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Study on Strength of Innovative Mortar Synthesis with Epoxy Resin, Fly Ash and Quarry Dust

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ABSTRACT:*Generally, mortar is a uniform combination of Fine aggregate and cement. In this study an innovative concept adopts to synthesis a hybrid mortar with Epoxy resin, Fly ash and quarry dust which are replacing the fine aggregate and cement. The alternative materials are preferably waste products such as quarry dust and fly ash in order to moderate the cost of mortar. The main objective of this work is to study the compressive strength of mortar cubes by various combinations of cement and fine aggregate replaced by Epoxy resin, fly ash, and quarry dust at the age of 7 days. The results of mortarmade with cement replaced with 20%, 25%, and 30% (w/w) of Epoxy resin, and fine aggregate replaced by (0% QD - 100% FA) (100% QD - 0% FA) and (70% QD - 30% FA) of quarry dust and fly ash were compared with conventional mortar cubes. It was observed that all mortar cubes made with Epoxy resin, fly ash, and quarry dust had found to have a compressive strength of more than 150% when compared to compressive strength with normal cement of OPC53 grade at the age of 7 days (Approx.35.5Mpa).*

Keywords: *Fly-ash, Quarry Dust, Epoxy Resin, Compressive Strength*

I. INTRODUCTION

The use of fly ash in mortar and concrete 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. However, the use of fly ash leads to a reduction in early strength of concrete. 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. They are Low Thermal (LT) fly ash operating at combustion temperature of 750-850 degrees centigrade and High Thermal (HT) fly ash operating at the temperature of 900-1400 degrees centigrade. It is observed that both LT and HT fly ashes behave distinctly different. Use of fly ash in structural concrete is acceptable as per IS 456.

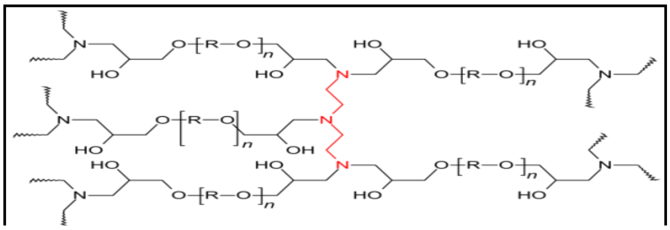
Quarry dust has been proposed as an alternative to river sand that gives additional benefit to mortar. Quarry dust is known to increase the strength of concrete over concrete made with equal quantities of river sand, but it causes a reduction in the workability of concrete. When examining the above qualities of fly ash and quarry dust it becomes 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 improvement in 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.

II. NEED FOR THE REPLACEMENT OF SAND AND CEMENT

Large scale efforts are required for reducing the usage of the raw material that is present, so that large replacement is done using the various by-product materials that are available in the present day. Materials like fly ash especially Class F fly ash is very useful as the fine aggregates. The fly ash is obtained from the thermal power plants which is a by-product formed during the burning of the coal. The other material that can be used is quarry dust which ismade while in the processing of the Granite stone into aggregates, this is formed as a fine dust in the crushers that process the coarse aggregates, which is used as a filler material in the road formationson a large scale. Many studies are made with several other materials which gave the concrete to be a material made of recycled material but the parameters that are primary for the material was not satisfied.

Epoxy resins are the most commonly used thermo set plastic in polymer matrix composites. Epoxy resins are a family of thermo set plastic materials which do not give off reaction products when they cure and so have low cure shrinkage. They also have good adhesion to other materials, good chemical and environmental resistance, good chemical properties and good insulating properties. The epoxy resins are generally manufactured by reacting epichlorohydrinwith bisphenol. Different resins are formed by varying proportions of the two: as the proportion of epichlorohydrin is reduced the molecular weight of the resin is increased.



Structure of epoxy glue derived from a triamine hardener (red) mixed with bisphenol-diglycidyl ether resin (abbreviated in black). Notice that the material is highly cross linked and that it contains many OH groups, which confer adhesive properties**.** (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

III. EXPERIMENTAL STUDY

a. **Physical properties of Quarry dust:** Various physical properties of Quarry dust are determined in the laboratory and reported in Table1.

