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An Experimental Investigation on Partial Replacement of Cement by Fly Ash and Lime in Concrete

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Abstract - *An experimental investigation was performed to study the effect of fly ash and lime on the strength properties of concrete made by partial replacement of cement with fly ash and lime. Various concrete mixtures were prepared with different proportion of fly ash and lime ranging from 0% (for control specimen) to 15%. In this research work, cement is replaced with fly ash and lime simultaneously in the reach of 0, 5%, 10% & 15% by weight of M-30 grade of concrete. The concrete mixtures were evaluated for compressive strength, split tensile strength and flexural strength test. The samples were specified as S0 (control specimen), S1 (5% FA+ 5%lime), S2 (10%FA + 15%lime) & S3 (15%FA + 10%lime) with the replacement of cement in the concrete mixtures. Various tests were conducted to investigate the properties of concrete and the results obtained from experiment for concrete mixtures indicated that there is an increase in compressive strength and flexural strength for the specimen S1 whereas the split tensile strength slightly decreased as compare to control mixture (S0). However, there is a strength reduction with the addition of more fly ash and lime both simultaneously.*

Key Words: cement, concrete, fly ash, lime, strength

1. INTRODUCTION

Concrete is largest produced material in the construction industry and as per WHO concrete is the largest consumed material by human beings after food and water. About 75% of the concrete is composed of aggregates and because of huge demand of concrete all over the world, availability of natural aggregates is becoming scarce. Civil engineers have always been looking for an alternative for the use of more ecofriendly and easily available materials as a replacement to conventional constituents in concrete. Concrete industry has always welcomed the use of various industrial waste materials as a replacement to these constituents since, otherwise such industrial waste need to be disposed in the form of landfills causing enormous amount of land pollution. Use of fly ash and lime as the replacement of cement in concrete mix is considered very eco-friendly and it is also economical. It saves the cement requirement for the same strength thus saving of raw materials such as limestone, coal etc required for manufacture of cement. Fly ash is pozzolanic material & it improving the properties of concrete like compressive strength & durability. This project presents the experimental investigation carried out to evaluate the effect of partial replacement of cement with fly ash and lime which is waste product generated from the industries.Various tests are performed such as compressive test on concrete cube for size (150 x 150 x 150) mm, flexural strength on concrete beam (500 x 100 x100) and split tensile strength on concrete cylinder (150 mm ø x 300mm) as per IS: 516 – 1959, IS: 5816 – 1999 and IS: 516 – 1959 respectively. P. R. Wankhede et. al performed the experimental study on partial replacement of cement by fly ash. The author observed that for mix of M25 grade of concrete loss in the slump of concrete increases with increase in w/c ratio of concrete. Ultimate compressive strength of concrete goes on decreasing with increase in w/c ratio of concrete. Concrete with 10% and 20% replacement of cement with fly ash shows good compressive strength for 28 days than normal concrete for 0.35 w/c ratio but in the case of 30% replacement of cement with fly ash ultimate compressive strength of concrete decreases. S. H. Sathawane et. al. performed the experimental study on the effect of partial replacement of cement by fly ash, rice husk ash with using steel fiber in concrete. The author concluded that the compressive strength increases with the increase in the percentage of fly ash and rice husk ash up to replacement (22.5%FA & 7.5% RHA) of cement in concrete for different mix proportions. The split tensile strength and flexural strength of concrete was obtained after 28 days with the replacement of 22.5% fly ash and 7.5% rice husk ash mix. Based on the literature review the objectives of this research are following:

- The relative strength development with age of concrete with incorporation of OPC cement by fly ash and lime with control concrete.
- The compressive strength test on cube (150mm x 150mm x 150mm) with and without replacement (lime + FA) of materials.
- To perform flexural strength test on beam (100mm x 100mm x 500mm) with and without replacement (lime + FA) of materials.
- To perform split tensile strength test on cylinder (100mm ø x 300mm) with and without replacement (lime + FA) of materials.

2. MATERIAL PROPERTIES

2.1 Cement

The cement that was used in this study of 43 grade OPC manufactured by the JP cement company confirming to IS 8112:1989. The properties of cement are shown in Table 1.

