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STRENGTH ENHANCEMENT OF PREFABRICATED RENFORCED CONCRETE PIPE AND MANHOLE COVER USING FRP

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Abstract

The composite materials are more attractive due to their high specific strength; light-weight and biodegrability. Composite structural components are subjected to various loads during their service life. This paper presents the results of an experimental investigation on the strengthening and behaviour of large 300mm diameter non-pressure precast concrete pipe with FRP laminated. In this study, the effect of the number of layers of FRP wrap is determined. Through experimental investigation the FRP composites is developed and their mechanical properties such as Flexural strength, Shear strength, Loads, Deflection and cracking are evaluated A computer based on Finite element model in MAT LAB environment has been developed to perform the analytical study .In this study, reinforced concrete pipe with the application of continuous glass fiber reinforced polymer sheet (FRP). The pipe material is considered to be composed of reinforced concrete and the pipe is strengthening by FRP. The reinforced pipe is analyzed with different layers of externally applied FRP sheet. A Twenty node isoparametric element is employed in present analysis. A finite element model is developed for the pipe where in the material properties as mentioned are used. The solid 186 layered structural solid element has been used for discretization of the model. Two sets of FRP sheets (4 layers & 8 Layer) were considered for the analysis. Results obtained were compared with the normal pipe made up of reinforced concrete. The deformation and stress distribution across the pipe has also been analyzed. From results it may be concluded that, the pipe applied with GFRP sheet is stiffer in comparison with pipe which is without FRP.

Introduction

Strengthening has become the acceptable way of improving their load carrying capacity and their service lives. . Infrastructure decay caused by premature deterioration of structures and structures has lead to the investigation of several processes for repairing or strengthening purposes. The purpose of this research is to investigate the flexural and shear behaviour of reinforced concrete pipe strengthened with varying configuration and layers of FRP sheets. More particularly, the effect of the number of FRP layers and its orientation on the strength and ductility of beams are investigated. Two sets of pipe were fabricated and tested up to failure. In SET I three pipe weak in flexure were casted, out of which one is controlled pipe and other two pipe were strengthened using continuous glass fiber reinforced polymer (FRP) sheets in flexure. In SET II three pipe weak in shear were casted, out of which one is the controlled pipe and other two pipes were strengthened by using continuous glass fiber reinforced polymer (FRP) sheets in shear. Furthermore, due to the increasing use of high performance concrete, high strength reinforcing steel, larger diameter pipes and the advancements in analysis methods, previous empirical evaluations of the structural behaviour of reinforced concrete pipe must be revisited. Both the indirect and direct design methods need to be verified for their adaptability to these advancements in construction technology and structural analysis. A detailed study where the available design methods are critically reviewed and possibilities of incorporating these Banthia .et,al studied the FRC pipe composite material for uniformly discontinuous. Fibres which is used for different from of plane matrix to take care of post craching load carrying ability[2012]. Saadatmanesh and Schwinger were the first researchers to examine the use of FRP to strengthen the structural masonary components wall[1994].The detailed structural behavior of concrete members using CFRP fabric jackets by both analytical and experimental approaches investigated by Jian chen[1988]. A series of CFRP wrapped concrete cylinder tests were conducted to study the compressive stress-strain behaviour for CFRP confined concrete members. He concluded that the CFRP fabrics can increase the splitting tensile strength of normal concrete. The more layers applied to the specimens, the more increase in tensile strength can be attained. K. Olivova, J. Bilcik[2008] presented the results of an experiment at study on the structural behaviour of reinforced concrete columns strengthened with carbon fibre sheets and strips in pre-cut grooves. Increase in the lateral deflection of the confined columns resulted in the concrete failing in compression and rupturing the FRP confining jacket at approximately mid-height. Romuald-Kokou Akogbe conducted study to size effect of compressive strength of CFRP confined circular concrete cylinder. From stress strain curve comparison analysis, it was noticed that the scattering of plain concrete strength evaluated between small, medium and big specimens explains why the curves are not totally overcome. Murali G. and Pannirselvam **N.** made an attempt to address an important practical issue that is encountered in strengthening of beams with different type and different thicknesses of fibre reinforced polymer laminate.. The thickness of FRP in the strengthening system provides an economical and versatile solution for extending the service life of reinforced concrete structures. Houssam et al., investigated the long-term durability of concrete beams externally bonded with FRP sheets and studied the effect of harsh environmental conditions such as wet/dry cycling using salt water on the performance of FRP bonded concrete beams and on the interfacial bond between the fibre and the concrete.

