IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Vol. 6, Issue 8, August 2019

Strengthening of Concrete by GFRP and CFRP Wrapping

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Abstract: In recent Fiber Reinforced Polymers (FRP) is being introduced in a wide variety of civil engineering applications. This material is also used for strengthening of reinforced concrete structures. Strengthening of concrete structure is required for increasing the capacity of the structural members to sustain additional loads caused due to change in live load, design error, age of structure etc. The strengthening of concrete with CFRP wrapping seems to improve strength of concrete. Methods for strengthening include FRP wrapping, concrete jacketing etc. Strength of RC structure components are found to be reduced, before the service period is over due to several causes. These structures require strengthening to improve its capacity, hence the FRP wrapping is carried out. FRP wrapping is done from one layer to no. of layers as per the strength requirement of the structure. In this study experiment is carried out on M20 and M25 grade concrete. Total 60 cubes are moulded out of which 12 are control specimens and 48 cubes of which 24 cubes of M20 concrete and 24 of M25 concrete. Total 24 cubes include 6 of 50% distress, 6 of 60% distress for GFRP and same for CFRP for M20 concrete. Same set of 24 cubes were moulded and distressed for M25 concrete. Distressing was done with respect to average compressive strength of control specimens. All distressed Cubes were tested under CTM after FRP wrapping. The test results reveals that the strength of distressed concrete wrapped with GFRP and CFRP was found to be increased from 24% to 63% as compared to conventional concrete M20 grade. Similarly for conventional concrete of M25 grade the compressive strength was found to be increased from 12% to 32% when wrapped with GFRP and CFRP.

Keywords: Compression Compressive strength, Glass Fiber Reinforced Polymer (GFRP), Carbon Fiber Reinforced Polymer (CFRP), Compression Testing Machine (CTM)

I. INTRODUCTION

Today concrete is most widely used construction material due to its good compressive strength. During the design of concrete structure they are susceptible for damage by faulty construction, deficiency of material used , improper design, lack of regular maintenance, earthquake etc Severe earthquake structure undergo inelastic deformation and has to depend on ductility and energy absorption capacity to avoid collapse. Therefore strengthening of concrete has to be done to increase strength, stiffness and ductility. In such condition there are two possible solutions first is replacement or retrofitting. Replacement requires high cost of material and labour. It's the best way to repair or upgrade by strengthening the structure. FRP are applied to structure with the primer and saturant which gives good bond with the concrete . FRP are good compared to other retrofitting techniques due to various reasons. Main reason is they have higher ultimate strength and lower density compared to steel. FRP is used because of its easy applications. We can apply this FRP sheets to any odd shape and is less labour intensive. In this paper GFRP and CFRP wrapping is used to strengthen the distressed concrete cubes.

II. METHODOLOGY

An experimental investigation is to be carried out to evaluate the strength of distressed concrete cubes by GFRP and CFRP wrapping on four sides. Total 30 cubes of M20 and 30 cubes of M25 grade of concrete of standard size were casted. All specimens are tested after 28 days of curing period. Total 12 cubes were distressed at 50% of average load carrying capacity, and 12 cubes were distressed at 60 % of average load carrying capacity for M20 grade concrete. Out of 12 cubes, 6 cubes were distressed at 50% and wrapped with GFRP and 6 cubes with CFRP. Out of 12 cubes 6 cubes were distressed at 60% and wrapped with GFRP and 6 cubes with CFRP for M20 grade concrete. Same procedure of distressing and wrapping was followed for M25 grade concrete. After wrapping of GFRP and CFRP all cubes were tested on compression testing machine.

