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An experimental study on strength of hybrid mortar synthesis with epoxy resin, fly ash and quarry dust under mild condition

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Abstract. Fusion and characterization of bisphenol-A diglycidyl ether based thermosetting polymer mortars containing an epoxy resin, Fly ash and Rock sand are presented here for the Experimental study. The specimens have been prepared by means of an innovative process, in mild conditions, of commercial epoxy resin, Fly ash and Rock sand based paste. In this way, thermosetting based hybrid mortars characterized by a different content of normalized Fly ash and Rock sand by a homogeneous dispersion of the resin have been obtained. Once hardened, these new composite materials show improved compressive strength and toughness in respect to both the Fly ash and the Rock sand pastes since the Resin provides a more cohesive microstructure, with a reduced amount of micro cracks. The micro structural characterization allows pointing out the presence of an Interfacial Transition Zone similar to that observed in cement based mortars. A correlation between micro-structural features and mechanical properties of the mortar has also been studied.

Keywords: fly-ash; quarry dust; epoxy resin; compressive strength

1. Introduction

The use of fly ash in mortar is desirable because of benefits such as useful disposal of a by-product, increased workability, reduction of cement consumption, increased sulphate resistance, increased resistance to alkali-silica reaction and decreased permeability. The decrease in workability can be improved by replacing certain percentage of fly ash by quarry dust. The concurrent use of the two by-products will lead to a range of economic and environmental benefits. Quarry dust has been proposed as an alternative to river sand that gives additional benefit to mortar. Quarry dust is known to increase the strength of mortar over mortar made with equal quantities of river sand. When examining the above qualities of fly ash and quarry dust it becomes

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apparent that if both are used together, the loss in early strength due to one may be alleviated by the gain in strength due to the other, and the loss of workability due to the one may be partially negated by the improvementin workability caused by the inclusion of the other.

Epoxy is a term used to denote both the basic components and the cured end products of epoxy resins, as well as a colloquial name for the epoxide functional group. Epoxy resins, also known as poly-epoxides are a class of reactive pre-polymers and polymers which contain epoxide groups. Epoxy resins may be reacted (cross-linked) either with themselves through catalytic homopolymerization, or with a wide range of co-reactants including polyfunctional amines, acids (and acid anhydrides), phenols, and alcohols. These co-reactants are often referred to as hardeners or curatives, and the cross-linking reaction is commonly referred to as curing. Reaction of poly-epoxides with themselves or with polyfunctional hardeners forms a thermosetting polymer, often with high mechanical properties, temperature and chemical resistance. Epoxy has a wide range of applications, including metal coatings, use in electronics / electrical components, high tension electrical insulators, fiber-reinforced plastic materials and structural adhesives.

Scanning electron microscopy (SEM) analyses the surfaces of materials, particles and fibers so that fine details can be measured and assessed via image analysis. SEM provides a means for industry to resolve contamination issues, investigate component failure, identify unknown particulates or study the interaction between substances and their substrates. It can also provide a wealth of information to support research of materials, chemicals or biological samples.The process of interpreting SEM images is not always clear and direct. In tasks, such as the interpretation of surface pitting on metal components the identification of particulates, or the exploration of physical and chemical characteristics of material, SEM becomes a truly powerful technique if appropriate sample preparation methods are used and experienced microscopists perform the analysis.

2. Materials and methods

a. Physical properties of Quarry dust: Various physical properties of Quarry dust are determined in the laboratory and reported in Table 1.

b. Physical properties of Fly ash: The fly ash was procured from National Thermal Power Corporation (NTPC) in Visakhapatnam. The properties of Fly ash are as follows. Fineness of test Fly ash: 98%, Specific gravity of test Fly ash: 2.55, The chemical properties of fly ash are given in Table 2.

c. Physical properties of Epoxy resin: Araldite AW 106 resin/Hardener HV 953U epoxy adhesive is a multi-purpose,viscous material that is suitable for bonding a variety of materials including metal,ceramic and wood. Araldite AW 106 resin/Hardener HV 953U epoxy adhesive

