International Journal of Engineering & Technology, 7 (4.2) (2018) 30-34

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Characteristics of Epoxy Resin Polymer Mortar with Different Filler Materials

Surendar M*, Saravana Karthika V, Naresh Kumar D

[1] *Assistant Professor, Department of Civil Engineering, Easwari Engineering College, Chennai, Tamil Nadu, INDIA*
[2] *Assistant Professor, Department of Civil Engineering, Easwari Engineering College, Chennai, Tamil Nadu, INDIA*
[3] *UG Student, Easwari Engineering College, Chennai, Tamil Nadu, INDIA*
**Corresponding author E-mail: m.srndr@gmail.com*

Abstract

A binding material forms the core of any construction material as it physically, chemically and mechanically holds the mix together. From lime to cement, the binding materials used conventionally has changed and evolved. Cement is a mineral binding material which reacts with water and has to be cured over a 28-day period to attain its characteristic strength in addition to holding the mix together as a homogenous substance. An organic binding material is one in which an organic substance like resins, bitumen, etc., make a transition from a plastic state to hardened state by a physical or chemical process. In this investigation, cement is completely replaced by epoxy resin as an organic binder and specimen were cast with combinations of epoxy and different filler materials. The filler materials used are Fly Ash, Fumed Silica, GGBS, Quartz, Copper Slag and Silica Fume. The specimen were tested for compressive strength, tensile strength, Flexural Strength and Chemical Resistance. The flexural test was conducted on prisms with and without fibre subjected to three-point and four-point cyclic loading. Compressive Strength was done on cubes 40X40X40 mm on 1,3,5 and 7th days of casting. Dog-bone shaped specimens were subjected to tensile stress by a specially prepared tensile setup. The chemical resistance of the specimen was also tested by immersing it in 5% diluted solutions of Sulphuric acid, Nitric Acid and Hydrochloric acid. The main objective of this project is to analyse each mix design and deduce its suitable field of application based on its various characteristics exhibited by each mix combination.

Keywords: *Epoxy, Polymer Concrete, Fly Ash, Fumed Silica, GGBS, Quartz powder, Copper Slag, Silica Fume*

1. Introduction

Cement as a conventional binding material has its own demerits, some of which are weak resistance when subject to acid attack, longer construction time and minimal tensile strength. Some of these disadvantages can be overcome by Polymer concrete which has excellent chemical resistance, vastly improved tensile, compressive and flexural strength.

Polymer mortars or resin mortars are made by full substitution of cement binder in ordinary cement mortar and no water is added. It is prepared by integral mixing of polymerisable materials such as liquid resin and monomer with moisture – free filler and aggregate. When epoxy resin systems are used, single molecules (monomers) of the epoxy resin chemical and the curing agent (hardener) combine to form long chains of molecules (polymers). As the mixture cures, it becomes a hard polymer. Some epoxies cure in a few minutes at room temperature. Other epoxy systems need additional time or heat to harden. The characteristics of hardened epoxies (such as whether they are firm or flexible, or resistant to heat or chemicals) depend on which epoxy monomers, curing agents, solvents, and fillers are added.

2. Methodolgy

Based on the literatures on resin mortar different trial were done to determine the optimum Resin: Hardener (R:H) proportions. Test specimen was cast in the form of cube, beam and dog-bone shape and tested for their compression, tension and flexure strength. To determine the acid-resistance the specimens are immersed in diluted acids (H_2SO_4, HCl, HNO_3) and the acid attacked are tested for strength.

3. Mix Proportions and Preparation of Test Specimen

The mix contains resin, filler and fine aggregate. The mix proportion by weight of the resin mortar consisting of binder, filler and aggregate was 1:1:4. This ratio was adopted according to “Japanese Industrial Standard method of making polyester resin concrete”, JISA 1181. Cubes of 40X40X40 mm were used to test the compressive strength and acid resistance test of the mortar.
Dog-bone shaped specimen of 160 mm length, 80 mm flange width, 40 mm throat thickness and 40 mm high with 45˚ inclination at the junction between the flange and web was prepared for tensile tests.[Fig.1].

