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An experimental investigation on mechanical behaviour of eco - friendly concrete

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Abstract: Fly ash (FA) and Alccofine are the eco-friendly materials that can be used in the production of concrete composites. Initially, concrete mixes of M30 grade with replacement of cement by 0%, 5%, 10%, 15%, 20% and 25% by weight of Fly ash were prepared. They were subjected to compression test so as to select the optimum replacement percentage of FA. Keeping this optimum percentage of FA as constant, additional replacement of cement with Alccofine was done varying its replacement in the range of 8%, 10%, 12% and 14%. The mechanical properties such as compressive, split tensile and flexural strengths of these mixes were computed for 7, 14 and 28 days. The results of Eco-Friendly Concrete (EFC) are compared with those of control concrete. It was observed that EFC mixes exhibited superior qualities like quick setting and enhanced workability, their mechanical properties were found to be higher than that of the conventional concrete. This goes to prove that the combination of FA and Alccofine together as replacement for cement would enhance the properties of EFC.

1. Introduction:

Cement-based substances have been the most essential construction materials for many decades now and they are likely to continue to enjoy this kind of an importance in the distant future too. Many waste and eco-friendly materials like FA, Ground Granulated Blast Furnace Slag (GGBS), Rice Husk Ash (RHA), Limestone Fines and Alccofine have been shown to exhibit pozzalonic properties; thus they have been used as alternative cementitious substances. They can be mixed either directly to cement or at the concrete mixer. Such cementitious substances for concrete should be fine mineral powders; further, when they are mixed with water, they should react chemically to shape as rigid mass to make concrete. This paper presents an experimental study on the use of Alccofine and FA in combination. These materials have exceptional characteristic in enhancing the performance of concrete both in the fresh and the hardened stages due to their optimized particle size distribution.

2. Literature Review:

D. Sharma et.al.,[12] conducted experimental investigation on concrete using foundry slag as an alternative for conventional fine aggregate and Alccofine as substitute for cement. They concluded that reasonably high strength concrete can be achieved by means of substituting fine aggregate with 45% of foundry slag and replacement of cement with 15% of Alccofine.

K. Gayathri et.al.,[17] has performed research on performance of Alccofine replacing the cement in concrete at 5%, 10%, 15% and 20%. It is found that 15% replacement of cement by Alccofine is yielding good strength when compared to other percentages and also Alccofine increases the cementing efficiency at earlier ages of concrete.

M. Y. Patel et.al.,[6] has conducted experimental investigation on compression strength of concrete mix at 28 and 56 days. They have concluded that concrete with combination of Alccofine and Glass powder has given higher compressive strength. The maximum strength was attained by replacing cement by 10% Alccofine and 30% Glass powder.

D. S. Kumar et.al.,[4] did experimental studies on the performance of M50 grade concrete with partially replacement of cement with Alccofine at 10 % by weight. The mechanical and durability studies were conducted and found that the strength attained by the use of 10% Alccofine showed higher strength to that of the nominal mix with 7 day and 28 days curing. The durability of the Alccofine concrete is relatively higher than that of nominal mix.

Siddharth et.al.,[20] conducted experimental work on compressive strength of self compacting concrete by replacing cement with Alccofine, FA and natural sand with m-sand. They observed that by adding Alccofine the strength has been increased rapidly at early stages then that of FA. The combination of FA and Alccofine yielded better strength at all levels. The highest compressive strength is achieved by replacing cement at 10% Alccofine and 30% FA. The addition of Alccofine increases the self compatibility characters of concrete like filling and passing abilities, it also helps in resisting segregation.

3. Materials:

3.1Cement:

In our investigation, 53 Grade cement as per IS 12269: 1987 is used for all type of mixes. The physical and chemical properties of the cement used are given in Table 1 and Table 2 respectively.

Table 1: Physical Properties of Cement

Properties	Content	Values per IS 12269 : 1987
Grade	53	53
Specific gravity	3.12	3.15
Fineness of cement	6.50%	< 10%
Normal Consistency	32%	30% - 35%
Initial Setting Time	50 min	> 30
Final Setting Time	420 min	< 600
Soundness	1.2 mm	< 10 mm

Table 2: Chemical composition of Cement

Chemicals	Content %	Chemicals	Content %
SiO_2	21.3%	CaO	63.1
Al_2O_3	4.5	Na_2O	0.1
Fe_2O_3	4.0	K_2O	1.2
MgO	2.4	SO_3	2.2

3.2Fly ash (FA):
FA is a waste by-product from thermal power plants. Fly ash used in our work is class - F type obtained from Vijayawada thermal power station in Vijayawada, Andhra Pradesh. The physical and chemical properties of Fly ash are mentioned in Table 3 and Table 4 respectively.