In Canada, University of Manitoba and Queens University in Kingston has provided the development of FRP bars of concrete buildings. In 1995, the foot-bridge was built by GFRP bars in Britain using glass FRP reinforcement. The first application of fibre composites in a highway bridge in Australia occurred in 2005. The highway bridge, that was constructed using fibre composite girders and reinforced concrete deck slab, is of two spans 10m and 12m, and retrieved an existing reinforced concrete deck slab, is of two spans 10m and 12m, and retrieved an existing timber bridge. The bridge was opened to traffic in July 2005.

Using FRP systems to increase the confinement was first applied in japan in the 1980s. [Fardis and khalili 1981].Due to the resulting benefits, FRP composite applications have revolutionized entire industries.[Nystrom et.al 2003]

The worldwide level of interest in the strengthening technique reflects its potential benefits. Although the level of experience in the bonding technique of composite plates is limited, the investigations reported in this chapter have gone some way to illustrate its potential and to establish a basic technical understanding of short term and long term behaviour. The effect of anchoring GFRP sheet on ultimate strength of slab was studied by Chothani D.G. et al.,(2012). An experimental work was done by casting three simply supported slabs reinforced with steel rods and tested under one way condition. The test result showed that the overall performance of bonded and anchored GFRP slab and bonded GFRP slab was better than the control slab. Strengthening of RC Cantilever slabs using bonded glass fiber reinforced plastic (FRP) strips were studied by Lam and Teng (2001)**.**They considered the cantilever slabs with steel reinforcement of different amounts and different positions to analyse the effect of preloading on the strength of slabs.It was found that the effect of preloading is generally insignificant if the slab fails by FRP rupture.

The behavior of axially loaded rectangular columns strengthened with glass fiber reinforced polymer (GFRP) wraps was studied by Kumutha, Palanichamy and Vaidyanathan (2007).The specimens were tested under axial compression. Result showed that compressive strength improved with increase in number of layers of GFRP. As a result ductility and load carrying capacity were enhanced.The use of glass fiber reinforced polymer inclined strips on the web of beam for shear strengthening of beam was found by Sundarraja and Rajamohan (2009). An experimental work was done to obtain the effective width and spacing of strips for better shear capacity of beam. For experimental purpose, two-point loading method was adopted. The result showed that the use of GFRP enhance the structural strength in shear and inhibit the development of cracks.

The structural behavior of RC beams with externally bonded FRP reinforcements were studied by Pannirselvam, Nagaradjane and Chandramouli (2009).The analysis was carried out by casting five rectangular beams bonded with four different types of GFRP. The result showed that the beams strengthened with GFRP laminates exhibited better performance. Saadatmanesh and Ehsani (1991) performed experimental study on flexural strength of reinforced concrete beams by using GFRP. Total five rectangular beams and one

T-beam were tested under four point loading. The test result indicated that the epoxy bonded plates delayed formation of cracks and increased in flexural strength. Ameli et al**.,** (2007) made an investigation on reinforced concrete beams subjected to torsion and strengthened with FRP wraps in different configurations. The result showed that FRP wraps increase the ultimate torque of fully wrapped beams considerably in addition to enhance ductility. The effects of two types of fiber sheets namely carbon and glass fiber sheets on the flexural behaviors of RC beams when they are boned to tension zones of beams were studied by Lenwari and Thepchatri (2009).The flexural strength and stiffness of RC beams were found to increase significantly after installation of fiber sheets. The effectiveness of shear strengthening of continuous beams using GFRP was studied by Raj and Surumi (2012).They used two methods, i.e near surface method and externally bonded reinforced method. They found that the specimen strengthened with EBR showed an increase of 1.33 times in ultimate load as compared to control beam.

MTHEMATICAL FORMULATION

Design Mix Proportion

cement	w/c	water	sand	Coarse aggregate	
				10mm	20mm
400	0.43	172	642	619	546
1		0.43	1.6	1.547	1.36

DESIGN OF SPUN PIPE:-

Length=2mm

Internal dia=300mm

Thickness=30mm

For HYSD bar permissible stress (σst) =150 n/mm2

For rich concrete for which permissible tensile stress is 2.8 n/mm2

Subjected to water pressure=7m of head

Effective pressure= 4 times of working stress=28 m head of water

Pressure (p) = w. h = 2744400 n/mm2

Hoop tension pt=(p.d)/2=41160 n/mm2

M=7m, for HYSD bar permissible stress = 150 n/mm2

Area of hoops, A sw = pt/(σ st)= 260mm

Spacing of 6mm Ø bar hoops.