Table 1 Physical properties of Quarry dust

S. No	Property	Quarry dust	Code of practice
1.	Specific gravity	2.38	IS: 2386 (Part III)
2.	Sieve analysis	Zone II (coarser)	IS: 383
3.	Bulking	70% @ 8% water content	IS: 2386 (Part III)
4.	Bulk density	1670 kg/m^3	IS: 2386 (Part III)

Table 2 Chemical properties of Fly ash (**Courtesy:** NTPC, Visakhapatnam)

Chemical	**SiO_2**	**Al_2O_3**	**Fe_2O_3**	**Na_2O**	**MgO**	**$CaCO_3$**	**SO_3**
%	61.24	25.00	8.71	0.09	0.05	4.42	0.49

Table 3a, 3b The properties of Epoxy resin/Hardener are as follows, **Courtesy:** HUNTSMAN, USA)

Mix ratio	Parts by weight	Parts by volume
Araldite AW 106 (Specific Gravity : 1.17)	100	100
Hardener HV 953 IN (Specific Gravity : 0.92)	80	100

Temperature	Min. Handling Time	Max. Cure Time
68°F (20°C)	12 hours	15 hours
77°F (25°C)	7 hours	12 hours
104°F (40°C)	2 hours	3 hours
158°F (70°C)	30 minutes	50 minutes
212°F (100°C)	6 minutes	10 minutes
302°F (150°C)	4 minutes	5 minutes

cures attemperatures from 68ºF (20ºC) to 356ºF (180ºC) with no release of volatile constituents.

d. Methodology adopted for the compression strength test:

The compressive strength tests on mortar cubes compacted.

Code of Practice: Is: 4031 - (Part-6)

Apparatus description and specification:

1. Compression testing machine
2. Vibration machine conforming to IS 10080
3. Gauging trowels conforming to IS 10086
4. Cubical Mould: The mould shall be of 70.6 mm size conforming to IS 10080
5. Measuring jars, tray and Standard Sieves used: 4.75, 2.36, 1.18 mm, 600, 300, 150, 90 microns

3. Results and discussions

Various combinations of mixes are tried and the same are shown in Table 4. The compressive strength values for 3 days of open air curing for all mixes are shown in Tables 5. The relative comparison of compressive strengths of all mixes are shown in Figs. 1 to 3 for all total number of cubes 90 nos.

Table 4 Various Mixes prepared with different combination of Innovative materials

Variations	QUARRY DUST (grm)					Flyash (grm)
	4.75-2.36 mm	2.36-1.18 mm	1.18-600 mic	600-90 mic	90 mic passing	
1	-	300	300	-	-	-
2	200	200	200	-	-	-
3	150	150	150	150	-	-
4	-	200	200	-	-	200
5	150	150	150	-	-	150
6	-	150	150	150	-	150
7	-	-	-	300	-	300
8	-	-	-	-	600	-
9	-	-	-	-	300	300
10	-	-	-	-	-	600

Table 5 Average compressive strength of all variations in MPa at the age of 3 Days

Epoxy Percentage (By weight)	**Average ultimate compressive strength of Cubes (3 Nos) (MPa)**									
	V-1	**V-2**	**V-3**	**V-4**	**V-5**	**V-6**	**V-7**	**V-8**	**V-9**	**V-10**
20	57.6	62.3	59.8	66.3	65.2	68.7	68.3	54.6	67.9	68.9
25	66.7	68.7	67.5	72.4	73.3	75.3	72.3	68.3	78.3	82.1
30	72.3	74.5	79.5	81.9	79.6	85.4	84.5	83.9	94.1	96.6