Table 3: Physical Properties of Fly Ash

Properties	**Values**
Specific Gravity	1.975
Fineness Modulus	1.195

Table 4: Chemical composition of Fly ash

Chemicals	**Formula**	**Content (%)**
Silicon Dioxide	SiO_2	59.04
Aluminum Oxide	Al_2O_3	34.08
Iron Oxide	Fe_2O_3	2.0
Lime	Cao	0.22
Sulphur Trioxide	SO_3	0.05
Magnesium Oxide	MgO	0.43
Alakalies	Na_2O	0.5
Alakalies	K_2O	0.76
Loss of ignition	LOI	0.63

3.3Alccofine:
Alccofine used in our investigation was manufactured by M/S Counto Microfine Products Pvt. Ltd., (CMPP), Alcon Organization, Goa, India. The physical and chemical properties of Alccofine can be found in Table 5 and Table 6 respectively.

Table 5(a): Physical Properties of Alccofine

Property	**Values obtained**
Fineness (cm^2/gm)	>12000
Specific Gravity	2.9
Bulk Density(Kg/m^3)	700-900

Table 5(b): Physical Properties of Alccofine

Particle Size Distribution in Microns	
D10	1.5
D50	5
D90	9

Table 6: Chemical composition of Alccofine

Chemicals	**% Values**
CaO	61-64 %
SO_3	2-2.4 %

SiO_2	21-23 %
Al_2O_3	5-5.6 %
Fe_2O_3	3.8-4.4 %
MgO	0.8-1.4 %

3.4Coarse aggregate:
The coarse aggregate used in our investigation was rounded uncrushed gravel which are passed through a 20 mm sieve and were retained in 12 mm sieve obtained locally. The physical properties of coarse aggregate are shown in Table 7.

Table 7: Properties of Coarse Aggregate

Property	Values obtained
Specific Gravity	2.63
Fineness Modulus	7.22
Water Absorption	0.83%

3.5Fine aggregate:
The fine aggregate used in our investigation was the locally available river bed sand. Its characteristics are listed down in Table 8.

Table 8: Properties of Fine Aggregate

Property	Values obtained
Specific Gravity	2.68
Fineness Modulus	2.7
Grade Zone	II
Water Absorption	0.20

3.6Water:
Tap water available in our University campus was used in this investigation for the purpose of preparing the mixes.

4. Mix Design:
M30 Grade of concrete mix design was arrived at according to IS 10262-2009. The mix proportion arrived at for the experiments are shown in Table 9.

Table 9: Mix Proportion

Materials	Cement kg/m^3	Fine Aggregate kg/m^3	Coarse Aggregate kg/m^3	Water kg/m^3
Quantity	438	699.2	1109.8	197

Mix Proportion =1: 1.59: 2.53 with water cement ratio (w/c) of 0.43.

5. Results:

5.1Trail Mixes:
In general, workability is the term used in concrete technology to describe all the necessary qualities like ease of placing, compacting and finishing of concrete. Slump cone test is the experimental procedure for workability. Table 10 depicts the results of the slump test conducted on the various concrete mixes.

Table 10: Slump Test Results

Mix Identification	Slump in mm (From bottom)
Control Mix **(CM)**	225
Mix with15% Fly ash replacement of cement **(M1)**	218
Mix with 15% Fly ash and 8% Alccofine replacement of cement **(M2)**	186
Mix with 15% Fly ash and 10% Alccofine replacement of cement **(M3)**	173
Mix with 15% Fly ash and 12% Alccofine replacement of cement **(M4)**	175
Mix with 15% Fly ash and 14% Alccofine replacement of cement **(M5)**	183

From the results displayed in above table 10, it can be concluded that concrete with combination of FA and Alccofine gives more workability when compared to CM.

5.2Compressive Strength:
The specimens were subjected to compression test on the Compression Testing Machine (CTM).This part of the research work was performed in two phases.

5.2.1 Phase I - Selection of optimum percentage of Fly ash:
Phase I describes the investigation carried out to evaluate the compressive strength of concrete into different percentages of FA as a partial replacement of cement to find the optimum percentage of FA replacement (M1). The results are tabulated in Table 11 and graphically illustrated in Fig. 1.

