Strength and Durability Characteristics of Fibre Reinforced Concrete

Shankarkumar V[1], Arun K[2], Dhivya P[3], Mahesh Kumar M[4], Suresh Babu R[5]

[1]Assistant Professor, Indra Institute of Engineering and Technology, Chennai

[2, 3]Assistant Professor, Vel Tech High Tech Dr.Rangarajan Dr.Sakunthala Engineering College, Avadi, Chennai

[4, 5]Final Year Student, Vel Tech High Tech Dr.Rangarajan Dr.Sakunthala Engineering College, Avadi, Chennai

Abstract: ***Invention of new methods in strengthening concrete is under work for decades. On the track of such invention Fiber Reinforced Composite materials plays a significant role. The main function of fiber reinforcement is to carry the load along its length and also to provide stiffness and strength in one direction. FRP thus alters the compressive strength, tensile strength and flexural strength of concrete to a good extent and hence it imprints as a good solution for strengthening concrete. FRP materials can be externally bonded or wrapped to the existing structure; hence they can also be used for rehabilitation works. There are three major types of fiber reinforced polymers used in construction works. They are Glass fiber reinforced polymer (GFRP), Carbon fiber reinforced polymer (CFRP) and Aramid fiber reinforced polymer (AFRP). In the present investigation the effect of GFRP on M25 and M50 concrete mix is studied at two cases. First, Effect of GFRP on the compressive and flexural strength of M25 and M50 concrete mix with respect to number of layers, and secondly Effect of GFRP on compressive strength M25 and M50 concrete mix with respect to number of layers at 200^{0}C temperature which is termed as durability studies.***

Keywords: Glass fibre reinforced polymer, Carbon fibre reinforced polymer, Creep, Durability.

1. Literature Review

Yaquband Bailey (2011) studied repair of fire damaged circular reinforced concrete columns with FRP composites. An experimental study was undertaken to investigate the axial capacity of post-heated circular reinforced concrete columns repaired with glass and carbon fiber reinforced polymers. The results indicated that repairing heat damaged circular columns with a single layer of unidirectional glass or carbon fiber reinforced polymer has a significant effect on the axial strength and the ductility of circular columns. It was shown that the load-carrying capacity of post-heated columns can be restored up to the original level or greater than those of un-heated columns. However, it was shown that the effect of a single layer of glass or carbon fiber reinforced polymer on the axial stiffness was not significant. Sangeetha and Sumathi (2010) studied behaviour of glass fiber wrapped concrete columns under uniaxial compression. Fiber – wrapping using fiber – reinforced Plastic (FRP) shells is one of effective methods, significantly enhances the strength and ductility of concrete columns. The paper reports the behaviour of the GFRP wrapped concrete columns under uniaxial compression. The cross section of the concrete columns considered in the work is circular with diameter of 150mm and height 300mm. The Parameters that are varied in the investigation

Are wrapping shell materials, (which includes GFRP Materials Surface Mat(SM), Chopped Strand Mat (CSM) and Woven Roving Mat (WRM)), Number of Plies (1Ply and 3plies) and Period of Curing (7 & 28 Days). Results from a series of the experimental study were reported and discussed. The study on small – scale specimens showed that confinement increased the strength of the concrete columns loaded axially. Yourself Al-Salloum and Hussein Elsanadedy et al. (2011) studied behavior of FRP-confined concrete after high temperature exposure. This paper presents the results of an experimental program to investigate the effect of high temperature on the performance of concrete externally confined with FRP sheets. The objective of this testing was to evaluate the degradation in bond strength between FRP and concrete substrate when exposed to elevated temperature environments. One prism was exposed to room temperature whereas the other two specimens were exposed to heating regime of 100^{o}C and 200^{o}C for a period of 3 hours. It was concluded that a significant degradation in the bond strength occurred at a temperature of 200^{o}C especially for CFRP-overlaid specimens.