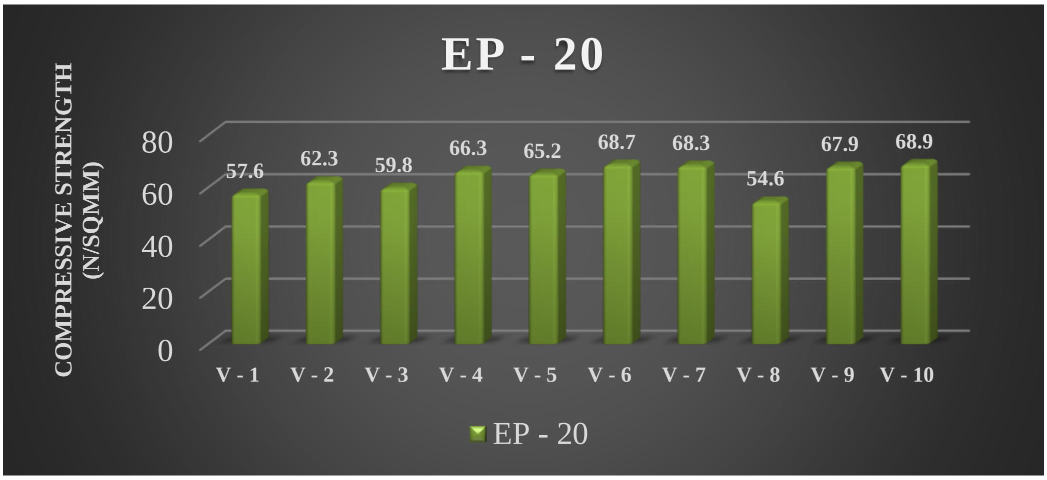


Fig. 1 Comparison of Compressive strength of all Variations with 20% of epoxy

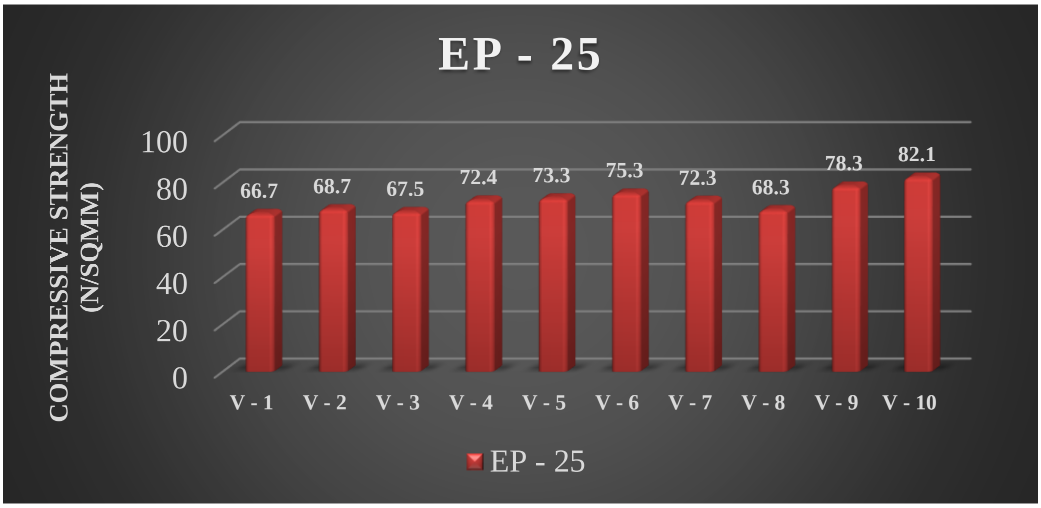


Fig. 2 Comparison of Compressive strength of all Variations with 25% of epoxy

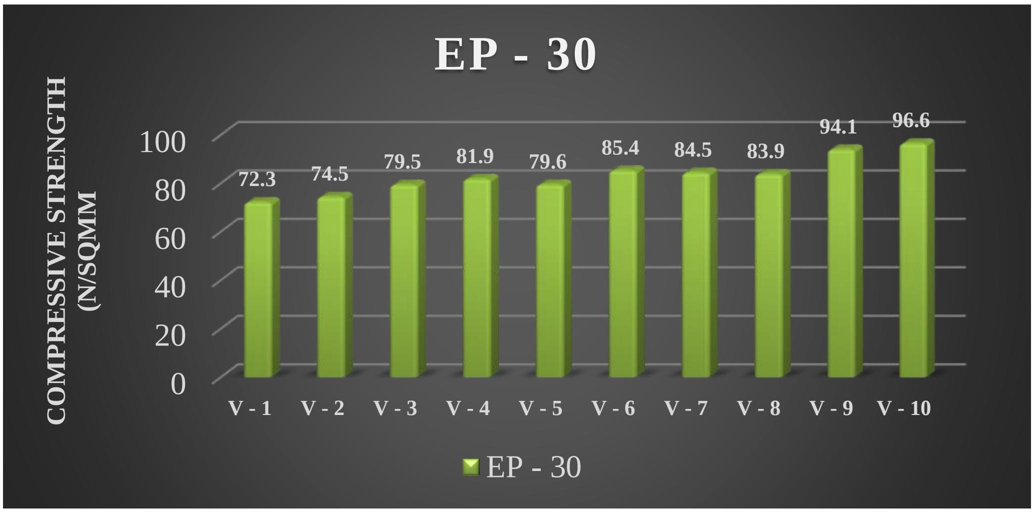
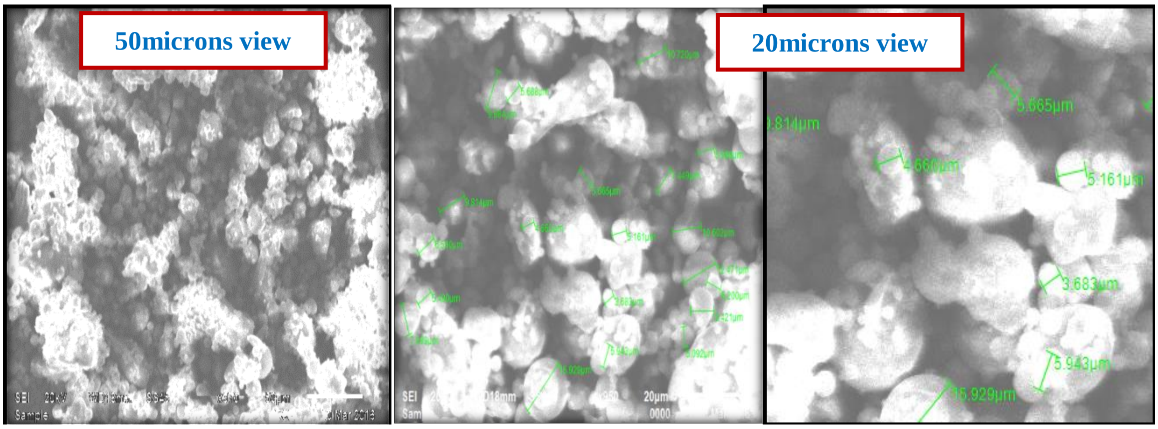


Fig. 3 Comparison of Compressive strength of all Variations with 30% of epoxy

From Fig. 1, variations 6, 7, 9, and 10 with 20% of epoxy shows relatively same strength with quarry dust combination of fly ash. From Figs. 2 and 3, variations 9, and 10 shows more strength when compared to all design variations. From Figs. 1, 2, and 3 fly ash with 30% of epoxy shows more strength.

