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Analytical Performance of Hybrid GFRP Deck Panel Strengthen with Corrugated Ribs

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Abstract— *This paper deals with the analytical performance of hybrid GFRP deck panel strengthen with corrugated ribs. This study was proposed to increase the strength of hybrid GFRP deck panel and structural performance of GFRP deck panel are evaluated. The load deflection behavior of GFRP deck panels were compared with the conventional system on the basis of finite element analysis done using ANSYS software. The result indicates that the strength of GFRP deck panel effectively increased by the proposed method of hybridization presented in this paper.*

Keywords— *GFRP deck panel, Static loading, corrugation, patch loading.*

I. INTRODUCTION

Glass Fiber Reinforced Polymers (GFRP) composites have continued to play an important role in solving some of the persistent problems in infrastructure applications due to their superior material properties such as high specific stiffness, high specific strength, high corrosion resistance, light weight, and durability. GFRP composites are more expensive than steel, the cost of the GFRP deck panel is roughly estimated to be at least 1.4 times greater than the cost of a conventional steel deck panel. Compared with a conventional steel panel, the GFRP deck panel is a lighter and has a higher level of skid resistance. The GFRP deck panel's light weight and ease of handling make it ideal for the rapid construction of temporary structures and for the reduction of the dead load in super structures. 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 light weight construction that can pass the required wheel load. The results of a finite element (FE) analysis conducted on the hybrid GFRP deck panel indicated that it increases the strength of deck panel using corrugated ribs.

Fig. 1. GFRP deck panel

II. SCOPE AND OBJECTIVES OF THE STUDY

Use of GFRP in construction is rapidly growing in 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. The results of a finite element (FE) analysis conducted on the hybrid GFRP deck panel indicated that it increases the strength of deck panel using corrugated ribs. Study the feasibility of the hybrid GFRP deck panel with corrugated ribs. Evaluate long-term performance of the GFRP deck panel. Study the durability characteristics of the GFRP deck panel under various environmental conditions, particularly conditions of alkali, chemical agents. Study the response of the hybrid deck panel subjected to impact load should be performed to ensure the safety and durability of deck for practical applications. The main objectives of the study are as follows.

- To evaluate the performance of deck panel, the static loading tests of panels with different shapes will be conducted
- To analyze the load deflection behavior of the hybrid GFRP deck panels which is done in ANSYS 16.1 software
- To compare the load deflection behavior and ultimate strength of the hybrid GFRP deck panel strengthen with corrugated ribs with conventional system.

III. FINITE ELEMENT MODELLING OF GFRP DECK PANEL WITH DIFFERENT SHAPES

A. Geometry

Three dimensional models were developed to demonstrate the behavior properly. The models includes the different shapes ie rectangular, trapezoidal and elliptical shapes of GFRP deck panels. The dimensions and material properties considered in this thesis are fixed with reference to *Hyeong-Yeol Kim et al.* In this thesis, total 3 models were developed with different L/D ratios along the length and across the width of deck. For all models, GFRP deck panel has a size of 750 x 200 x 2500 mm. The thickness of outer and inner webs are 13.5 and 12.6 mm respectively and thickness of both bottom and top flanges are 16.6 mm. Fig. 2 shows the cross-sectional profile of steel reinforced GFRP deck panel. The top and bottom flanges of the series steel reinforced specimen were reinforced with 5mm diameter steel wires uniformly spaced at about 30 mm.

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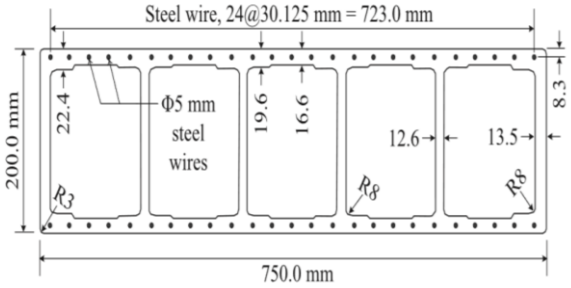


Fig. 2. Cross-sectional profile of steel reinforced GFRP deck panel

B. *Material Properties*

Material properties used for GFRP and structural steel of all models are given in Table I.