2. Materials Used

The ordinary Portland cement of grade (53) is used for the present investigation and tested as per IS 12269-1987. Natural river sand with fineness modulus 3.12 and specific gravity of 2.5.Coarse aggregate of size 20mm has been selected for the study. The fineness modulus of coarse aggregate is 5.94 with specific gravity of 2.7. Fiber used is GFRP. The present work considers the epoxy resin as a bonding material. The properties of GFRP are shown in table1. Table 1.a. shows the mix proportion adopted from IS 10262:2009.

Table 1: Physical and mechanical properties of glass fiber reinforced polymer

FRP	*Tensile strength (MPa)*	*Young's modulus (GPa)*	*Ultimate strain (%)*	*Thickness (mm)*
GFRP	2270	72	3.2	1.30

Table 1.a: Mix proportion (IS 10262:2009)

Concrete Mix	*Water content*	*Cement*	*Fine aggregate*	*Coarse aggregate*
M25	0.45	1	1.57	2.66
M50	0.42	1	1.35	2.39

3. Results and Discussions

3.1 Test for compressive strength

Concrete was made according to the above mentioned mix design and the slump value was checked. Slump value was found to be 50mm (low slump).Compression test was carried out on cylindrical specimen wrapped with 1, 2, 3 layers of GFRP. Cylinders of size 15cm X 30cm (as per IS: 10086-2009) were cast. Specimens were tested on 28days curing as per IS 516 -1959 and the results are tabulated below in table2 and table3 for both M25 and M50 concrete respectively. Fig1 and Fig2 show the stress strain curve of M25 and M50 concrete respectively. Fig3 shows the casting and testing of specimens.

Table 2: Compressive strength for M25 concrete

Specimens	*Ultimate load(KN)*	*Compressive strength (N/mm^2)*	*Percentage of increase in strength (%)*
C	*333*	*18.87*	*-*
GF_1	*557*	*31.52*	*67*
GF_2	*764*	*43.28*	*129*
GF_3	*843*	*47.72*	*150*

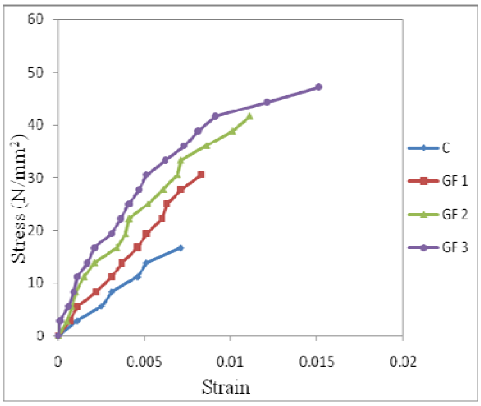

Figure 1: Stress strain curve of M25 concrete

Table 2 and Fig.1 shows the compressive strength (M25 grade) at 28 days for GFRP wrapped concrete of 1, 2, 3 layers. The rate of increase in compressive strength was 67%, 129%, 150% respectively for 1, 2, 3 layers of GFRP wrapped concrete when compared to conventional concrete.

Table 3: Compressive strength for M50 concrete

Specimens	*Ultimate load(KN)*	*Compressive strength(N/mm^2)*	*Percentage of increase in strength (%)*
C	588	33.30	-
GF_1	735	41.62	25
GF_2	853	48.28	45
GF_3	961	54.38	63

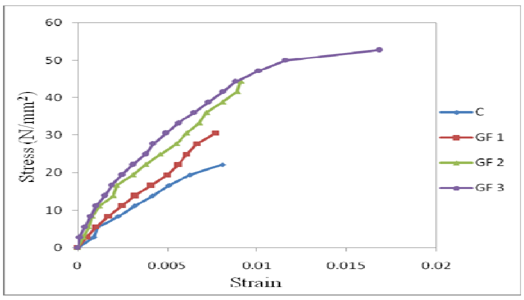

Figure 2: Stress strain curve of M50 concrete

Table3 and Fig.2 show the compressive strength (M50 grade) at 28 days for GFRP wrapped concrete of 1, 2, 3 layers. The rate of increase in compressive strength was 25%, 45%, 63% respectively for 1, 2, 3 layers of GFRP wrapped concrete when compared to conventional concrete.