III. EXPERIMENTAL WORK

A. Procedure for casting of cubes and Distressing of specimen.

IS-456 has laid down the acceptance criteria of quality concrete. In all the cases, the 28-days compressive strength shall alone be the criteria for acceptance or rejection of the concrete. The cube mould plates should be properly cleaned and all the bolts should be fully tight. A thin layer of oil then shall be applied on all the faces of the mould. The concrete sample shall be filled into the cube moulds in 3 layers, each layer approximately 5 cm deep. Each layer shall be compacted either by hand or by the vibration. Each layer of the concrete filled in the mould shall be compacted by not less than 35 strokes by tamping bar. Where voids are left by the tamping bar the sides of the mould shall be tapped to close the voids.Casted cubes are stored in vibration free area for 24 hrs. After 24 hrs moulds are open and cubes are kept in curing tank for 28 days age of curing. Cubes are removed and natural dried after 28 days. 6 cubes of M20 and 6 cubes of M25 are tested for Compressive strength. Cubes distressed at 50% of average compressive strength and cubes distressed at 60% of average compressive strength for M20 and M25 grade concrete. Total 12 cubes are 50 % distressed out of which 6 cubes for GFRP and 6 cubes for CFRP. Total 12 cubes are 60% distressed out of which 6 cubes for GFRP and 6 cubes for CFRP.

Cubes were distressed in compression testing machine.
1)Average compressive strength = 453.16 kN of M20 for 28 days. Distress cubes of 50% average compressive strength marked with (A)= 226.58 kN and for 60% marked with (B)=271.896 kN.
2)Average compressive strength = 573.83 kN of M25 for 28 days. Distress cubes of 50% average compressive strength marked with (C)= 286.915 kN and for 60% marked with (D)=344.298 kN.

Fig. 1. Casting of cubes

B. Material used for retrofitting

Glass fiber reinforced polymer: Tensile strength (MPa):-2060, Density of wrap:-900 gm/m²

Carbon fiber reinforced polymer: Tensile strength (MPa):-3800, Density of wrap: -1.74gm/m²

Sealant , Primer and Saturant: Sealant is applied with trowel to get even surface of the cubes. After drying of sealant primer is applied.After drying of primer saturant is applied with the GFRP and CFRP wrap.

C. Wrapping of distressed cubes with GFRP and CFRP.

After distressing of cubes, loose concrete is removed and cleaned with iron brush. Corners of cubes are rounded with grinder. Sealant is applied with the help of trowel to the faces , and corners of cubes to get even surface on the cubes. After drying of sealant one coat of primer is applied to the cubes with brush to get smooth finish.

Fig. 2. Surface prepared cubes

After drying of primer , one coat of saturant is applied to the cubes. GFRP and CFRP is wrapped to cubes without drying of saturant. Next day one more coat is applied and kept for drying.

Fig. 3.Application of saturant

D. Testing of GFRP and CFRP wrapped cubes: After complete drying of 2nd coat of saturant they are tested in CTM.

Fig. 4. Testing of cubes on CTM

Compressive strength results for M20 concrete cubes shown below.

Table 1.Compressive strength of M20 cubes wrapped with GFRP and CFRP.

	Cubes wrapped with GFRP		Cubes wrapped with CFRP	
	A (50%) kN	B (60%) kN	A (50%) kN	B (60%) kN
M20 (Avg.) = 453.16 kN	638	557	743	670
	642	572	738	665
	648	579	745	672
	654	554	749	680
	628	564	736	689
	635	568	747	683
Average	640.83	565.66	742.2	676.5
Increase in strength	41.41%	24.28%	63.78%	49.28%

Compressive strength results for M25 concrete cubes shown below.

Table 2. Compressive strength of M25 cubes wrapped with GFRP and CFRP.

	Cubes wrapped with GFRP		Cubes wrapped with CFRP	
	A (50%) kN	B (60%) kN	A (50%) kN	B (60%) kN
M25 (Avg.) = 573.83 kN	669	640	784	721
	666	632	757	719
	679	652	760	747
	677	645	756	726
	686	659	750	723
	663	647	757	740
Average	673.33	645.83	761.4	729.33
Increase in strength	17.33%	12.54%	32.68%	27.09%

E. Graph: Graph of percent increase in strength to the compressive strength of conventional concrete cubes when they are 50% and 60 % distressed for M20 concrete cubes.

