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Mechanical Performance of Mild Steel Pipe Connector on GFRP-Concrete Composite Panel

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Abstract - *Composite panels are factory engineered products used for exterior cladding, roofing, partitioning etc. Glass fiber reinforced polymer (GFRP) and concrete composite panel consist of two concrete blocks separated by a layer of GFRP sheet, thus utilizing high compressive strength of concrete and tensile strength of GFRP. The overall performance of this panel largely depends on the type of shear connector, used to transfer shear forces at the interface between GFRP and concrete. Strong shear connection at the interface allow them to act together as a single unit under loading. Conventional shear stud connectors demand it in more numbers with lesser efficiency and non-uniform distribution of shear forces. This paper addresses the potential of using Mild Steel (MS) pipe connectors with and without rubber sleeve, as an alternative to ordinary shear studs and epoxy adhesives. The objective is to improve split resistance in the sandwich panel, while transferring shear forces to develop composite action. The load-slip response of the system has been established through experimental tests. Numerical simulation on the nonlinear response of shear connectors was conducted.*

***Key Words*: Bridge repair, Composite panels, Glass Fiber Reinforced Polymers, Hybrid bridge deck, Pipe connectors, Rubber sleeved studs, Shear connection.**

1. INTRODUCTION

Most of the structures experience structural deterioration before their full service life. The elements of bridges are often subjected to increased traffic load and aggressive environments. The problems are accelerated by deicing of salts, carbonation induced corrosion distress, exposure to uneven moisture and marine chlorides. The above mechanisms induce defects such as cracking, corrosion, spalling, concrete honey combing, and loss of reinforcement and cement paste. The factors such as high strength, light weight, corrosion resistance and rapid construction make fiber polymer composites excellent for various applications in bridge repair, rehabilitation and replacement projects. GFRP –Concrete composite panels utilize the high compressive strength of concrete and high tensile strength of GFRP, thus act as a protective shield for bridge decks. The shear connectors placed at the interface between GFRP and concrete plays an important role in forming the structural integrity of the composite panel. They transfer shear forces at interface to keep the panel not to slip away from each other and will also help the composite panel to act together as one unit under load.

2. METHODOLOGY

The project work includes the experimental investigation of the performance of Mild steel pipe with and without rubber sleeve as shear connector between GFRP and concrete. Four shear test specimens were performed and the variation is recorded. The experimental results were compared analytically using ANSYS Workbench 16.1.

3. FINDINGS

Previous works indicate approach towards evaluation of service life of bridges and understanding fatigue and corrosion of bridge elements [2] and distress mechanism and symptoms [4]. Despite many advantages over the conventional construction materials, the contemporary development of FRP composites in bridge engineering is limited due to high initial cost, low stiffness (in case of glass fibers) and sudden composite failure mode. The hybrid bridge deck panel satisfied the performance limitations Although GFRP application in concrete is widely reported, the shear connecting system of GFRP -Concrete Composite panel has not been extensively researched.Mild steel pipes as an innovative shear connector between GFRP and concrete is discussed in this paper. The specimens are experimentally tested and analytically validated using ANSYS WORKBENCH 16.1.

4. EXPERIMENTAL STUDY

4.1 Materials and Mix Proportion

Ordinary Portland cement (53 grade) which conforms to ASTM Type I was used in the study. Naturally crushed stone of nominal size 20 mm, specific gravity of 2.85, and absorption percentage of 0.14% was used as coarse aggregate. Fine aggregate used was artificially manufactured sand with specific gravity of 2.81. Concrete mixture proportions are given in Table 5.1. The mixture was designed as per IS 10262: 2009 to have a 100mm slump and 28 days compressive strength of 30 MPa which represents a typical structural concrete grade. The water cement ratio obtained was 0.44.

Table -1: Concrete mix proportion

Material	Quantity(kg/m^3)
Cement	450
Fine aggregate	682.46
Coarse aggregate	1183.307
Water Content	201.773

4.2 Preparation Procedure

GFRP panels of required size were fabricated using glass fibre sheets of 500 mm length. It was cut into two sheets of 200 mm and joined back to back using an adhesive .GFRP panels are then installed with mild steel pipes, with and without ultra-high strength silicone rubber sleeve of thickness 2 mm, shown in Fig.1.