TABLE I. Material properties of GFRP and structural steel

MATERIAL PROPERTY	VALUE
Structural Steel	
Density	7850 Kg/m^3
Poisson's ratio	0.3
Young's modulus	2x10^5 MPa
Shear modulus	7.69 x10^4 MPa
Bulk modulus	1.67 x10^5 MPa
GFRP Flange	
Density	1900 Kg/m^3
Young's modulus	2.69x10^4 MPa
Poisson's ratio	0.21
Shear modulus	3.1x10^3 MPa
Yield strength	405 MPa
GFRP Web	
Density	1900 Kg/m^3
Young's modulus	2.87x10^4 MPa
Poisson's ratio	0.31
Shear modulus	5.3x10^3 MPa
Yield strength	422.3 MPa

C. *Modelling and Analysis*

The different shapes of GFRP deck panels are modelled using ANSYS Workbench 16.1. Bonded contact was used to explain the interaction. Static analysis were performed using ANSYS software package. The material properties were assigned, support and loading conditions were provided. Each model was analyzed for different L/D ratios. To simulate the real condition, GFRP deck panel were analyzed with fixed support at both ends to restrain axial deformation whereas the load imposed to the top. The bilinear isotropic hardening rule was used for the finite element analysis of all GFRP deck panels. Fig. 3 shows the cross section of different models used for the study. Each models shown below is analyzed for another L/D ratio 2.5 & 3.

D. *Results and Discussions*

After the analysis of the structures, the results are noted and summarized as follows. The fig. 5 shows the load deformation curve of the different GFRP deck panels with different L/D ratios along the length and across the width of deck.

- In rectangular cross section of GFRP deck panel, load carrying capacity is higher in L/D ratio 2.5 along the length of deck. So it stronger than other L/D ratios. But in across the width of deck the load carrying capacity is higher in L/D ratio 3.

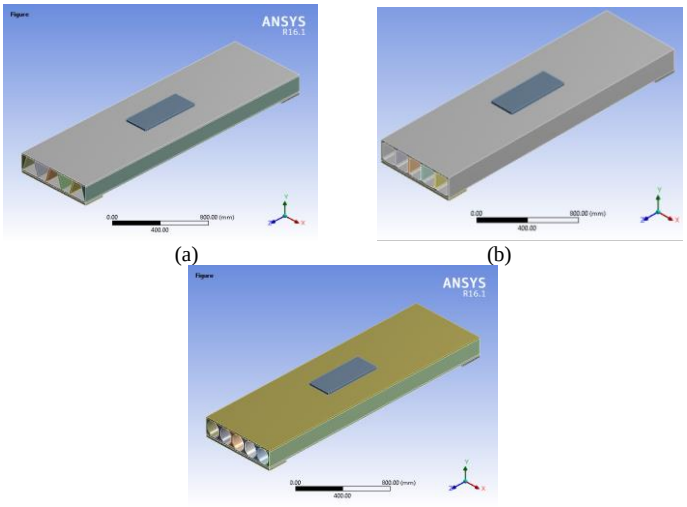


Fig. 3. Cross section of all GFRP deck panels – (a) Rectangular GFRP deck panel with L/D ratio 2 (b) Trapezoidal GFRP deck panel with L/D ratio 2 (c) Elliptical GFRP deck panel with L/D ratio 2

- In trapezoidal cross section of GFRP deck panel, load carrying capacity is higher in L/D ratio 3 along the length of deck. So it stronger than other L/D ratios. But in across the width of deck the load carrying capacity is higher in L/D ratio 2.
- In trapezoidal cross section of GFRP deck panel, load carrying capacity is higher in L/D ratio 3 along the length of deck. So it stronger than other L/D ratios. But in across the width of deck the load carrying capacity is higher in L/D ratio 2.