 DOI 10.17148/IARJSET.2019.6812

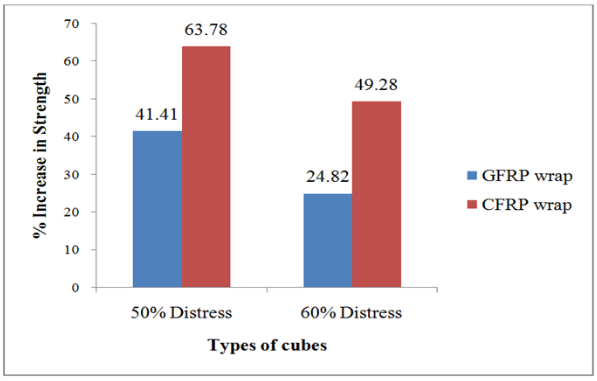

Fig.5. Percent increase in strength.

Graph of percent increase in strength to the compressive strength of conventional concrete cubes when they are 50% and 60 % distressed for M25 concrete cubes.

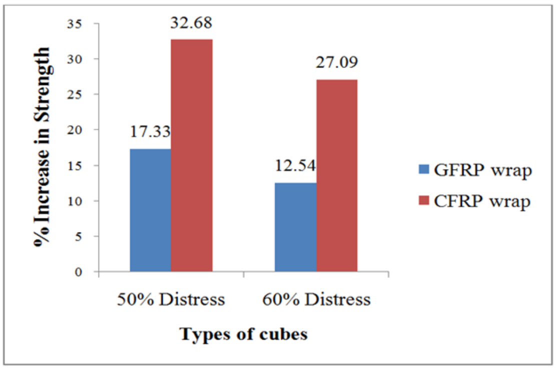

Fig.6. Percent increase in strength

F. Observation

These are the observed failure on GFRP wrapped cubes shown below.

Fig.7 Fiber ruptured at face of cube and corners

These are the observed failure patterns on CFRP wrapped cubes shown below.

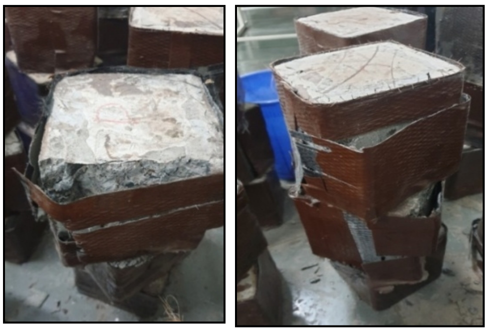

Fig.8 Opening of lapping joint

IV. CONCLUSION

Based Based on observation and results following are the conclusions from experimental investigation:

1) Compressive strength of conventional concrete M20 grade increases to 41.41% for GFRP and 63.78% for CFRP when cubes were distressed by 50% of average compressive strength.
2) Compressive strength of conventional concrete M20 grade increases to 24.82% for GFRP and 49.28% for CFRP when cubes were distressed by 60% of average compressive strength.
3) Compressive strength of conventional concrete M25 grade increases to 17.33% for GFRP and 32.68% for CFRP when cubes were distressed by 50% of average compressive strength.
4) Compressive strength of conventional concrete M25 grade increases to 12.54% for GFRP and 27.09% for CFRP when cubes were distressed by 60% of average compressive strength.
5) Comparing the one wrap of GFRP and CFRP wrapping on M20 and M25 grade, CFRP provides more compressive strength compared to GFRP.
6) Failure of wrapping material was observed at lap joint hence lap length should be increased.

ACKNOWLEDGMENT

Project work was carried out using the facilities in Civil Engineering Department laboratory of MIT-SOE, lonikalbhor Pune. I express my heartiest gratitude and sincere thanks to my project guide **Prof. Dr. Kishore Ravande**, principal, Department of Civil Engineering, and co-guide **Prof. Abhijeet Galatage, Prof. Dr. SatishPatil** Head of Department of civil engineering, for their valuable guidance, authorities and expert comments. Finally I am thankful to the supporting staff and all those who directly or indirectly contributed to this project work.

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