Fig -1: Mild Steel pipe connectors
(i)Without rubber sleeve (S)
(ii) With rubber sleeve (RS)

Two types of shear connectors prepared were specimens in the GFRP –Concrete composite panel; Mild steel pipe connector with and without rubber sleeve. The pipes have a diameter of 26.67 mm and thickness of 2.11 mm. Two samples were prepared for each connector. Four openings were provided on each side of GFRP combined section to accommodate mild steel pipe shear connectors. Concrete were then cast to combine shear connectors. The dimension of concrete slab was 200 mm wide, 400 mm high and 150 mm thick. Concrete slabs were cast using timber blocks as shown in Fig.2.

Fig -2: Timber blocks cast with pipe connectors

The concrete blocks were then combined with GFRP panel ,inserted with the shear connectors to form GFRP-Concrete Composite panel as shown in Fig.3.

Fig -3: GFRP-concrete composite panel

4.3.Experimental Setup

The experiments were performed on Universal testing machine of 1000 kN capacity. The load was provided on the upper end of GFRP-Concrete composite panel as shown in Fig.4.The load and displacement of the samples was recorded by the UTM machine.

Fig -4: Experimental Setup

4.4 Experimental results

Chart 1 shows the experimental load displacement responses of both types of shear connectors.it shows that the samples with rubber sleeved mild steel pipes showed greater composite action with greater load carrying capacity. The mild steel pipe connector without rubber sleeve sustained greater load in comparison to conventional studs and epoxy adhesion, but inferior to rubber wrapped MS pipe connectors. The failure modes of MS pipe connectors without rubber sleeves are shown in Fig.5 and 6.This type of connectors could only carry a load of 172.55 kN for specimen 1 and 157.39 kN for specimen 2.In average ,they carry a load of 164.97 kN.

Fig -5: Failure mode of steel specimen (S1)

Fig -6: Failure mode of steel specimen(S2)

The rubber sleeved steel pipes could carry a load of 205.75 kN for specimen 1 and 212.45 kN for specimen 2; having 209.10 kN in average, whereas the unwrapped steel pipe could only sustain 164.97 kN. Failure modes of rubber sleeved specimens are shown in Fig.7 and 8. The higher load carrying capacity of rubber wrapped steel connectors are attributed due to the higher elongation and tear strength of rubber sleeve, improving partial composite action and split resistance.

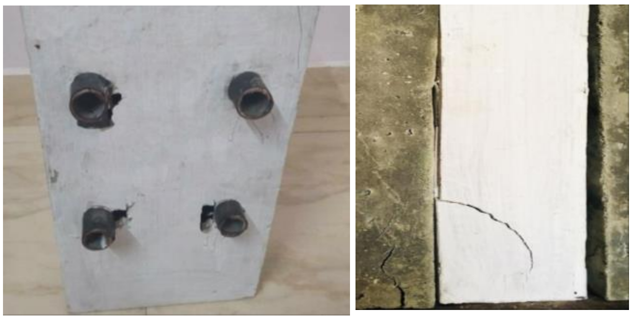


Fig -7: Failure mode of Rubber Steel pipe Specimen (RS1)

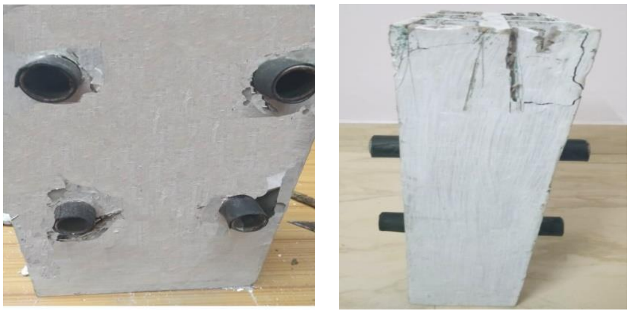


Fig -8: Failure mode of Rubber Steel pipe Specimen (RS2)

The rubber sleeved connectors possess greater tear strength and act as better crack arresters by elongating themselves with in the outer surface of the connector.

