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Epoxy Resin Vs MBC Binder for GFRP Retrofit Structures

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Abstract: ***Retrofitting is a process of strengthening the structural components of a building using various techniques in order to make it a safe place for habitation. This paper deals mainly about the cost effective and efficient way of retrofitting the structural elements of a building using fiber reinforced polymer grids bonded with inorganic resin adhesives. Here, the conventionally used epoxy binder is replaced with mineral based composites (MBC) considering the health aspects of residents and workers, environmental pollution reduction and to achieve better performance during high temperatures. The strength achieved and performance yielded by bonding Fiber Reinforced Polymers with conventional epoxy resins and mineral based composite mortar are compared and contrasted in detail with suitable graphical representations to understand the concepts better. The mix proportion of various ingredients of MBC mortar with suitable references are discussed. From the results obtained, it is concluded that MBC binder gives almost equal strength when compared with epoxy binder but proves better at extreme temperatures, provides good insulation, resists acid attack and reduces health hazards of people thereby making this process, a better one.***

Keywords: FRP, MBC, epoxy resin, retrofitting.

1. Introduction

We live in a modern world mostly containing structures made out of reinforced concrete. All these structures have a life period of their own for which it is designed. Many a times, a building deteriorates during its lifetime due to weathering, lack of maintenance or due to seismic effects. Therefore, upgradation of reinforced concrete structures becomes necessary in order to sustain in that building and to extend its life period. To serve the purpose of strengthening the damaged building, retrofitting of structural elements comes into play. No material lasts forever the same rule is applicable to the structures to. They incur damages which are categorized into two. First case is where the structural elements are not damaged and can be easily repaired second case is where they are to be replaced. Replacing a building has the following advantages such as high cost for materials and labour, inconvenience due to interruption of the functions of structures. So we adopt another technique called retrofitting. In retrofitting, there are several methods adopted such as enlarging the cross section element, shortening the span by providing the supports, external or internal post-tensioning along with steel plate bonding or using Fibre reinforced polymer composite.

2. Why not use epoxy?

To upgrade and rehabilitating the structures externally bonded FRP system is an effective method for repairing and strengthening the structures. This can be done by bonding the sheets with the use of epoxy as the bonding agent. Epoxy provides good bond strength to concrete and also it transmit a load. However, the use of epoxy agent will have several drawbacks on it. Thermosetting process of epoxies are considered to be toxic and will cause irritation when it is in contact with our skin. Additionally, epoxies will create diffusion in tight surfaces which can be subjected to freeze and thaw problems, particularly for concrete structures and also it cannot be applied on the wet surface. The solution for this was to use mineral based composites to rectify the above mentioned drawbacks.

3. Mineral Based Composites (MBC) overview

MBC (Mineral based composites) is a system in which Fiber Reinforced Polymer grid will be applied to the outermost surface of the structure which has to be strengthened by using a bonding agent such as cement-based mortar. It has excellent properties such as to bond with the base concrete and also has good workability and is economical. In addition to all of these, the bonding agent will be able to transfer its stresses to the fiber composite efficiently. The fiber composite should have excellent tensile properties and in addition to all of these, it has to be compatible with the binder or bonding agent. Generally, fine grained mortar are used as bonding agents.

4. Methodology

Firstly, a surface primer will be applied on the rough base concrete outer surface to reduce the moisture transfer from the polymer modified mortar to the dry base concrete. Second thing is to apply a layer of cementitious bonding agent on the base concrete surface which has been primed. Thirdly, FRP will be applied to the first layer of mortar and then a second layer of mortar will have been applied on the top surface of the first layer and on FRP.

4.1 Scope of study

AIM of the thesis is to carry out an experimental study on compressive strength and behaviour of stress-strain curvature of wrapping cylinder with Glass Fiber Reinforced sheet.

4.2 Materials used

Cement: Portland Pozzolona Cement
Fine aggregate: Sand according to standard specifications IS: 383-1970 belonging to zone II

Table 1: Properties of aggregate

1.	Fineness modulus	3.24
2	Specific gravity	2.64
3	Water absorption	Nil

Coarse aggregate: 20mm sized aggregates (also called as Blue Metal)
Metakaolin is a de-hydroxylated form of mineral clay called kaolinite. It is formed by calcining purified kaolinite, generally between 650–700 °C in an externally fired rotary kiln.