Table1 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)

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 : 94%,
Specific gravity of test Fly ash : 2.55

The chemical properties of fly ash are given in Table2.

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

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

The properties of Epoxy resin/Hardener are as follows (Courtesy: HUNTSMAN, America)
Specific gravities:1.17 for resin and 0.92 for hardener

d. Methodology adopted for the compression strength test:

The compressive strength test is conducted on mortar cubes.
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

IV. MIX PROPORTIONS, MIXING& CASTING

The appliances that are to be used kept clean and dry. Each cube shall be mixed separatelywith the quantities of cement, sand and water, and they shall be 200 grams, 600 grams and (P/4+3.5) percentage of combined weight of cement and sand respectively. Where P is the standard consistency of the cement used. The sand 600 grams is taken in three equal ratios of 2mm, 1mm and 0.6mm particle sizes. The mixture of cement and sand in the proportion of (1:3) by weight is placed on a non-porous plate. Mix it in dry state with a trowel and then with water until the mixture is of uniform color. The time of mixing shall in any event be not less than 3 minutes. Now this mixture is filled in 70.6 mm^3 of cube moulds. Remove the specimens from the casted moulds and then cured for 7 days and 28 days in potable water. Later at 7 days and 28 days curing the specimens are tested under compressive testing machine for compression test according to IS: 516 and the results are presented under the results heading.

V. Results

Various combinations of mixes are tried and the same are shown in Table 3. The compressive strength values for 7 days curing period for all mixes are shown in Tables 4 to 6. The relative comparison of compressive strengths of all mixes is shown in Figures 1 to 4.

Table 3: Various Mixes with different combination of Innovative materials

S.No	**Epoxy (%)**	**Only with fly ash (FA)**	**Only with quarry dust (QD)**	**Combination of fine aggregate and quarry dust (FA&QD)**
1)	20	FA-E20	QD-E20	FA30QD70-E20
2)	25	FA-E25	QD-E25	FA30QD70-E25
3)	30	FA-E30	QD-E30	FA30QD70-E30

(FA: 100% of Fly ash, **QD:** 100% of Quarry Dust, **FA&QD:**(30% - 70%)

Table 4: Fly ash based epoxy mortar compressive strength in MPa at the age of 7 Days curing

S.No	**Mix type**	**Sample 1**	**Sample 2**	**Sample 3**	**Average ultimate compressive strength (MPa)**
1	FA-E20	42.80	42.20	43.10	42.70
2	FA-E25	68.10	67.90	68.60	68.20
3	FA-E30	85.10	84.80	85.50	85.10

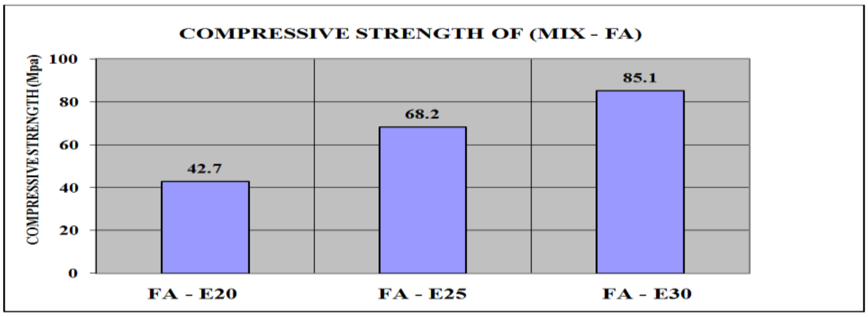


Figure 1: Compressive strength of fly ash based epoxy mortar with different % of epoxy

Table 5:QD based epoxy mortar compressive strength in MPa at the age of 7 Days curing

S.No	Mix type	Sample 1	Sample 2	Sample 3	Average ultimate compressive strength (MPa)
1)	QD-E20	36.50	36.20	37.20	36.60
2)	QD-E25	46.10	47.10	46.60	46.60
3)	QD-E30	62.30	62.80	61.60	62.20