Fig. 1: Dog-bone shaped Mould

Seven different combinations containing Resin & Hardener with different filler materials were cast in Dog-bone. Beams of 40*40*160 mm were used to test the flexural strength of the specimen. The beams were cast with and without micro-steel fibre. For beams with fibre, 3g (0.5%) micro-steel fibres were added to the total weight of the beams without fibre. After running trail tests with Resin: Hardener (R:H) 1:1,1:0.8 and 1:1.2, R:H ratio with 1:1 was found to be optimum. Sand passing through 2.36 mm sieve and retained on 150µ sieve was used as the fine aggregate. Table 1 and 2 gives the quantity of materials for one specimen for dog-bone shaped specimens and cube specimens, respectively. Fig.2 showsa the sured dog-bone shaped specimens

Table 1: Mix Proportion for one Dog-Bone + cube specimen

S.No	Specimen Combination	Binder (g)		Filler (g)	Fine Aggregate (g)
		Epoxy	Hardener		
1	Fly Ash	71	71	142	565
2	Quartz	71	71	142	565
3	Fumed Silica	71	71	3	565
4	GGBS	71	71	142	565
5	Copper Slag	71	71	142	565
6	Silica Fume	71	71	142	565
7	Vermiculate	71	71	142	565

Fig. 2: Dog-Bone shaped specimen

Table 2: Mix Proportion for one Prism without fibre

S.No	Specimen Combination	Binder (g)		Filler (g)	Fine Aggregate (g)
		Epoxy	Hardener		
1	Fly Ash	52	52	105	415
2	Quartz	52	52	105	415
3	Fumed Silica	52	52	2.5	415
4	GGBS	52	52	105	415
5	Copper Slag	52	52	105	415

Resin mortar mixtures with different filler materials were mixed by hand mixing at ambient temperature of 30°C. The filler materials used were Fly Ash, Copper Slag, Quartz Powder, GGBS, Silica Fume, Fumed Silica, and Vermiculate. Mortar cube specimens of 40x40x40 mm cubes, 40x40x160 mm prism and dog bone were cast for compression and flexural strength test, respectively. After 24 hours of casting, specimens were demoulded and kept in room temperature and were kept for air curing. The specimens were tested at the age of 1,3,5 and 7th days and the gradual increase in strength was observed.

4. Experimental Observations

Epoxy Resin Polymer mortars were subjected to compression, tension, flexure and chemical attack and the observations are recorded below.

4.1. Compression Test

Compressive strength of the resin mortars were found by testing the 40*40*40 mm cubes of varying composition on 1st ,3rd,5th and 7th day after casting the specific mix. The compressive tests were conducted using the UTM of 40kN capacity [Fig 3]. The results are presented in Table 3.

Fig 3: Compression Test

Table 3: Compressive strength of resin mortar tested at age of 1, 3,5and 7 days

Specimen Combination	1-Day (MPa)	3-Day (MPa)	5-Day (MPa)	7-Day (MPa)
Fly Ash	46.25	52.50	55.63	68.75
Quartz	57.19	57.19	60.00	68.75
GGBS	54.57	54.56	65.63	67.19
Copper Slag	35.94	45.63	44.06	51.56
Vermiculate	19.69	21.92	24.38	26.25

Fig 4 shows flow chart of Compressive strength of resin mortar tested at the age of 1, 3, 5 and 7 days of air curing.

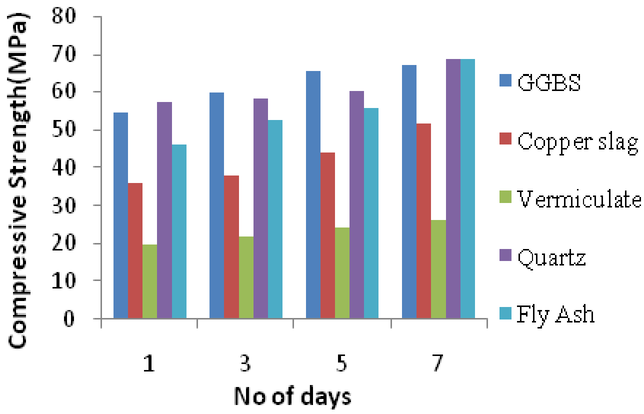

Fig 4: Comparative Chart of Compressive Strength

4.2. Flexure Test

Beams with different filler combinations were cast with and without fibre. The beams without fibre were subjected to three point loading and the beams with fibre were subjected to three-point and four-point loading and load-deflection was recorded.
The flexural strength for three-point & four-point loading is calculated as per the following formulae:

$$f = 3Pl/2bd^2 \quad \text{(Three point loading)}$$
$$f = Pl/bd^2 \quad \text{(Four point loading)}$$

where,
f - Flexural Strength (N/mm^2)
P - ultimate load (kN)
l - span between two supports(mm)
b - width of the specimen
d - depth of the specimen