Figure 1: Metakaolin (strengthening agent)

Woven roving (e-glass) is a continuous glass fibers which are interlaced along with heavy weighing fabrics to make it strong. They are compatible with most of the resin systems. Woven Roving Fabrics will be able to provide the most economical and stronger solution for raising the glass content of laminates for increasing its stiffness and impact resistance without addition of any thickness, weight, or other non-reinforcing materials.

Figure 2: GFRP sheet used

Superplasticizers are also known as high water reducing agents. They are chemicals which are used as admixtures where a well-dispersed particle suspension is required. These polymers are also used as dispersants in order to avoid the aggregation of particles together and to improve the flow characteristics of suspended particles drastically as in case of concrete applications.

GLENEIUM B233 admixture is used in this project based on polycarboxylic ether. This superplasticizer is free from of chloride and it is compatible with all types of cements.

Viscosity modifying agent GLENIUM STREAM 2 is a premier ready-to-use, liquid, organic, viscosity-modifying admixture (VMA) specially developed for production of concrete with enhanced viscosity properties and with controlled rheology.

4.3 Mix Design for M30 grade

Table 2: Mix design values obtained

Water	*Cement*	*Fine Aggregate*	*Coarse Aggregate*
186 Kg/m^3	502.7 Kg/m^3	482.32 Kg/m^3	1172.67 Kg/m^3
0.37	1	0.96	2.33

Preliminary laboratory works include:
- Slump test to find the consistency of concrete.
- Sieve analysis test for fine and coarse aggregates.
- Specific gravity of aggregates.

4.4 Mixing and compaction

With specimens of 150mm x150mm x 150mm, the concrete mixture was cast in three layers with each layer receiving 25 manual strokes, and should be vibrated for 10 seconds on a vibrating table. In some cases, internal needle vibrator will be used to successfully compact the concrete mortar. After casting, the test specimen was left to air dry in ambient conditions for 24 hours. After releasing from the mould, the test specimens are cured for 28 days in water.