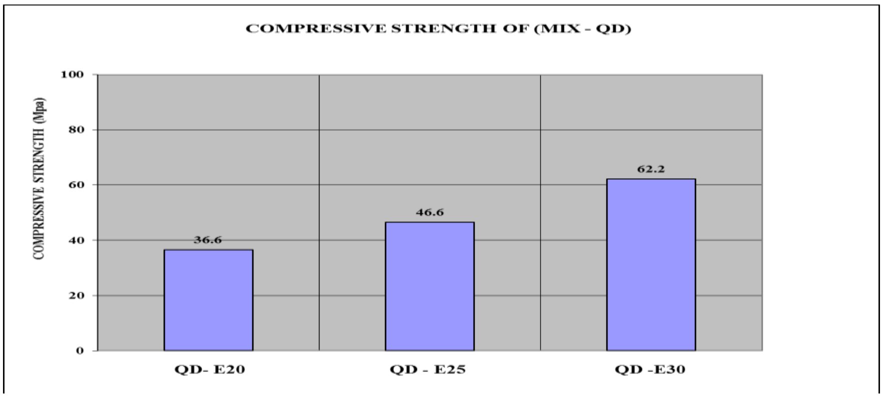


Figure 2: Compressive strength of quarry dust based epoxy mortar with different % of epoxy

Table 6:FA and QD based epoxy mortar compressive strength in MPa at the age of 7 Days

S.No	Mix type	Sample 1	Sample 2	Sample 3	Average ultimate compressive strength (MPa)
1	FA30QD70 E20	38.30	39.80	38.40	38.80
2	FA30QD70 E25	52.20	53.10	52.40	52.50
3	FA30QD70 E30	71.80	72.40	71.40	71.80

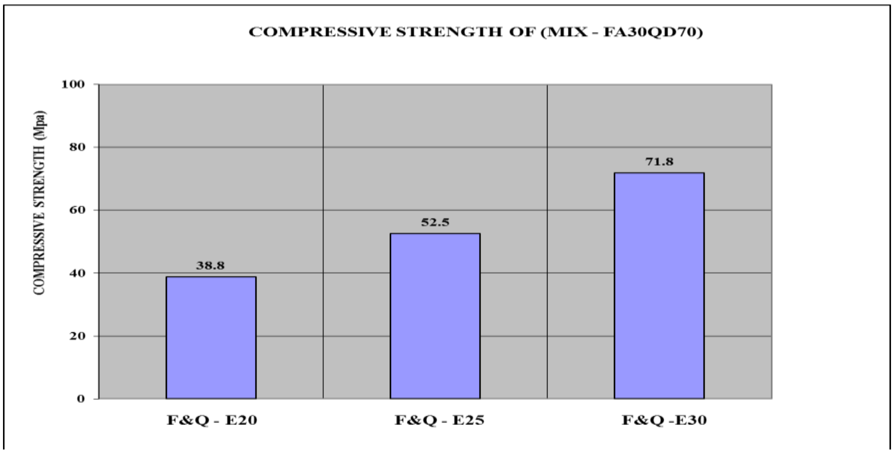


Figure 3: Compressive strength of FA30QD70 based epoxy mortar with different % of epoxy

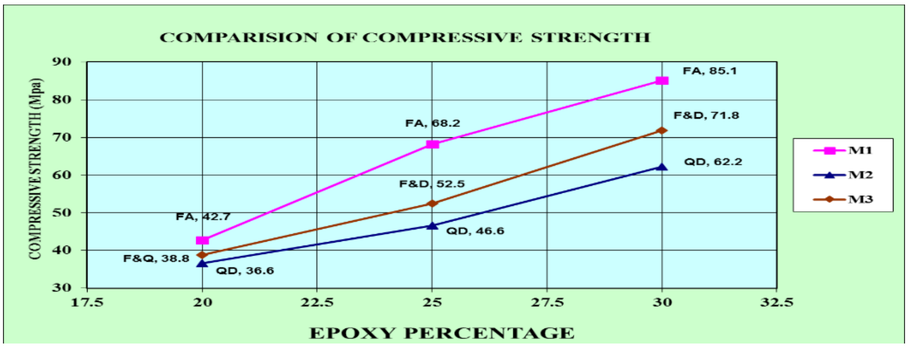


Figure 4: Comparison of compressive strength in MPa of all three mixes

VI. Sem Analysis

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.