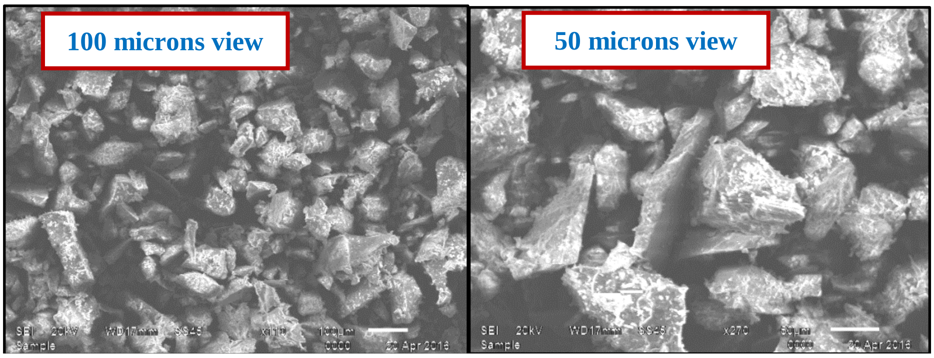
4. SEM analysis report

Inference of Fig. 4: Above is the SEM analysis of Fly Ash which reveals that the Fly Ash particle is of spherical in shape, its particle size is varying between 2-11, micron meter. The following are the particle sizes noted from above picture 4(a), 4(b), and 4(c) at the stage of micro structural investigationin between 50 to 20, micron scale view is, 3.683, 4.66, 5.16, 5.40, 5.665, 5.998, 6.54, 7.449, 7.998, 8.421, 9.814, 10.602, 12.47, 15.929, micron meter.