Table -1: Physical properties of cement

Test	Result	Specified by IS (8112:2013)
Fineness of cement (kg/m^2)	241	225
Consistency of cement	35	30
Initial setting time (minutes)	85	30
Final setting time (minutes)	290	600
Specific gravity	3.24	2.5-3.5
Compressive strength (N/mm^2)	35.3	30
Soundness (mm)	5	10

2.2 Fine aggregate

Fine aggregate is obtained after sieving of sand material which passed through 4.75mm IS sieve.

2.3 Coarse aggregate

The coarse aggregate is used from a local quarry. The coarse aggregate is used with maximum size of 12-20 mm according to IS 383 (1970).

2.4 Fly ash

In this study class F fly ash is used. It was grey in color, particle size less than 35µm. Its specific gravity was 2.24.

Table-2: Physical properties of fly ash

Parameters	Fly Ash
Bulk density (gm/cc)	0.85-1.35
Specific gravity	1.50-2.75
Plasticity	Lower or non-plastic
Shrinkage limit	Higher
Clay	Negligible
Free swell index	Very low
Classification (Texture)	Sandy silt to silty loam
Water holding capacity	35%-65%
Porosity	33%-65%

Table-3: Chemical properties of fly ash

Compounds (%)	Fly Ash
SiO_2	38-63
Al_2O_3	27-44
TiO_2	0.4-1.8
Fe_2O_3	3.3-6.4
MgO	0.01-0.5
CaO	0.2-8
K_2O	0.04-0.9
Na_2O	0.07-0.43
LOI	0.2-5.0
pH	6-8

2.5. Lime

In construction the white powder slaked lime has a wide range of application. The properties of lime are:

- Cementing capability: This is obtained by their carbonation with carbon dioxide. Lime is used as lime mortar for brick masonry construction.
- Lime has a higher acid resistance due to its alkaline nature.
- Lime has gain pozzolanic activity, this gives cementitious products.
- Sealing of micro cracks: This is done by the precipitation made by the calcium carbonate when carbon dioxide passes through the lime mortar mix.

The table below shows the physical and chemical properties of lime under various classes as per IS: 4031-1968 and IS: 6932-1972 Part (3 to 10).

Table-4: As per IS 6932-1973 (Part 1 to 11, RA 2009), Building Lime Physical Requirements

Characteristic of lime	Class and type of building lime										Test method or test reference
	A	B		C		D		E	F		
	Hyd	Quick	Hyd	Quick	Hyd	Quick	Hyd	Hyd	Quick	Hyd	
1 Fineness											
(a) residue on 2.36 mm IS sieve, %, max	Nil	-	Nil	-	Nil	-	Nil	Nil	-	Nil	IS 6932-1973 (part 4)
(b) residue on 300 micron IS sieve, %, max	5	-	5	-	Nil	-	Nil	5	-	5	
(c) residue on 212 micron IS sieve, %, max	-	-	-	-	10	-	10	-	-	-	
2 Residue on slaking											

(a) residue on 850 micron IS sieve, %, max	-	10	-	5	-	5	-	-	10	-	
(b) residue on 300 micron IS sieve, %, max	-	-	-	5	-	5	-	-	-	-	IS 6932-1973 (part 3)
3 Setting time											
(a) Initial set, min, hour	2	-	-	-	-	-	-	2	-	-	
(b)) Final set, min, hour	48	-	-	-	-	-	-	48	-	-	IS 6932-1983 (part 11)
4 Compressive strength, min MPa											
(a) At 14 days	1.75	1.25	1.25	-	-	-	-	1	1.25	1.25	IS 6932-1973
(b) At 28 days	2.8	1.75	1.75	-	-	-	-	1.75	1.75	1.75	(part 7)
5 Transverse strength, min, MPa											
(a) At 28 days	1	0.7	0.7	-	-	-	-	0.7	0.7	0.7	
6 Workability bumps, max	-	-	-	12	10	12	10	-	-	-	IS 6932-1973 (part 8)
7 Soundness	free	-	free	-	free	-	free	-	-	free	IS 6932-1973 (part 8)