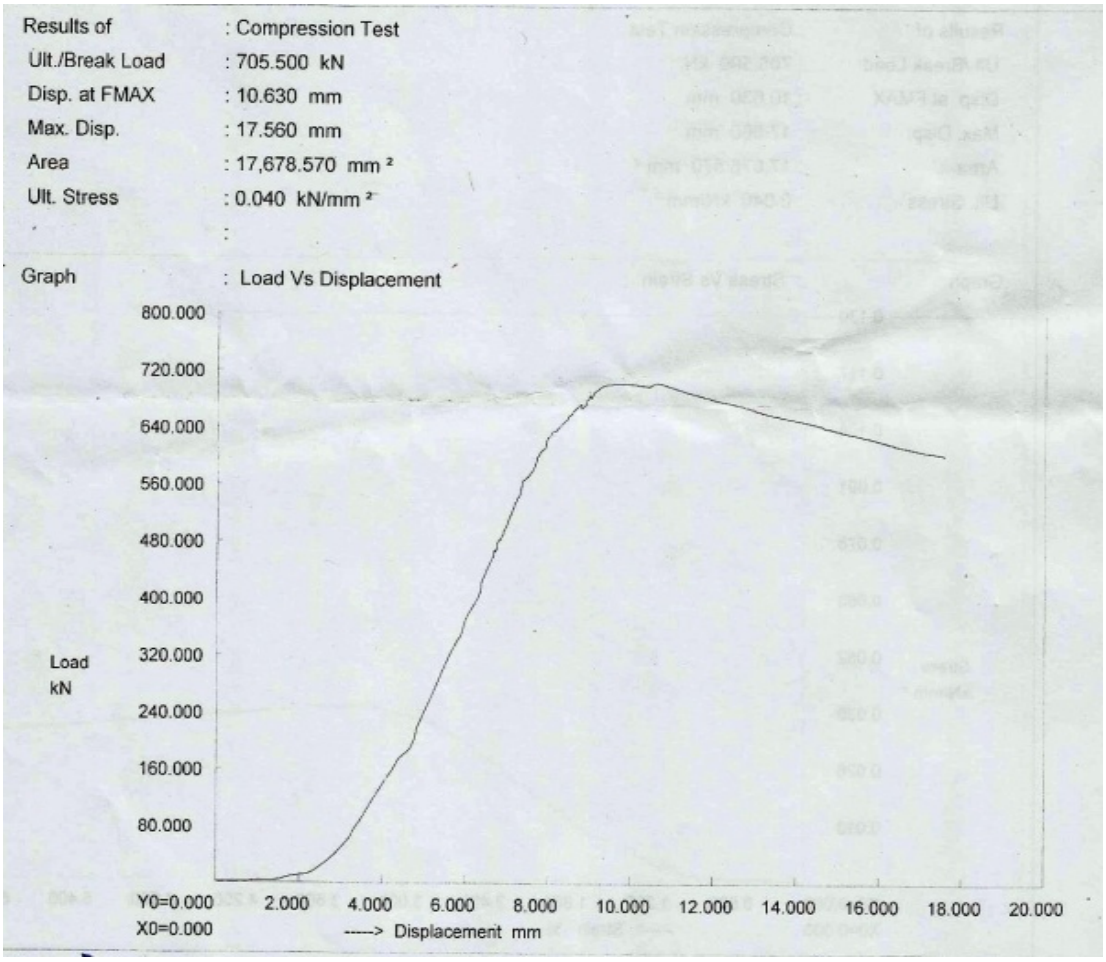

Figure 3: Stress-strain graph obtained

4.5 Wrapping on cylinders

- Specimen is dried for the surface to be free of any moisture
- Resin and hardener are mixed in proportion of 100: 35 by weight and mixed continuously for 5 minutes to have uniform color.
- Surface is made smooth by rubbing with sand paper and loose particles were removed using brush.
- One coat of epoxy was applied on the surface of cylinder.
- Cylinder was wrapped with glass fiber sheet having an overlap of 75mm to avoid failure in overlap region.
- One more layer of epoxy was applied and specimen was cured for 7 days.

4.6 Extensive testing methodology

- Control specimens were tested up to failure.
- Specimens were loaded up to first crack.
- Cracks were repaired with cement mortar and cured for seven days.
- Specimens were wrapped with one and two layer of GFRP.
- Specimen were loaded up to failure
- Repaired specimens were cured for seven days.
- Specimens were wrapped with one and two layer of GFRP.

Note: The same procedure was followed to test the cylinders wrapped with GFRP sheets

Figure 4: Woven GFRP sheet installed on cylinder specimen

4.7 Mix content and its proportion

- Cement 75g per cylinder
- Metakaloin 10% of cement
- Super plasticizers=Gelenium b233 (3%of cement)

- Viscous modifying agent=Gelenium stream II (0.04% of cement)

5. Results and Discussions

The stress-strain graphs obtained for a cylinder with single wrap of GFRP sheet using epoxy and then with MBC binder is given below.

Cylinder with single wrap: 1st-Crack with single Wrap, Full Failure cylinder with single Wrapping using EPOXY

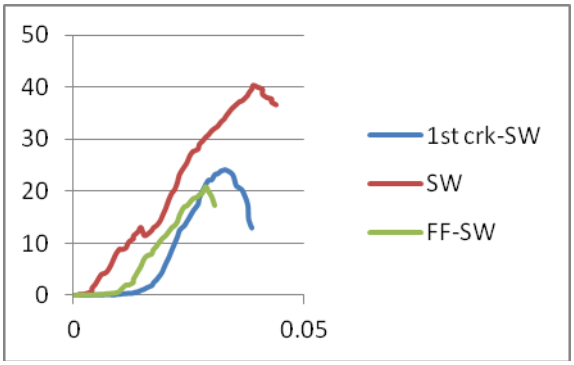

Figure 5: Epoxy resin binder - single wrapped cylinder

Cylinder with single wrap: 1st-Crack with single Wrap, Full Failure cylinder with single Wrapping using MINERAL BASED COMPOSITES

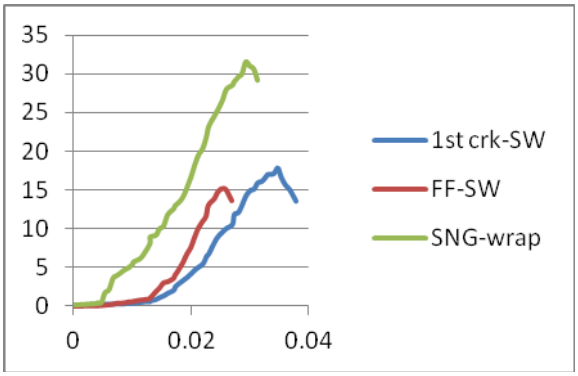

Figure 6: MBC binder - single wrapped cylinder
SCALE: On x-axis 2cm = 0.01 strain.
On y-axis 2cm = 5 N/ mm2 stress

6. Tabulation

The results obtained for increase in strength for test specimen along with cracked and wrapped specimen are tabulated.