Table -2: Experimental Results

SPECIMEN		Load (kN)	Slip (mm)	Average Load(kN)
1.Mild steel pipe connector without rubber sleeve	1	172.55	3.6	164.97
	2	157.39	3.2	
2. Mild steel pipe connector with rubber sleeve	1	205.75	2.7	209.1
	2	212.45	2.9	

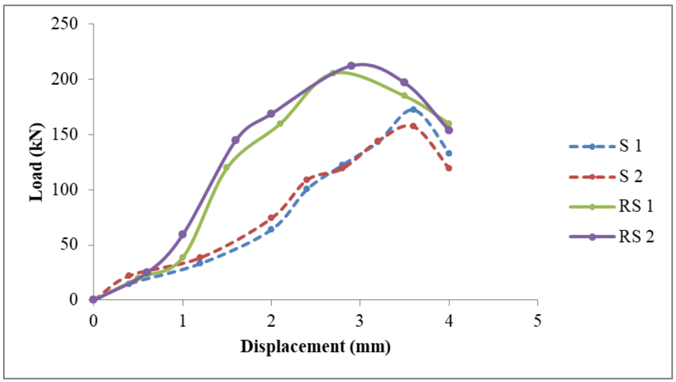


Chart -1: Load –displacement graph obtained from Experimental study

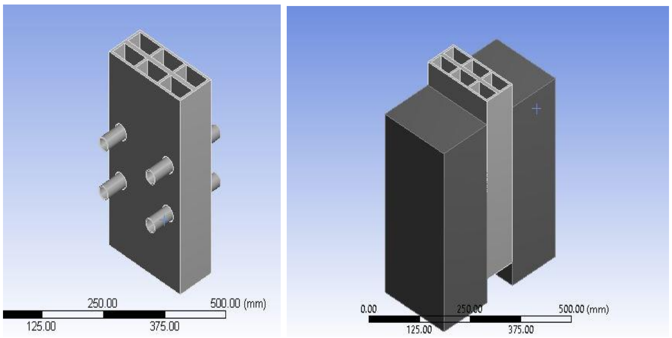
5 .FINITE ELEMENT ANALYSIS

A commercial finite element modeling software, ANSYS WORKBENCH 16.1 was chosen to model the experimental set-up of GFRP –concrete composite conducted in this study due to ability in modeling wide range of materials and extensive analyzing mechanical components including material nonlinearity behaviour. The FE stimulations results were first validated against experimental results.

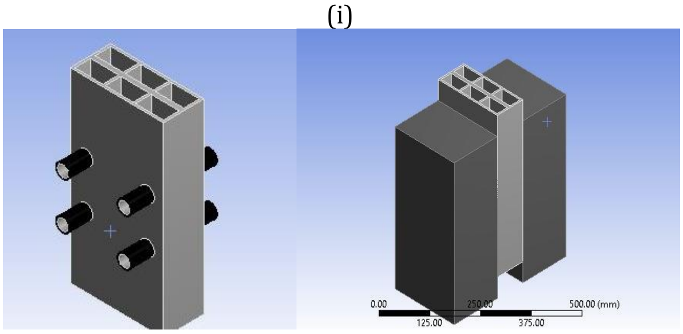
5.1 Validation of FE models

The quantitative and qualitative accuracy of FE Stimulation were assessed by comparing experimental results of two types of shear connection systems, namely mild steel pipe shear connector with and without rubber sleeve. The modeling of the composite panel is shown in Fig.9.The FE model for the normal MS pipe connector showed a maximum load of 161.66 kN ,similar to the average experimental load of 164.97 kN. This FE model predicted almost the same displacement, about 3. 4mm.The failure mode showed by the FE model was the failure at the interface, same as experimental results. For the samples with rubber sleeved MS pipe connectors, the ultimate load of 191.52 kN , is in agreement with experimental average load of 209.1 kN. The displacement is about 2.5 mm.