Figure 3: Casting and testing of cylindrical specimens

3.2 Test for flexural strength

Flexural strength test was carried out on the beam of dimension 10cm*10cm*50cm of M25 and M50 concrete. Specimens were cast and wrapped with 1, 2, 3 layers of GFRP and the test carried out based on standard procedures. The results were tabulated below. Specimens were tested on 28days curing as per IS 516 -1959 and the results are tabulated below in table4 and table5 for both M25 and M50 concrete respectively. Fig4 and Fig5 show the load deflection curve of M25 and M50 concrete respectively.

Table 4: Flexural strength for M25 concrete

Specimens	Ultimate load(KN)	Modulus of Flexure(N/mm^2)	Percentage of increase in strength (%)
C	11.77	5.885	-
GF_1	17.66	8.830	50
GF_2	25.51	12.755	116.7
GF_3	35.32	17.660	200

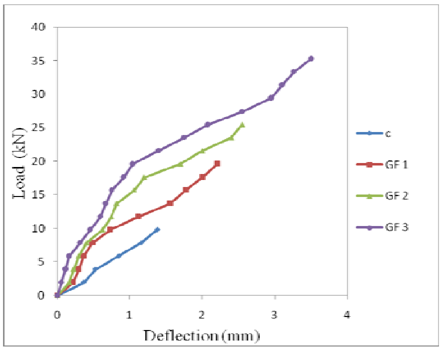

Figure 4: Flexural strength of M25 concrete

Table4 and Fig.4 show the flexural strength (M25 grade) at 28 days for GFRP wrapped concrete of 1, 2, 3 layers. The rate of increase in flexural strength was 50%, 116.7%, 200% respectively for 1, 2, 3 layers of GFRP wrapped concrete when compared to conventional concrete.

Table 5: Flexural strength for M50 concrete

Specimens	*Ultimate load (KN)*	*Modulus of flexure (N/mm^2)*	*Percentage of increase in strength (%)*
C	13.73	6.865	-
GF_1	19.63	9.815	30
GF_2	29.43	14.715	114.3
GF_3	39.24	19.620	185.8

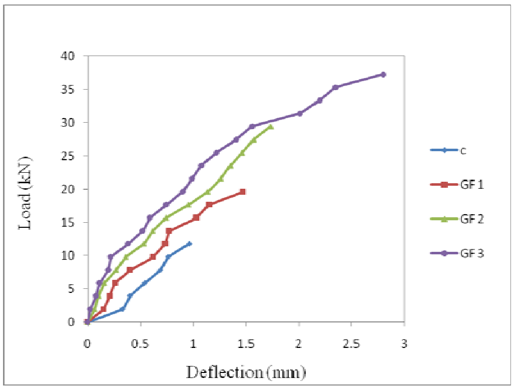

Figure 5: Flexural strength of M50 concrete

Table5 and Fig.5 show the flexural strength (M50 grade) at 28 days for GFRP wrapped concrete of 1, 2, 3 layers. The rate of increase in flexural strength was 28.6%, 114.3%, 185.8% respectively for 1, 2, 3 layers of GFRP wrapped concrete when compared to conventional concrete.

Figure 6: GFRP wrapped beams and beams under testing

3.3 Durability Test

FRP is a passive reinforcement, which directly depends upon the type of fibers and bonding agent, direction of wrap and other environmental factors. Present study investigates; the behaviour of GFRP wrapped specimens at various temperatures. When temperature of GFRP becomes greater than or equal to the glass transition temperature T_g of the resin, GFRP jackets experienced severe damage resulting creep and melting of epoxy. The damage was more severe after 3 hours of fire exposure. When the specimens were heated to temperature equal to twice the glass transition temperature $2T_g$ for a time period of 3 hours it was found that their strength reduced significantly. The effect of increase in temperature environments on performance of concrete cylinders confined/wrapped with FRP-strengthening system need to be studied. For this study, unconfined as well as FRP-confined concrete cylinders were made and then exposed to room temperature and heating regimes of 200°C for a period of 3 hours. After being exposed to high temperatures, cylinders were tested under uniaxial compression up to failure. Fig.7 shows the oven dried specimen and testing of oven dried specimen.