Table 3: Results obtained using epoxy binder

S. No	*Specimen description*	*Maximum load carried (KN)*	*Compressive strength (N/mm^2)*	*Percentage increase in strength (%)*
1	Control specimen	431.479	24.407	-
2	Control specimen single wrapping	712.373	40.296	65.10
3	Control specimen double wrapping	1148.50	64.966	166.17
4	First cracked specimen	340.187	19.243	-
5	First cracked specimen single wrapping	495.311	28.850	48.84
6	First cracked specimen double wrapping	518.852	32.913	71.03
7	Full failure specimen	431.479	24.407	-
8	Full failure specimen single wrapping	454.055	26.447	8.35
9	Full failure specimen double wrapping	505.393	28.588	15.31

Table 4: Results obtained using MBC binder

s.no	*Specimen description*	*Maximum load carried (KN)*	*Compressive strength (N/mm^2)*	*Percentage increase in strength (%)*
1	Control specimen	421.952	23.868	-
2	Control specimen single wrapping	646.911	36.593	53.31
3	Control specimen double wrapping	963.535	54.503	128.35
4	First cracked specimen	324.472	18.354	-
5	First cracked specimen single wrapping	504.546	28.54	55.5
6	First cracked specimen double wrapping	554.842	31.385	71
7	Full failure specimen	421.952	23.868	-
8	Full failure specimen single wrapping	476.349	26.945	12.89
9	Full failure specimen double wrapping	531.347	30.056	25.92

7. Comparison of Results (Epoxy Vs MBC)

The results obtained for a cracked, wrapped cylindrical specimen for epoxy resin and MBC binder is compared and contrasted in the table provided below for our reference.

Table 5: Results comparison for epoxy Vs MBC binder

S. No	*Specimen description*	*Percentage increase in strength using EPOXY binder(%)*	*Percentage increase in strength using MBC binder (%)*
1	Control specimen single wrapping	65.10	53.31
2	Control specimen double wrapping	166.17	128.35
3	First crack specimen single wrapping	48.84	55.5
4	First crack specimen double wrapping	71.03	71
5	Full failure specimen single wrapping	8.35	12.89
6	Full failure specimen single wrapping	15.31	25.95

8. Conclusion

Having the concept of sustainability in mind along with labor safety, the use of mineral based composites will reduce the dangerous impacts .The results above indicate that even though epoxy binder increases the strength, it causes dangerous impacts on labor health due to long exposure to it. Moreover it is costly when compared with MBC. The above tabulated result shows the comparison between epoxy binder and MBC binder. It shows that the strength obtained between the two do not differ much. Epoxy in comparison with MBC gives higher increase in strength but it also accompanied by demerits like High cost, highly dangerous to work with, requires special condition for its usage. These are overcome by using mineral Based composites which can be made by using normally used materials. Thus we conclude that the uses of mineral based composites have also shown good results and it is comparatively inexpensive as compared to epoxy and the materials are also easily available. Thus this new method is the sustainable development to protect the environment from pollution by using epoxy resins.

Figure 5: Cylinder wrapped with MBC binder and fully cracked specimen

9. Future Scope of this Project

Research on this topic helps us to obtain an innovative method of FRP sheets bonding using MBCs which acts as a replacement for conventionally used epoxy binders. Further, the strength achieved using MBCs can be increased by various other admixtures, superplasticizers, etc. as it will overcome the demerits of epoxy by reducing the carbon footprint and providing a safe and sustainable atmosphere for human habitation in the near future.

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Author Profile

Raghavendra, V has completed his B. Tech in Civil Engineering and M. Tech in Structural Engineering from SASTRA University, Thanjavur, INDIA in 2014. He has worked with IISc, Bangalore on a project regarding Dynamic response of Underground Metro tunnel and also has done some research work on retrofitting using FRP techniques using MBC binders and analyzed ut using ANSYS finite element software.