It was observed that shear damage initiated at one side of the opening as the shear connectors pushed against the section to transfer the load. The deformation patterns of the composite panel with and without rubber sleeve are shown in Fig.10.and 11.



(i)



(ii)

Fig -9: Modelling of GFRP-Concrete composite panel in ANSYS (i)Without rubber sleeve (ii) With rubber sleeve (RS)

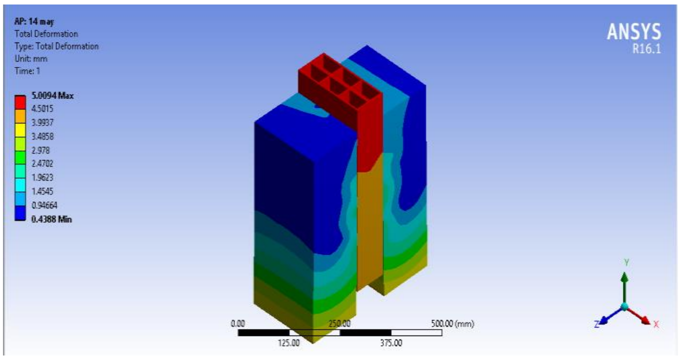


Fig -10: Deformation of GFRP-Concrete composite panel without rubber sleeve connector

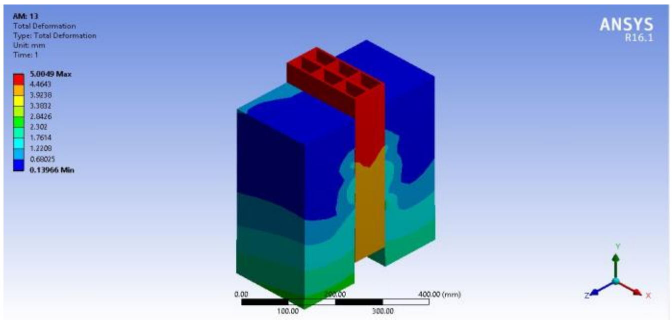


Fig -11: Deformation of GFRP-Concrete composite panel with rubber sleeve connector

Table -3: Validation Results

Type of connector	Average Load from Experiment Tests(kN)	Results From ANSYS (kN)	Percentage Variation
1.MS Pipe Connectors	164.97	161.66	2.04 %
2.Rubber Sleeved MS Pipe Connectors	209.1	191.52	9.48 %

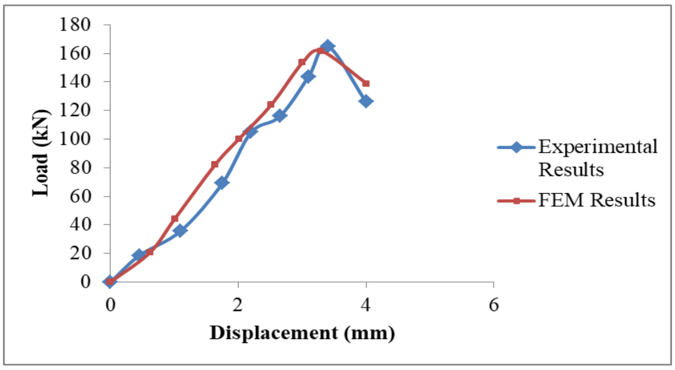


Fig -12: Experiment results versus FEM results of Specimens without rubber sleeve.

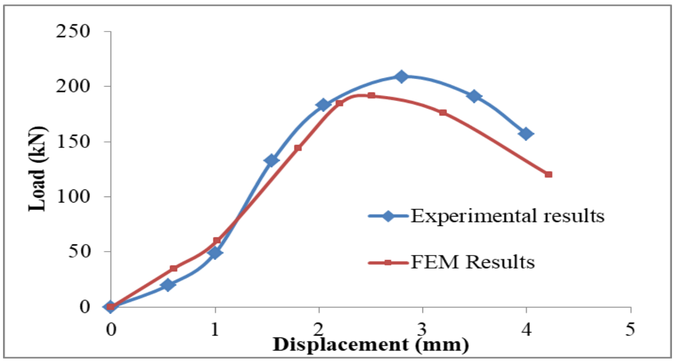


Fig -13: Experiment results versus FEM results of Specimens with rubber sleeve.