3. EXPERIMENTAL RESULTS AND DISCUSSION

In this study four types of samples were prepared for the experimental work. The first sample (S0) specified as a control specimen without replacement of materials. For the preparation of mix sample with the replacement of cement with fly ash and lime is replaced by 5% of lime & 5% of fly ash (S1), 10% of fly ash & 15% of lime (S2) and 15% of fly ash & 10% of lime (S3) for M30 grade of concrete. The test moulds are kept ready before preparing the mix. Tighten the bolts of the moulds carefully because if bolts of the moulds are not kept tight the concrete slurry coming out of the mould when vibration takes place. Then moulds are cleaned and oiled on all contact surfaces of the moulds and place the moulds on vibrating table. The concrete is filled into moulds in layers and then vibrated. The top surface of concrete is struck off level with a trowel. The number and date of casting are put on the top surface of the cubes, cylinders and beams. In this research work total number of samples were 36 that including 12 cubes (150mm X 150mm X150mm), 12 beam (500mm X 100mm X 100mm) and 12 cylinders (150mm X 300mm). The results are analyzed after curing of 7, 14 and 28 days of concrete. The Data obtained from the replacement of fly ash and lime is compared with data obtained from a conventional concrete.

3.1 Preparation of samples

A mix of M30 grade of concrete was prepared and the same is used to prepare the test samples. The concrete mix proportion (cement: fine aggregate: coarse aggregate) is 1: 0.75: 1.5 by volume and a water-cement ratio of 0.45 is used. Designed mix is prepared for the conventional concrete. The details of replacement of fly ash and lime by cement are shown in Table 5.

Table-5: Replacement of fly ash and lime (% by weight)

Sample No.	Cement	Fly ash	Lime	Fine aggregate	Course aggregate
S0	100	0	0	100	100
S1	90	5	5	100	100
S2	75	10	15	100	100
S3	75	15	10	100	100

3.2 Compressive strength

Compression testing machine is used for testing the compressive strength of concrete. The samples of concrete mixed with fly ash and lime with different proportion are tested after curing of 7, 14 and 28 days. The results obtained from the experiment are shown in Table 6. Out of many test applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not. For cube test the size of mould (15cm X 15cm X 15cm) was used. The concrete is poured in the mould and tempered properly so as not to have any voids. After 24 hours these moulds are removed and test specimens are put in water for curing. The top surface of these specimens should be made even and smooth. These specimens are tested by compression testing machine after 7, 14 and 28 days. Load should be applied gradually at the rate of 140 kg/cm^2.

Table-6: Compressive Strength Results

Specimens	Compressive strength at 7 days(N/mm^2)	Compressive strength at 14 days(N/mm^2)	Compressive strength at 28 days(N/mm^2)
S0	25.04	28.74	33.33
S2	39.85	35.9	32.14
S3	26.32	31.28	38.19
S4	29.09	30.35	36.26

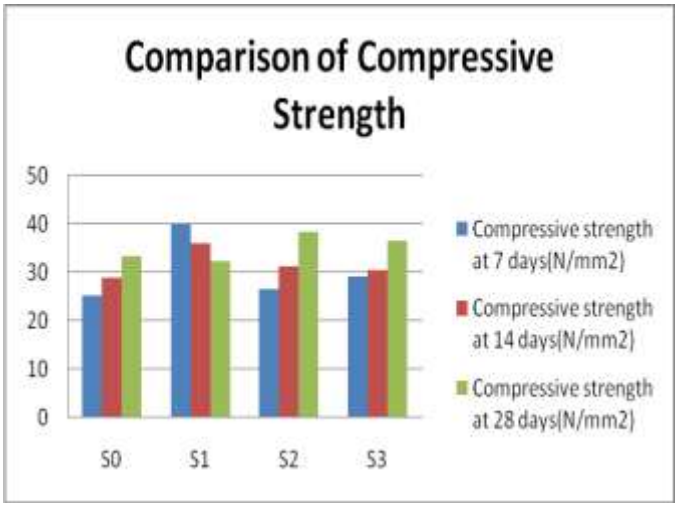

Chart-1: Compressive strength of various samples

3.3 Split tensile strength

Compression testing machine is used for testing the split tensile strength of concrete. The samples of concrete mixed with fly ash and lime with different proportion are tested after curing of 7, 14 and 28 days. The results obtained from the experiment are shown in Table 7. It is standard test cylinder of concrete specimen (300mm X 150mm diameter) is placed horizontally between the loading surfaces of compression testing machine. The compression load is applied diametrically and uniformly along the length of cylinder until the failure of cylinder along the vertical diameter. To allow the uniform distribution of this applied load and to reduce the magnitude of high compressive stresses near the point of application of this load, strips of plywood are placed between the specimen and loading platens of testing machine. Concrete cylinder splits into two halves along this vertical plane due to indirect tensile stress generated by poisson's effect. Due to compressive loading, an element lying along the vertical diameter of the cylinder is subjected to vertical compressive stress and a horizontal stress. The loading condition produces a high compressive stress immediately below the loading points. It is estimated that the compressive stress is acting 1/6 depth and the remaining 5/6 depth is subjected to tension due to Poisson's effect.