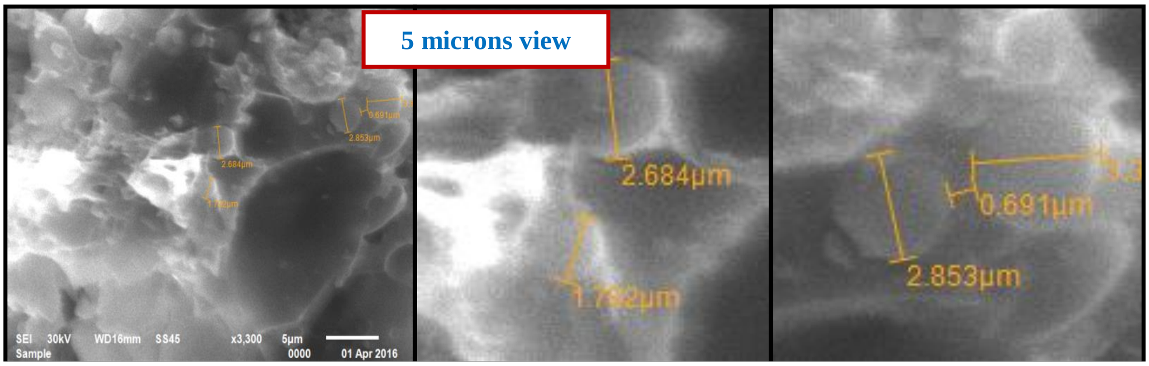
(a) (b) (c)

Fig. 4 SEM analysis of Fly Ash



(a) (b)

Fig. 5 SEM analysis of Quarry Dust



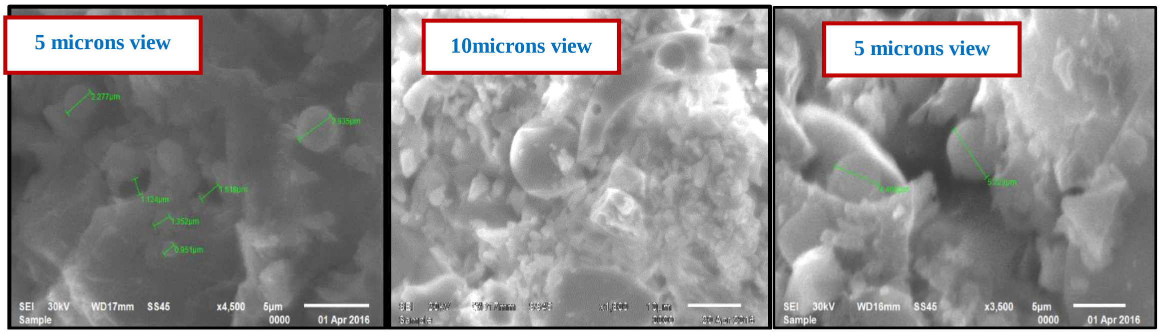
(a) (b) (c)

Fig. 6 SEM analysis of Fly Ash with 30% epoxy (Variation-10)

Inference of Figure 5: Above is the SEM analysis of Quarry dust which reveals us from figure 5(a) and 5(b), that the Quarry dust particle are relatively angular in shape and also sharp edge pin headed faces found all around the particle surface at the stage of microstructural investigation up to 100 to 50, micron scale view.

Inference of Fig. 6: Above is the SEM analysis of Fly Ash with 30% Epoxy on its weight of (Variation-10), it reveals us that how compactly Fly Ash particle is bonded with epoxy and forming a massive structure with no micro level crack and with no voids in it from Fig. 6(a) at the stage of microstructural investigation in between 10 to 5, micron scale view. From Fig. 6(b), it reveals that the fly ash particles having size 1.782 and 2.684, micron meter having bond length is less than 1.0, micron meter length and also from Fig. 6(c), it reveals that the fly ash particles having size 2.853 and 3.30, micron meter having bond length 0.691, micron meter length which supports the high strength mortar results.