Actual Ash = 260mm2

Spacing = 1000× (AØ)/Ash = 150

Hence use 6mm Ø bar hoops a spacing of 150mm c/c

Thickness of pipe given by, pt/ (1000T+(m-1)Ash) = 2.7

T=30mm

Figure-1 Casting of pipe

Figure-2 After Casting

Data **:**
Manhole cover diameter = 330 + 35 + 35 = 400 mm

Thickness = 55mm

Clear cover = 15 mm

Radius (r) = 200mm

Diameter of bar = 6mm

F_{ck} =35N/mm^2

F_y = 415 N/mm^2

Depth Calculations:

Thickness = 55mm

Adopt overall depth (D) = 60mm

Effective depth (d) = 42mm

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Steel Calculation :

$$M_u = 0.87 f_y A_{st} d \left[1 - \left(\frac{A_{st} f_y}{bdf_{ck}} \right) \right]$$

Solving A_{st} =175.3mm^2

Provide 6mm diameter bars,

$$Spacing = \frac{\frac{\pi}{4} \times (\phi)^2}{A_{st}} \times 1000 = 161.2mm$$

$$Number\ of\ steel\ reinforcement(n) = \frac{A_{st}}{-X(\emptyset)} = 6Nos$$

Spacing provided = 65mm

So provide 6mm dia. bars at 65mm c/c spacing.

EXPERIMENTAL PROCEDURE

The experimental results of SET I pipe (weak in flexure) and SET II pipe (weak in shear). Their behaviour throughout the static test to failure is described using recorded data on deflection behaviour and the ultimate load carrying capacity. Two sets of pipe were tested for their ultimate strengths. In SET I three pipes (F1, F2 and F3) weak in flexure are tested. In SET II three pipes (S1, S2 and S3) weak in shear are tested. The pipes F1and S1 were taken as the control pipe. It was observed that the pipe F1 and S1 had less load carrying capacity when compared to that of the externally strengthened pipes using GFRP sheets. In SET I pipe F2 is strengthened only at the pipe of the pipe and F3 is strengthened up to the neutral axis of the pipe along with the soffit of the pipe. SET II pipe S2 is strengthened only at the sides of the pipe in the shear zone and S3 is strengthened by wrapping of the GFRP sheets in the shear zone of the pipe .Deflection behaviour and the ultimate load carrying capacity of the pipes were noted. The ultimate load carrying capacity of all the pipe along with the nature of failure is given.

RESULTS AND DISCUSSION

A number of failure modes have been observed in the experiments of RC pipe strengthened in flexure and shear by FRPs. These include flexure failure, shear failure, flexural failure due to GFRP rupture.

The FRP strengthened pipe and the control pipes were tested to find out their ultimate load carrying capacity. It was found that the control pipe F1 and S1 failed in flexure and shear showing that the pipe was deficient in flexure and shear respectively. In SET I pipe F2 failed due to fracture of GFRP sheet in two pieces and then flexural-shear failure of the pipe took place. pipe F3 failed due to delamination of the FRP sheet after that fracture of FRP sheet took place and then flexural-shear failure of the pipe. In SET I pipe F2 and F3, GFRP rupture and flexural-shear Curve is plotted for the entire three pipe. From this load vs deflection curve, it is clear that pipe F1 has lower ultimate load carrying capacity compared to pipe F2 and F3. Pipe F1 had also undergone higher deflection compared to pipe F2 and F3 at the same load. Pipe F2 had higher ultimate load carrying capacity compared to the controlled pipe F1 but lower than pipe F3. pipe F3 had higher ultimate load carrying capacity compared to the pipe F1 and F2. Both the pipe F2 and F3 had undergone almost same deflection upto 50 KN load. After 50 KN load pipe F3 had undergone same deflection as pipe F2 but at a higher load compared to pipe F2. The deflection undergone by pipe F3 is highest. Pipe F2 had undergone higher deflection than pipe F1

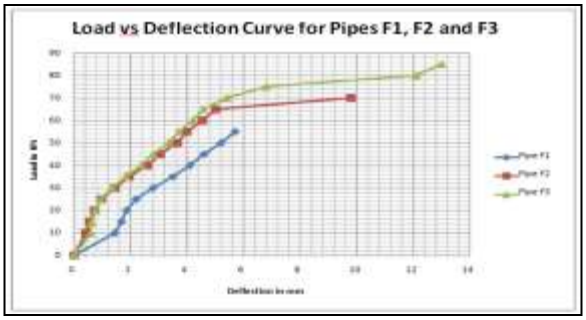

Figure 3 Load deflection curve for pipes F1,F2 and F3

From the load and deflection of data of SET I pipe F1, F2 and F3, load vs deflection From the load and deflection of data of SET II pipe S1, S2 and S3, load vs deflection curve is plotted for all the three pipe. From this load vs deflection curve, it is clear that pipe S1 has lower ultimate load carrying capacity compared to pipe S2 and S3. Pipe S1 had also undergone higher deflection compared to beams S2 and S3 at the same load. Pipe S2 had higher ultimate load carrying capacity compared to the controlled pipe S1 but lower than pipe S3. Pipe S3 had higher ultimate load carrying capacity compared to the pipe S1 and S2. Both the pipe S2 and S3 had undergone almost same deflection upto 80 KN load. After 80 KN load pipe S3 had undergone same deflection as pipe S2 but at a higher load compared to pipe S2. The deflection undergone by pipe S3 is highest. Pipe S2 had undergone higher deflection than pipe S1.