Flexural strain is calculated as $\mathcal{E}_f = 6\Delta d/l^2$
where,
Δ- Maximum deflection at the centre of the beam (mm)
L- Span between two supports (mm)
D- Depth of specimen (mm)
$\mathcal{E}_f$ - Flexural strain

The beams without fibre were subjected to three-point static loading [Fig.6] and the results of 5th & 7th day testing are given in Table 4 and 5. Table 6 presents the 3 day flexural strength of resin mortar with steel fibre tested under three point static load. The failure pattern of flexural test specimen are shown in Fig.5

Table 4: Three-Day Testing of Beams without fibre under three-point loading

Specimen Combination	Load (kN)	Max Deflection (mm)	Flexural Strain (mm/mm)	Flexural Stress (MPa)
Fly Ash+F	3.28	3.81	0.064	9.23
Silica Fume+F	5.5	4.98	0.083	15.47
Quartz+F	5.5	5.69	0.095	15.47
Fumed Silica+F	6.25	5.24	0.087	17.58
GGBS+F	5.5	4.59	0.077	15.47
Copper Slag+F	2.32	2.31	0.039	6.53

Table 5: Five-Day Testing of Beams without fibre under three-point loading

Combination	Load (kN)	Span Length (mm)	Flexural Stress (MPa)
Fly Ash	4.2	120	23.63
Fumed Silica	3.6	120	20.25
Quartz	4.0	120	22.50
Copper Slag	3.0	120	16.88
GGBS	5.0	120	28.13

Table 6: Three-Day Testing of Beams with fibre under three-point cyclic loading

Combination	Load (kN)	Span Length (mm)	Flexural Stress (MPa)
Fly Ash	6.0	120	33.75
Fumed Silica	5.2	120	29.25
Quartz	7.0	120	39.38
Copper Slag	4.0	120	22.50
GGBS	4.5	120	22.50

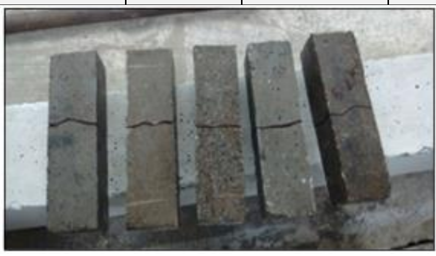

Fig 5: Beams tested for Flexure

The beams with fibre were subjected to three-point cyclic loading and four-point cyclic loading and were tested for three-day flexural strength. The results are presented in Table 7. Figs 7 and 8 illustrate the load-deflection curves for silica fume + fumed silica +fibre and flyash + fibre, respectively tested under three point and four point cyclic load.

Fig 6: Beams tested for Flexure

Table 7: Three-Day Testing of Beams with fibre under four-point cyclic loading

Specimen Combination	Load (kN)	Max Deflection (mm)	Flexural Strain (mm/mm)	Flexural Stress (MPa)
Fly Ash+F	3.8	3.70	0.062	10.69
Silica Fume+F	6.0	4.51	0.075	16.88
Quartz+F	5.5	5.38	0.090	15.47
Fumed Silica+F	6.5	5.01	0.084	9.14
GGBS+F	5.5	4.43	0.074	15.47
Copper Slag+F	2.8	2.88	0.048	7.88

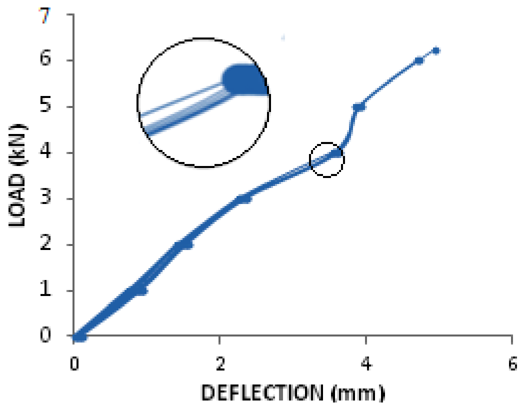

Fig 7: Load-Deflection curve for Specimen with Fumed Silica & Fibre under Three-Point