Table 11: Compressive Strength of various Mixes Containing Fly ash

Mixes	Strength in Mpa		
	7 days	14 days	28 days
CM	25.31	32.5	39.6
Mix with 5% Fly ash	20.36	22.03	32.9
Mix with 10% Fly ash	22.67	23.6	34.9
Mix with 15% Fly ash	**25.2**	**26.7**	**39.9**
Mix with 20% Fly ash	24.4	25.06	36.04
Mix with 25% Fly ash	21.11	21.9	33.4

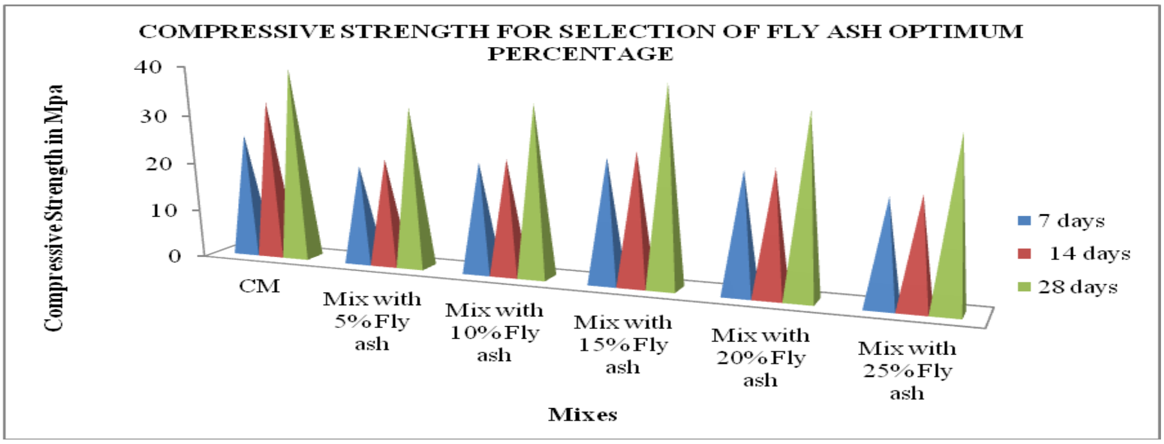

Figure 1: Graphical representation of selection of optimum percentage of Fly ash at different ages

The mix with 15% Fly ash replacement of cement has shown the maximum strength. Hence, it was concluded that the optimum percentage of replacement of cement by Fly ash could be taken as 15%.

5.2.2 Phase II - Compressive strength of concrete with Fly ash - Alccofine combination:
Phase II deals with the investigation carried out for the evaluation of the compressive strength of the mixes M2 to M5. The experimental results are shown in Table 12 and depicted in Fig. 2.

Table 12: Compressive strength of concrete with different percentages of Fly ash and Alccofine

Mixes	**Strength in Mpa**		
	7 days	**14 days**	**28 days**
CM	25.31	32.5	39.6
M2	27.11	36.53	43.53
M3	**31.11**	**38.66**	**45.69**
M4	28.88	35.95	39.11
M5	26.13	33.77	36.88

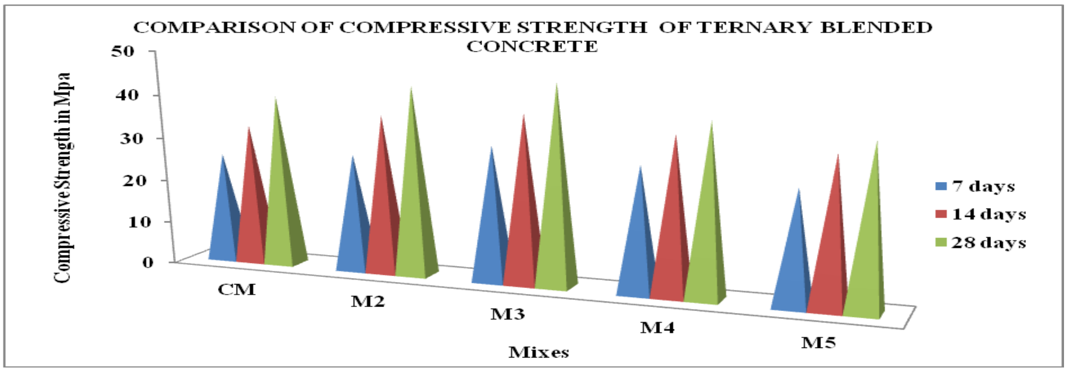

Figure 2: Graphical representation of Compressive strength of concrete at different ages

The mix M3 (Mix with 15% FA and 10% Alccofine replacement of cement) has shown higher compressive strength at all the ages.

5.3Split Tensile Strength Test of concrete with different percentages of Fly ash - Alccofine combination:
Split tensile strength test was performed on mixes M2 to M5. The experimental results are shown in Table 13 and depicted in Fig. 3.