6. CONCLUSIONS

The paper presents the study of analytical behaviour of GFRP – Concrete composite panels with mild steel pipe as mechanical shear connectors wrapped with and without rubber sleeve. Experiments were also conducted selecting circular mild steel pipe with and without rubber sleeve. The push out test of GFRP panels combined with concrete of compressive strength 30 MPa has been studied.

The steel pipe used was of grade Fe 250.The following observations was made from the study.

1. Rubber wrapped MS pipe connectors are more effective than Normal MS pipe connectors at about 26.70 %.
2. The rubber with its inherent natural property of elongation helps in crack control. The tear strength of rubber sleeve is also high enough to resist the applied load.
3. The hybrid bridge deck panel made of GFRP and concrete are advised due to durability, light weight and corrosion resistance.
4. The analytical study using circular pipe connector with and without rubber sleeve showed comparable results with those obtained in experimental studies. The percentage variation obtained is within permissible limits.

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REFERENCES

[1] Alagusundaramoorthy , I. E. Harik, and C. C. Choo, “Structural Behavior of FRP Composite Bridge Deck Panels”, Journal of Bridge Engineering.vol 11 , 2006,pp.384-393 .

[2] F.J. Olguin Coca, M.U. Loya Tello., C. Gaona-Tiburcio, J.A. Romero1, A. Martínez-Villafane, E. Maldonado B and F. Almeraya-Calderon, “ Corrosion Fatigue of Road Bridges: a review”,International Journal Of Electrochemical Science .vol. 17, 2011,pp. 3438-3451.

[3] Hailin Huang,Ao Li ,Lin Chen , Chuijun Zeng and Mingqiao Zhu, “Push –Out Tests for Shear Connectors in GFRP-Concrete Composite Bridge Deck Slabs”,Journal of Advanced Concrete Technology .Vol. 20 ,2018, pp. 569-571.

[4] Joao R. Correia , Fernando A. Branco , Joa o G. Ferreira, “Flexural behaviour of GFRP –concrete hybrid beams with interconnection slip”,Journal of Composite Structures.vol. 77,2016, pp. 66-78.

[5] Lihua Yang, “Research Status of FRP-Concrete Composite Beam/Bridge Deck Systems”, Applied Mechanics and Materials. vols. 587-589 ,2014,pp. 1424-1429.

[6] Mateusz Rajchel and Tomasz Siwowski, "Hybrid Bridge Structures Made of FRP Composite and Concrete". Civil and Environmental Engineering Report. vol. 26,2017, pp.161-169.

[7] Saeed Nasrollahi, Shervin Maleki , Mahdi Shariati , Aminaton Marto and Majid Khorami, "Investigation of pipe shears connectors using push out test", Journal of Steel and Composite Structures. Vol. 16,2018, No. 5 (2018) 368-381 .

[8] Sih Ying Kong, Xu Yang, Ze Yang Lee, Mechanical performance and numerical simulation of GFRP-concrete composite panel with circular hollow connectors and epoxy adhesion",Journal of Construction and Building Materials. vol.1184 ,2018,pp. 643-654.

[9] Woltman, Douglas Tomlinson, and Amir Fam, "Investigation of Various GFRP Shear Connectors for Insulated Precast Concrete Sandwich Wall Panels" ,Journal of American Society of Civil Engineers, vol. 20,2018, pp. 711-721.

[10] Xiaoqing Xu, Yuqing Liu, "Analytical and Numerical Study of the Shear Stiffness of Rubber Sleeved Stud", Journal of Constructional Steel Research. vol.123,2016, pp. 68-78.

[11] Xiaoqing Xu, Yuqing Liu, and Jun He. "Study on Mechanical Behaviour of Rubber-Sleeved Studs for Steel and Concrete Composite Structures",Journal of Construction and Building Materials, vol. 53, 2014, pp.533-546.