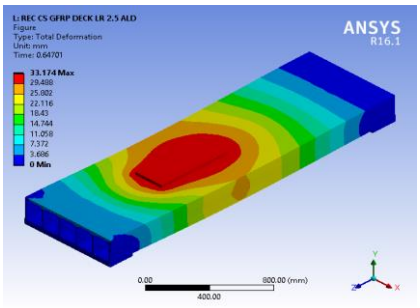
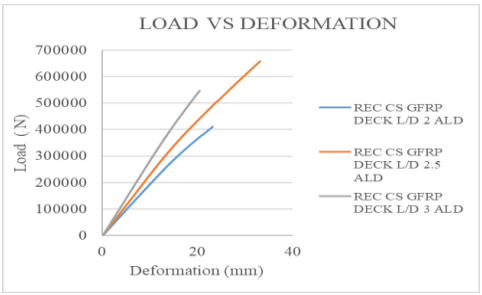


Fig. 4. Total deformation



(a)

Nisni M Hassain and Renny Varghese, "Analytical Performance of Hybrid GFRP Deck Panel Strengthen with Corrugated Ribs," *International Research Journal of Advanced Engineering and Science*, Volume 4, Issue 2, pp. 334-338, 2019.

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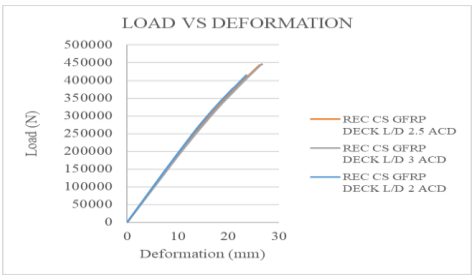

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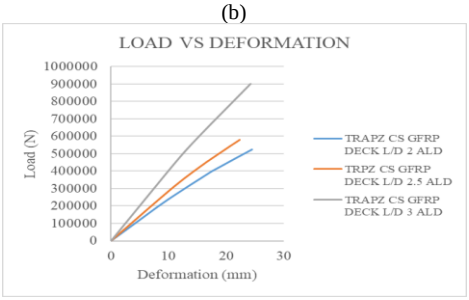

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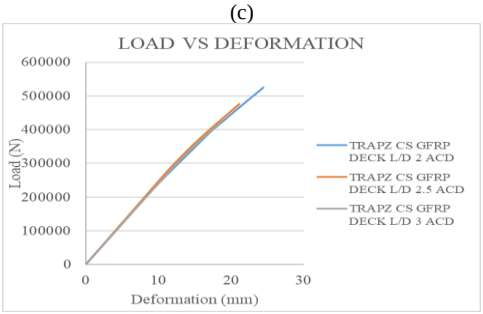

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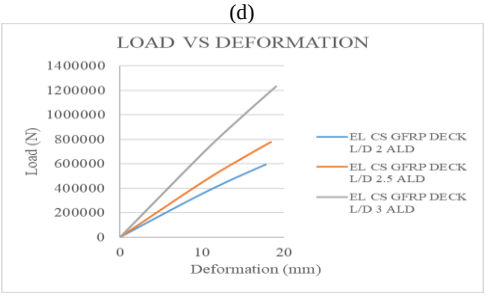

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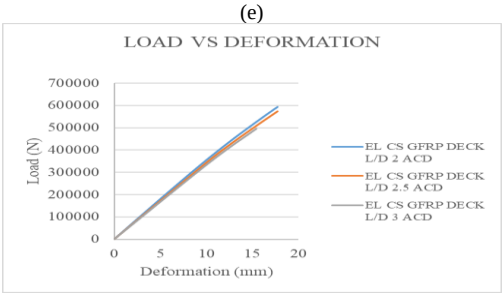

(f)

Fig. 5. Load deformation behavior of all GFRP deck panel along the length and across the width of deck

IV. Finite Element Modelling of Corrugated GFRP Deck Panel

Glass Fiber Reinforced Polymers (GFRP) composites have continued to play an important role in solving some of the persistent problems in infrastructure applications due to their superior material properties such as high specific stiffness, high specific strength, high corrosion resistance, light weight, and durability. In comparing the three different shapes of GFRP deck panels, the rectangular cross section of GFRP deck panels have lower load carrying capacity and hence weaker. The corrugations are applied on the rectangular cross section of GFRP deck panels. So in this section the strengthening of corrugated GFRP deck panels are studied. Conventional deck is modelled and their strengthening is also studied for comparison.

