRP increased the deflection of deck decreased.
b) Referring to the previous studies for interface between steel and concrete, by using LUSAS software and based on engineering knowledge, the appropriate interface element as a shear bond for using between FRP and concrete has been proposed as indicated in Table 1.

REFERENCES

Reference numbers in the text should be designated by square brackets, e.g., [1-3]. The references should be listed in the same order as cited in the text. See also examples in the REFERNCES section of this template [1-3].

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