Sem Analysis Results

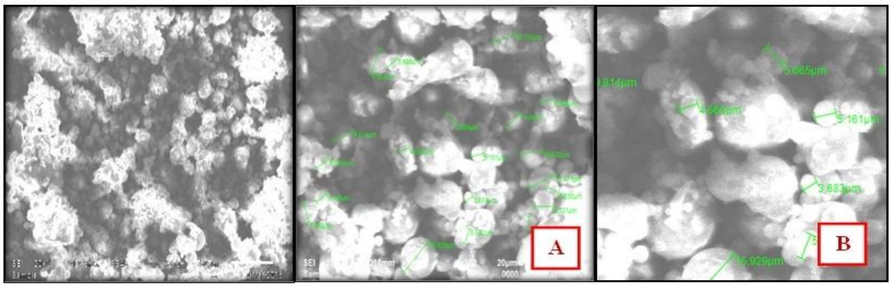


Figure 5 SEM analysis pic of Fly Ash

Inference of Figure 5

Above is the SEM analysis of Fly Ash which reveals us that the Fly Ash particle is of spherical in shape, its particle size is varying between 2-11 microns. The following are the particle sizes spotted from above figures A and B at the time of microstructural investigation, 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…. etc.

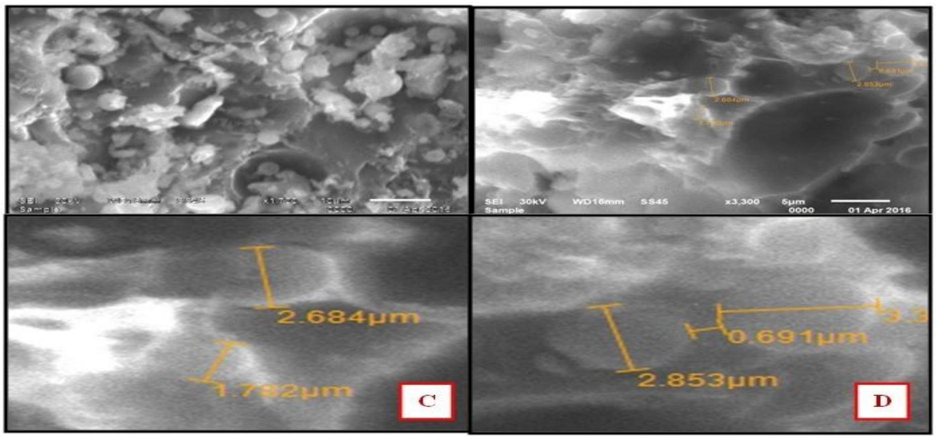


Figure 6. SEM analysis pic of Fly Ash with 30% epoxy

Inferenceof Figure 6:
Above is the SEM analysis of Fly Ash with 30% Epoxy on its weight it reveals us that how compactly Fly Ash particle is bonded with epoxy forming a massive structure with no micro level crack and with no voids in it yielding a homogenous mix. From figure C, it reveals that the fly ash particles having size 1.782 and 2.684 microns having bond length is less than 1.0 microns and from figure D, it also reveals that the fly ash particles having size 2.853 and 3.30 microns having bond length 0.691 microns which supports the high strength mortar results.

VII. CONCLUSIONS

From the above study the following conclusions are drawn.

1. From Figure-1, 2 & 3, All mixes are showed with 20%, 25% and 30% epoxy resin more than 150%, 175% and 225% (respectively) of compressive strength respectively at the age of 7 days with OPC53grade mortar cubes of strength (35.5 Mpa) as conventional mix as per IS: 4031.
2. From Figure-4, Mix(FA) with 30% Epoxy resin showed 30 to 15% more compressive strength were compared with balance mixes Mix(QD), and Mix(FA&QD) at same 30% Epoxy resin.
3. From Figure-5, & 6, according to the SEM analysis micro structure of Mix(FA) with 30% Epoxy shows its massive structure without any micro cracks, fractures and also voids. Hence it supports the reason for attainment of maximum strength obtained in case of FA-E30.

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