A. *Geometry and material Properties*

In comparing the three different shapes of GFRP deck panels, the rectangular cross section of GFRP deck panels have lower load carrying capacity and more deflection and hence weaker. The corrugations are applied on the rectangular cross section of GFRP deck panels. The corrugated rectangular GFRP deck panel has a size of 750 x 200 x 2500 mm. The top and bottom flanges of the series steel reinforced specimen were reinforced with 5mm diameter steel wires uniformly spaced at about 30 mm. Structural steel have Poisson's ratio and Young's modulus of GFRP flanges are 0.21 and 2.69×10^4 MPa respectively and that of the webs are 0.31 and 2.87×10^4 MPa respectively. Corrugations are made of steel material with yield strength of 250 MPa, Poisson's ratio of 0.3, Young's modulus of 2×10^5MPa. 5 mm steel plates are inserted in between the corrugation for avoiding the buckling.

B. *Modelling and Analysis*

Corrugated rectangular GFRP deck panels are modelled using ANSYS Workbench 16.1. Bonded contact was used to explain the interaction. Static analysis were performed using ANSYS software package. The material properties were assigned, support and loading conditions were provided. This model was analyzed for different L/D ratios. To simulate the real condition, corrugated GFRP deck panel were analyzed with fixed support at both ends to restrain axial deformation whereas the load imposed to the top. The bilinear isotropic hardening rule was used for the finite element analysis of corrugated GFRP deck panels. Fig. 6 shows the cross section of corrugated GFRP deck panel used for the study. Each models shown below is analyzed for another L/D ratio 2.5 & 3.

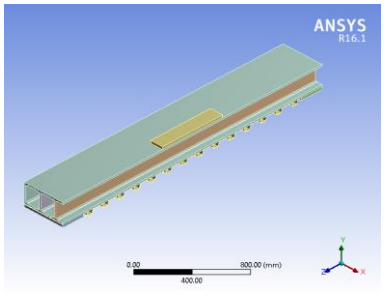

Fig. 6. Cross section of corrugated GFRP deck panels with L/D ratio 2

Nisni M Hassain and Renny Varghese, "Analytical Performance of Hybrid GFRP Deck Panel Strengthen with Corrugated Ribs," *International Research Journal of Advanced Engineering and Science*, Volume 4, Issue 2, pp. 334-338, 2019.

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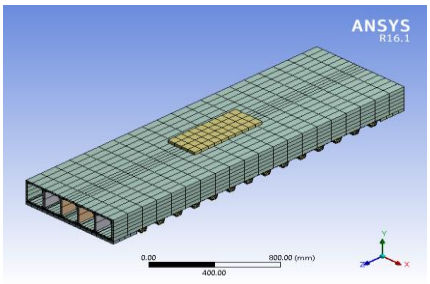

Fig. 7. Finite element modelling of corrugated GFRP deck panels with L/D ratio 2

C. Results and Discussions

After the analysis of the structures, the results are noted and summarized as follows. The fig. 8 shows the load deformation curve of the corrugated GFRP deck panels with different L/D ratios along the length and across the width of deck.

- For corrugated GFRP deck panel, load carrying capacity is higher in L/D ratio 3 in along the length of deck. So it stronger in this L/D ratio 3 than the other L/D ratios.
- Corrugated rectangular cross section of GFRP deck panel is better than the deck panel without corrugation because the load values are increased in all the deck panel with different L/D ratios after the application of corrugated ribs.
- So these deck panels are stronger than others.

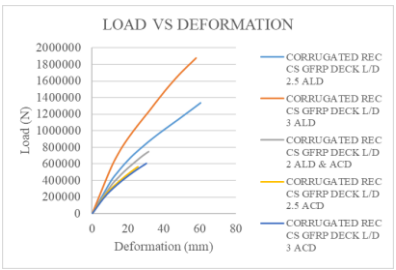

Fig. 8. Load deformation behavior of corrugated GFRP deck panel along the length and across the width of deck

For conventional deck panel, load carrying capacity is higher in L/D ratio 3 in across the width of deck. So it stronger in this L/D ratio 3 than the other L/D ratios. In conventional deck panel all load values are comparatively smaller than the GFRP deck panel with or without corrugation. fig. 9 shows the load deformation curve of the conventional deck panels with different L/D ratios along the length and across the width of deck.