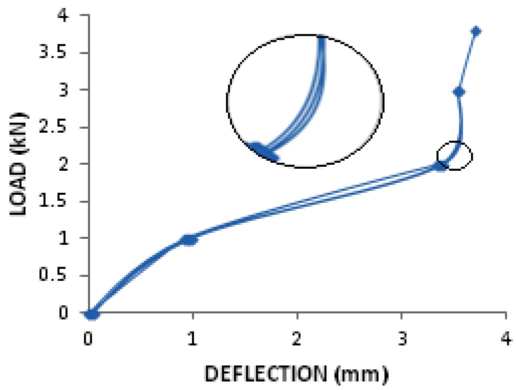

Fig 8: Load-Deflection curve for Specimen with Fly Ash & Fibre under Four-Point Cyclic Loading

4.3. Tensile Test

A Test Setup was made with reference to - *"A Prediction Method for Tensile Young's Modulus of Concrete At Early Age"* by Isamu Yoshitake, Farshad Rajabipour,Yoichi Mimura, and Andrew Scanlon [1]. Direct tension is applied to a dog-bone shaped specimen by the application of pulling force on the flange section of the dog-bone [Fig 9].

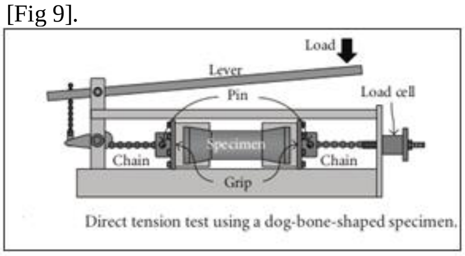

Fig 9: Direct Tension on Dog-bone shaped specimen

The Test setup [Fig 10] was held vertically and fitted in the UTM for the purpose of conducting direct tensile test on the dog-bone shaped specimen. The specimen were fitted in the test setup and a tensile force was applied till the failure occurs in the specimen. The testing was conducted and initially the failure of the specimen was not correct due to uneven distribution of load owing to undulations in the specimen. Then due corrections were made for uniform distribution of load. It was observed that the specimen containing Vermiculate had uniform distribution of load despite having undulations. Direct tensile strength of specimens are presented in Table 8. Figs 11 and 12 show failiure patten of test Specimens.

Fig 10: Tensile Test Apparatus

Table 9: Tensile Strength of Specimen

Combinations	Ultimate Load (kN)		Tensile Strength (MPa)	
	5-Day	7-Day	5-Day	7-Day
Silica Fume	11.04	11.6	6.90	7.25
Copper Slag	5.82	7.40	3.64	4.63
Quartz	9.36	10.3	5.85	6.44
Fly Ash	6.35	9.36	3.97	5.85
Fumed Silica	8.80	9.12	5.50	5.70
Vermiculate	4.72	5.28	2.95	3.30
GGBS	10.8	11.4	6.75	7.13

4.4. Acid Attack

The specimen were immersed in 5% solution of H_2SO_4, HNO_3 and HCl. The changes in the specimen were visually observed and the weight of specimen before and after immersion is compared. Th changes in weight of specimen are given in Table 9 and Fig 13. Shows discoloration of tested specimens.

Table 9: Variation in weight of specimen after immersion in acid

Specimen Combination	Weight Variation of specimen (g)		
	HCl	HNO_3	H_2SO_4
Fly Ash	-0.71	-0.72	-0.90
Quartz	+0.35	+1.61	+0.90
Fumed Silica	+2.18	+1.02	+1.20
Copper Slag	+0.40	+0.70	+0.80
GGBS	+0.41	+0.28	+0.80

Fig 13: Discoloration of Fumed Silica immersed in HCl

5. Inference

After recording the observations from the various tests conducted, the following inference has been made from the test results:

- Compression: Instant increase in compressive strength is seen in GGBS and gradual increase is seen in quartz and fly ash combinations, all three having almost equal compressive strength after 7 days
- The One-Day compressive Strength of Quartz is 290.4% greater than that of Vermiculate. Vermiculate being the least in both compressive and tensile strength, equalizes the strength of conventional concrete and is also lighter in self-weight
- The Compressive Strength of Fumed Silica is 223% greater than that of the mix with Copper Slag
- Flexure: Fumed silica shows relatively high flexural strength when compared to other filler materials, thus denoting good ductility
- Tensile Test: There is a very uniform distribution of tensile load in vermiculate when compared to other combinations
- The most superior mix is from the combination of quartz, showing the highest compressive strength and average flexural and tensile strength
- Acid Attack: Major discolouration occurs in quartz where the colour has changed from dark yellow to pale yellow
- Acid Attack: Discolouration of GGBS from beach colour to pale yellowish white colour
- Acid Attack: Formation of some form of clusters over the specimen with fumed silica
- Acid Attack: Fly ash remains unchanged after 14 days
- Acid Attack: Copper Slag is observed with discolouration and change in dimensions at a very minute scale
- Fly Ash has been recommended for industries which has to be designed for flooring requiring acid-resistance

5.1 Applications

- Polymer Resin Concrete floors are resistant to acid attack and hence can be used for flooring in acid industries
- It can be used in Hotel Flooring and in show rooms due to its glossy finish. it is alternatively called as decorative concrete and it is commercially used in Europe for table tops and counter tops
- Since they show high strength and quicker bonding they can also be used for transporting gases and other chemicals
- They can also be used to repairing the pipes carrying oil,water and any form of acids
- They can be used for sewer lines due to their higher flexural strength and resistance to chemicals
- It is highly resistant to abrasion and hence used in heavy duty industrial flooring

5.2. Demerits

- They are 10 times costlier than that of conventional concrete but saves cost in the long run where frequent laying of concrete is necessary
- Working with resin mortar is difficult since their setting time is quicker
- Removal of resin from skin, surfaces is difficult
- It requires skilled labour
- The mix with Fumed Silica has a low bonding capacity as it disintegrates on application of water. However, this being the case it can be used as a cleaning material for epoxy resin up to a certain extent

6. Conclusions

Thus, the specimen of different combinations were cast and tested for compression, flexure, tension and acid resistance. Based on the investigations carried out on the epoxy resin mortar, the following conclusions have been arrived:

- Quartz is the best mortar mix relative to other combinations carried out with good compressive and average flexure and tensile strengths
- The combination with Fly Ash is highly resistant to acid attack and can be used for flooring in acid industries

The combination of GGBS can be used where good aesthetic appearance is required as it gives a very good finish.

Acknowledgement

We are extending our sincere thanks to our Professor Dr. M. Neelamegam of Easwari Engineering College and our beloved students Ms.N.E.Vandana, Mr.D.Naresh Kumar, Ms.R.Snega, Ms.A.D.Valli for their direct and indirect supports.

References

[1] Isamu Yoshitake, Farshad Rajabipour,Yoichi Mimura, and Andrew Scanlon " A Prediction Method Of Tensile Young's Modulus Of Concrete At Early Age ", Advances in Civil Engineering Volume 2012 (2012), Article ID 391214, 10 page

[2] M. Golestaneh, G. Amini, G.D. Najafpour , M.A. Beygi "Evaluation of Mechanical Strength of Epoxy Polymer Concrete with Silica Powder as Filler", World Applied Sciences Journal 9 (2): 216-220, 2010

[3] Ferdous, W, Manalo, A, Aravinthan, T & Van Erp, G 2014, "Design of epoxy resin based polymer concrete matrix for composite railway sleeper", ST Smith (ed.),23rd Australasian Conference on the Mechanics of Structures and Materials (ACMSM23), vol. I, Byron Bay, NSW, 9-12 December, Southern Cross University, Lismore, NSW, pp. 137-14

[4] J.K.Dattatreya, C.Srinivasan, D.Sabitha, K.V.Harish and M.Neelamegam, "A Comparative Study of Mechanical Properties of Epoxy and Vinyl Ester Concretes", Fifth Asian Symposium on Polymers in Concrete, Page 437-444

[5] Manoj Singla and Vikas Chawla, "Mechanical Properties of Epoxy Resin – Fly Ash Composite", Journal of Minerals & Materials Characterization & Engineering, Vol. 9, No.3, pp.199-210, 2010