Table 13: Split Tensile strength of concrete with different percentages of Fly ash and Alccofine

Mixes	Strength in Mpa		
	7 days	14 days	28 days
CM	1.29	2.82	3.0
M2	1.34	2.82	3.12
M3	**1.69**	**3.25**	**3.698**
M4	1.98	3.12	3.42
M5	1.55	3.02	3.24

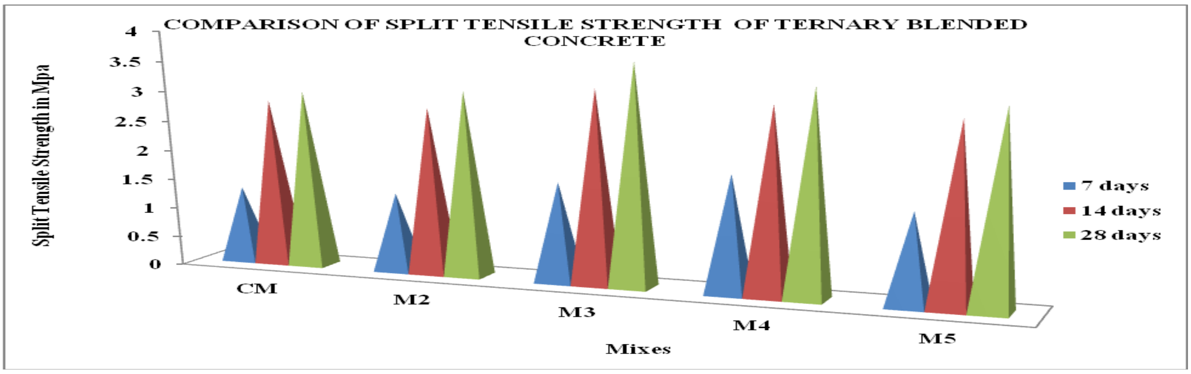

Figure 3: Graphical representation of Split Tensile strength of concrete at different ages

5.4Flexural Strength Test on concrete with different percentages of Fly ash - Alccofine combination:
Test for Flexural strength of the mixes M2 to M5 were performed in universal testing machine(UTM). The experimental results are shown in Table 14 and depicted in Fig. 4.

Table 14: Flexural strength of concrete with different percentages of Fly ash and Alccofine

Mixes	Strength in Mpa		
	7 days	14 days	28 days
CM	2.42	2.86	4.20
M2	2.53	3.01	4.21
M3	**2.88**	**3.66**	**4.80**
M4	2.46	3.21	4.10
M5	2.28	2.96	3.8

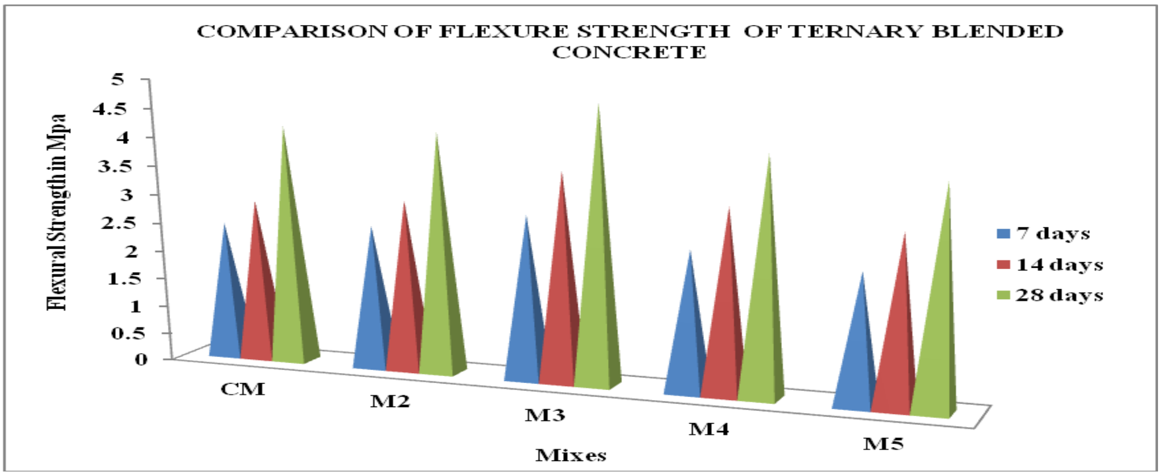

Figure 4: Graphical representation of Flexural strength of concrete at different ages

6.Conclusion:

It was observed that in EFC, having combination of Fly ash and Alccofine the concrete sets quickly than that of control concrete. It has also shown better workability as observed from slump cone test. The results of compression tests on EFC with Alccofine and Fly ash combinations at different ages show that the values are superior compared to control concrete. In our investigation, the highest compression strength was achieved by the combination of FA - Alccofine at 15% - 10% respectively, also it gave maximum strength values in split tensile and flexural strength. About 24.7%, 23.2% and 14.28% strength was increased for compression, split tensile and flexural tests at the age of 28 days when compared with CM. Addition of replacement materials leads to eco-friendly and sustainable concrete and at the same time results in the reduction of overall cost of manufacture of EFC.

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