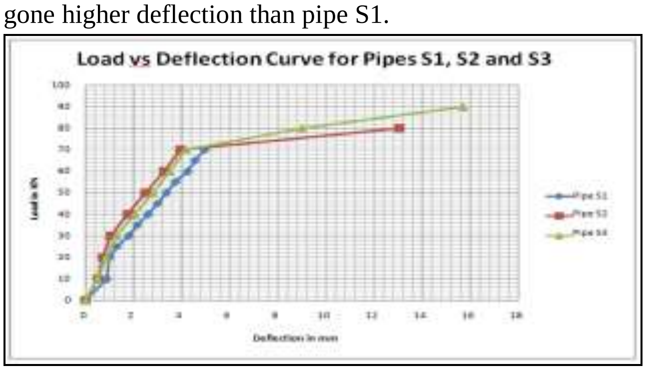

Figure 3 Load deflection curve for pipes S1,S2 and S3

In this experiment, the study of the behavior of manhole covers was based upon three light duty circular manhole cover specimens. All the specimens have dimensions (of 400mm in diameter and 55mm in thickness) and concrete compressive strength equal to 35Mpa at age of 28 days. All three specimens were reinforced by one bottom layer of (6mm in diameter) steel bars spaced at 65mm c/c in x and y directions and arranged to give a clear concrete cover of (15mm).

Among three manhole cover, specimen-1 was not strengthened by GFRP and considered as control or reference manhole cover (CM0) and other two (SM4, SM8) were strengthened with externally bonded GFRP sheets with four and eight layers respectively.

Casting of Manhole cover:

A proportion of 1:1.6:2.907 is taken for cement, fine aggregate and course aggregate for casting of manhole covers. The mixing of these materials is done by using concrete mixture. The manhole cover is cured for 28 days. Nine cubes are casted and tested after 28 days to determine the compressive strength of concrete for 28 days.

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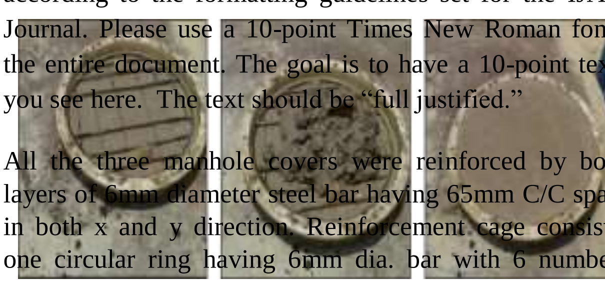
All the three manhole covers were reinforced by bottom layers of 6mm diameter steel bar having 65mm C/C spacing in both x and y direction. Reinforcement cage consists of one circular ring having 6mm dia. bar with 6 number of



main rod and 6 number of distribution rod (both have also 6mm dia. bar).

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Strengthening of Manhole Cover:

Sheets of bi-directional weaves are used. The ratio of mixing of resin and hardener was 10:1. A calculated amount of epoxy resin and hardener, by ratio 10:1 by weight was mixed thoroughly with gentle stirring to minimize air entrapment. After uniform mixing, fabrics are neatly measured and cut according to size then epoxy resin is applied to concrete surface of manhole cover SM4 and manhole cover SM8.

Before wrapping the specimens with GFRP Sheet (woven fiber), a surface preparation was carried out, which included cleaning and forming one layer of epoxy with hardener for bonding GFRP Sheets on manhole cover. Additional layers of epoxy with hardener were applied on GFRP sheets. In this way the other two specimens were wrapped externally by 4 and 8 layers of GFRP Sheets respectively.This operation is carried out at room temperature. Concrete manhole covers strengthened with glass fiber fabric are cured for 48 hours at room temperature before testing.

CONCLUSION

In present work, the conventional structure is modified to study the effects on structure and stability of laminated composites. Analysis for Glass/Epoxy woven fabric composite pipe subjected to different properties which are carried out experimentally. The board conclusions that can be made from the present study are as follows:

- There is a good agreement between the experimental and test results for safe load test.
- The FRP laminated structures deformation will decreases as compare to conventional structure.
- The maximum impact strength is obtained for fiber composites.
- Flexural strength of composite laminate is majorly controlled by the strength of outer layer which is in direct contact to leading load.
- The interlacing of yarns present in woven fabric offers higher stiffness against impact load and thus woven fabric composites have higher impact strength than nonwoven counter parts.

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