Inference of Fig. 7: Above is the SEM analysis of Variation-9, with 30% Epoxy on its weight it reveals us that how closely Fly Ash and quarry dust particle are bonded with epoxy to form a massive structure with no micro level crack from Fig. 7(a) and 7(b). It reveals that the fly ash particles having size 2.935, 2.277, 1.618, 1.352, and 0.951, micron meter having bond length 1.214, micron meter length and less than 1.0 microns from Fig. 7(a) and 7(c). From Fig. 7(b), it r e v e a l s



(a) (b) (c)

Fig. 7 SEM analysis of (Variation - 9) with 30% epoxy

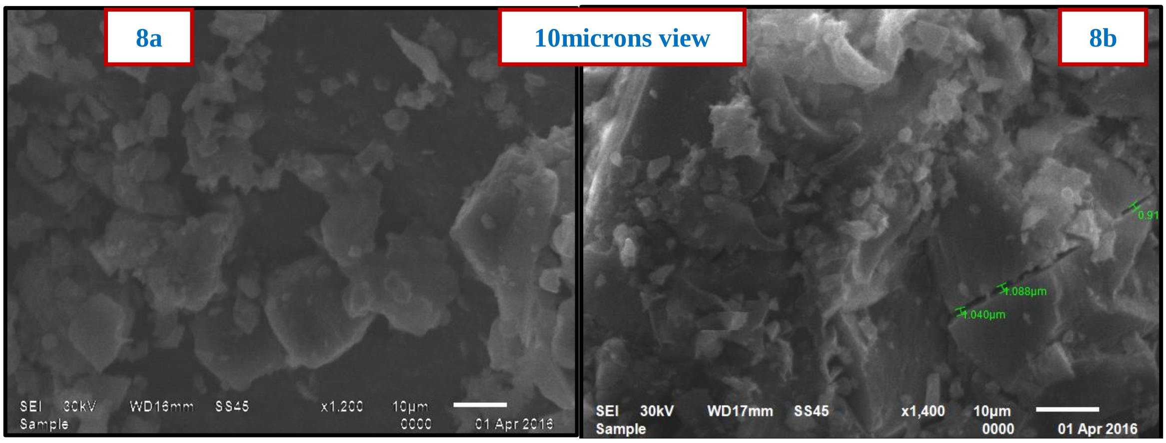


Fig. 8 SEM analysis of (Variation-8) with 30% epoxy

that some micro voids are observed at the stage of microstructural investigation in between 5 to 10, micron scale view which causes the lesser strength for mix variation-9, compare to mix variation-10.

Inference of Fig. 8: Above is the SEM analysis of Variation - 8, with 30% Epoxy on its weight it reveals us that how closely quarry dust particle arelinked and bonded with epoxy to forming a massive structure from Fig. 8(a) and also indicate the different shapes and sizes of quarry dust particles are observed as mentioned in Fig. 5. From Fig. 8(b), it reveals that some micro cracks of size 0.99. 1.04 and 1.088, micron meter length and some micro voids are observed at the stage of microstructural investigation at 10, micron scale view which causes the lesser strength for mix variation-8, compare to mix variation-9 and 10.

5. Conclusions

From the above study the following conclusions are drawn.

1. From Fig. 1, variations 6, 7, 9, and 10 with 20% of epoxy are shows relatively same strength with quarry dust and fly ash.
2. From Figs. 2, and 3, variations 9, and 10 with 25 and 30% of epoxy are shows more strength compare to all mixes.
3. From Figs. 1, 2, and 3 in all variations fly ash with 30% of epoxy (variation-10) is shows more compressive strength i.e., 96.6 N/mm^2.
4. According to SEM analysis Variation-10, fly ash with 30% epoxy is shows more massive structure (with no micro cracks and voids) that reveals more compressive and tough material.

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