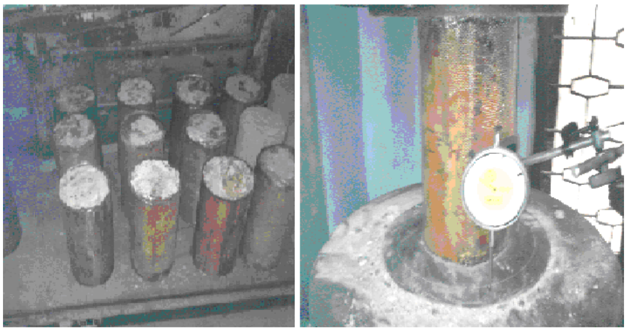

Figure 7: Specimen after oven drying and oven dried specimen under testing

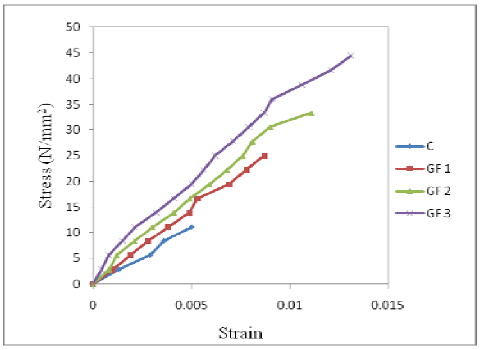

Figure 8: Stress strain curve of M25 concrete at 200^0c

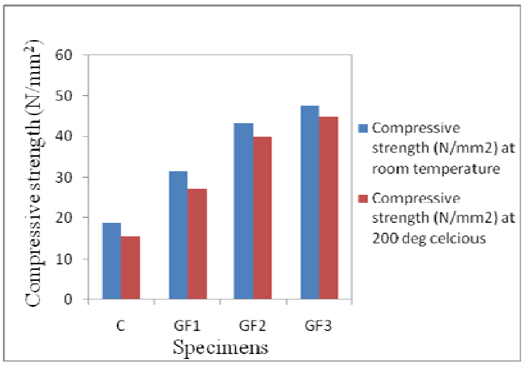

Figure 9: Compressive strength for M25 concrete at room temperature and 200^0c

From fig8 and fig9 we understand that the rate of increase in compressive strength was 74%, 157%, 185% respectively for 1, 2, 3 layers of GFRP wrapped concrete when compared to conventional concrete. The rate of decrease in compressive strength at 200^0c was 21%, 15%, 8%, 6% respectively for 0, 1, 2, 3 layers of GFRP wrapped concrete when compared to the test which has been carried out in normal room temperature. The reason for reduce in strength is the partial evaporation of inner moisture at 200^0c where these places remains as voids which results in reduce of strength. At 200^0c the bond between specimen and GFRP is non-uniform since the Epoxy resin starts melting down. These are the reasons for decrease in strength.

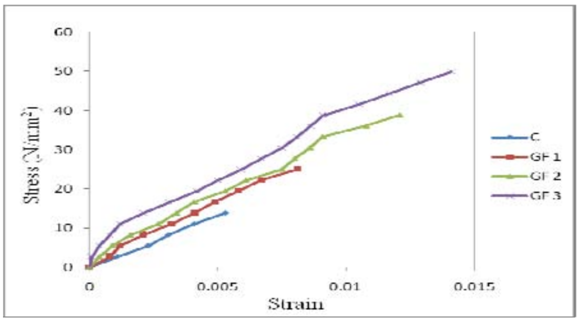

Figure 10: Stress strain curve of M50 concrete at 200^0c

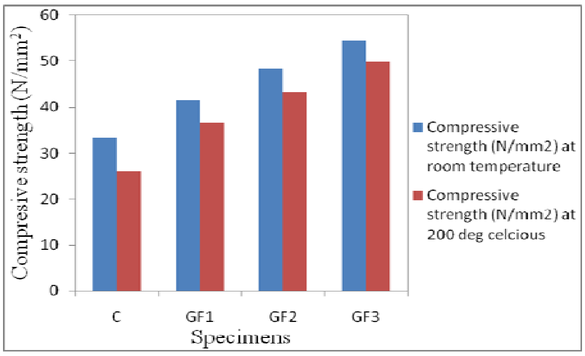

Figure 11: Compressive strength for M50 concrete at room temperature and 200^0c

From fig10 and fig 11 we infer that the rate of increase in compressive strength was 40%, 66%, 91% respectively for 1, 2, 3 layers of GFRP wrapped concrete when compared to conventional concrete. The rate of decrease in compressive strength at 200^0c was 27%, 13%, 11%, 8% respectively for 0, 1, 2, 3 layers of GFRP wrapped concrete when compared to the test which has been carried out in normal room temperature