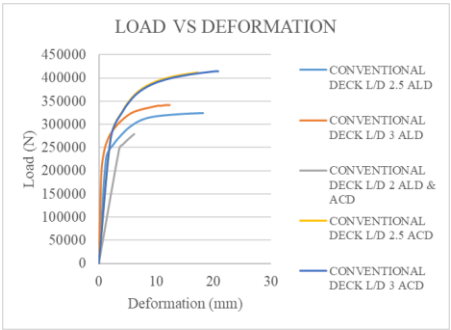

Fig. 9. Load deformation behavior of conventional deck panel along the length and across the width of deck

V. Summary of Results

Comparison of ultimate load values of different deck panels with different L/D ratios are shown in Fig. 10.

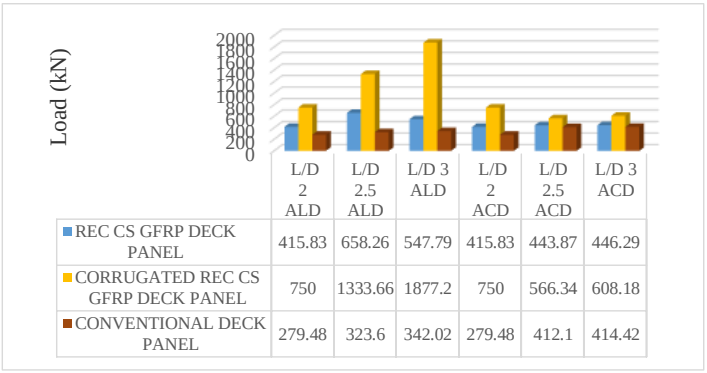

Fig. 10. Ultimate load comparison of deck panel with different L/D ratios

GFRP deck panels is much stronger than the conventional deck panel. Because all load values of GFRP deck panels is comparatively larger than the conventional deck panel. The corrugated GFRP deck panel is strengthen than the deck panel without corrugation. The strength of deck panel is increased when using the corrugated ribs. The structural performance and load carrying capacity of corrugated GFRP deck panel is much better and hence the life of bridge is more.

TABLE II. Comparison for load values of different deck panels with different L/D ratios

SPECIFICATION	LOAD (KN)		
	REC CS GFRP DECK PANELS	CORRUGATED REC CS GFRP DECK PANELS	CONVENTIONAL DECK PANEL
L/D 2 ALD	415.83	750	279.48
L/D 2.5 ALD	658.26	1333.66	323.6
L/D 3 ALD	547.79	1877.2	342.02
L/D 2 ACD	415.83	750	279.48
L/D 2.5 ACD	443.87	566.34	412.1
L/D 3 ACD	446.29	608.18	414.42

VI. Conclusions

- GFRP is the best material for the construction of deck panel than other conventional deck panel
- Using GFRP for the construction of the bridge deck leads to light weight construction that can pass the required wheel loads.
- GFRP deck panel exhibited a higher structural performance in terms of stiffness and strength than the conventional deck panel.
- In 3 different shapes ie, rectangular, trapezoidal, elliptical shapes of GFRP deck panel, the rectangular cross section of GFRP deck panel have lower load carrying capacity in different L/D ratios.

Nisni M Hassain and Renny Varghese, "Analytical Performance of Hybrid GFRP Deck Panel Strengthen with Corrugated Ribs," *International Research Journal of Advanced Engineering and Science*, Volume 4, Issue 2, pp. 334-338, 2019.

- So the rectangular cross section of GFRP deck panel is weaker than the other GFRP deck panels.
- The rectangular cross section of GFRP deck panel is strengthen with corrugated ribs.
- After the corrugations are applied, the structural performance and load carrying capacity of corrugated GFRP deck panel is much better and hence the life of bridge is more.

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