4. Conclusions

- For M25 grade of concrete the rate of increase in flexural strength was 50%, 116.7%, 200% respectively for 1,2,3 layers of GFRP wrapped concrete when compared to conventional concrete.
- For M50 grade of concrete the rate of increase in flexural strength was 28.6%, 114.3%, 185.8% respectively for 1,2,3 layers of GFRP wrapped concrete when compared to conventional concrete.
- For M25 grade of concrete the rate of increase in compressive strength was 67%, 129%, 150% respectively for 1,2,3 layers of GFRP wrapped concrete when compared to conventional concrete.
- For M50 grade of concrete the rate of increase in compressive strength was 25%, 45%, 63% respectively for 1,2,3 layers of GFRP wrapped concrete when compared to conventional concrete.
- Due temperature effect (at 200^0c), For M25 grade of concrete the rate of increase in compressive strength was 74%, 157%, 185% respectively for 1, 2, 3 layers of GFRP wrapped concrete when compared to conventional concrete. The rate of decrease in compressive strength at 200^0c was 21%, 15%, 8%, 6% respectively for 0, 1, 2, 3 layers of GFRP wrapped concrete when compared to the test which has been carried out in normal room temperature.
- Due temperature effect (at 200^0c), For M50 grade of concrete the rate of increase in compressive strength was 40%, 66%, 91% respectively for 1, 2, 3 layers of GFRP wrapped concrete when compared to conventional concrete. The rate of decrease in compressive strength at 200^0c was 27%, 13%, 11%, 8% respectively for 0, 1, 2, 3 layers of GFRP wrapped concrete when compared to the test which has been carried out in normal room temperature.

References

[1] Andrea Prota, Gaetano Manfredi and Edoardo Cosenza (2006), "Ultimate behavior of axially loaded RC wall-like columns confined with GFRP", Composite Structures journals Vol. 37, pp.670–678.

[2] Huang Gu and ZuoZhonge (2005), "Compressive behaviour of concrete cylinders reinforced by glass and polyester filaments" Materials and Design Vol.27, pp. 601–604.

[3] Huang Gu and Zuo Zhonge (2004), "Compressive behaviours and failure modes of concrete cylinders reinforced by glass fabric" Materials and Design Vol.26, pp. 450–453.

[4] Houssam Toutanji A. and William Gomezb (1997), "Durability characteristics of concrete beams externally bonded with FRP composite sheets", cement and concrete composites Vol.19, pp. 351-358.

[5] Kumutha R., Vaidyanathan R. and Palanichamy M.S. (2007), "Behaviour of reinforced concrete rectangular columns strengthened using GFRP", Cement & Concrete Composites journal Vol.29,pp.609–615.

[6] Kumar Singh, Guoqiang Li and Dinesh Maricherla (2005), "Effect of fiber orientation on the structural behavior of FRP wrapped concrete cylinders", Composite Structures journals Vol.74, pp. 475–483.

Author Profile

Arun K received the B.E degree in Civil engineering from Raja Rajeshwari Engineering College in 2008 and received M.E degree in Construction engineering and management from Anna University (CEG) in 2010.

Dhivya P received the B.E degree in Agriculture and Irrigation engineering from Anna University (CEG) in 2010 and received M.E degree in integrated water resource management from Anna University (CEG) in 2012.

Suresh Babu R is persuing B.E (final Year) civil engineering in Vel Tech High Tech Dr.Rangarajan Dr.Sakunthala Engineering College.

Mahesh Kumar M is persuing B.E (final Year) civil engineering in Vel Tech High Tech Dr.Rangarajan Dr.Sakunthala Engineering College.