Table-7: Split tensile strength results

Specimens	Split tensile strength at 7 days(N/mm²)	Split tensile strength at 14 days(N/mm²)	Split tensile strength at 28 days(N/mm²)
S0	2.310	2.68	3.39
S1	2.72	2.57	3.06
S2	2.40	2.65	2.86
S3	2.49	2.00	3.24

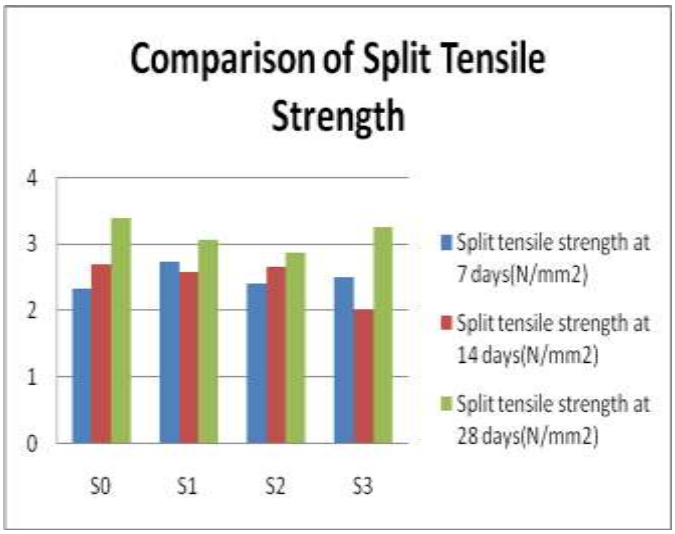

Chart-2: Split tensile strength of various samples

3.4 Flexural strength

The samples of concrete mixed with fly ash and lime with different proportion are tested after curing of 7, 14 and 28 days. The results obtained from the experiment are shown in Table 8. The test could be performed in accordance with as per BS 1881: Part 118: 1983. A simple plain concrete beam is loaded at one-third span points. Span of the beam is three times of its depth. For this test the beams of dimension 100*mm* x 100*mm* x 500*mm* were casted.

Table 8 Flexural strength results

Specimens	Flexural strength at 7 days(N/mm²)	Flexural strength at 14 days(N/mm²)	Flexural strength at 28 days(N/mm²)
S0	7.1	7.67	8.67
S1	5.1	7.8	10.5
S2	7.5	8.1	9
S3	8.1	8.2	8.2

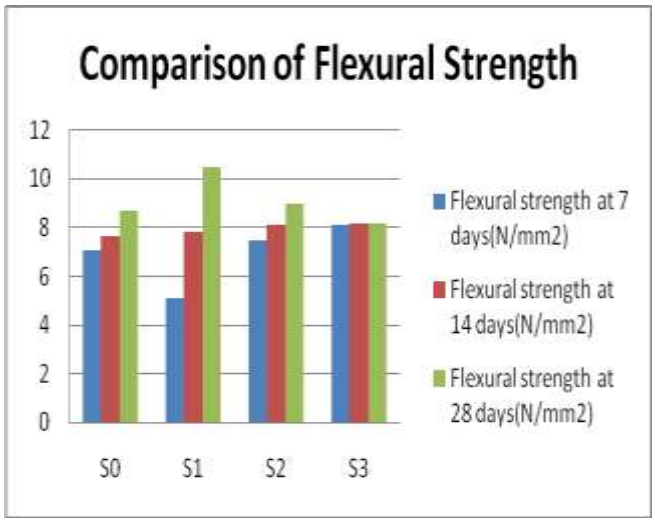

Chart-3: Flexural strength of various samples

4. CONCLUSIONS

i. Compressive strength of concrete is increased by replacement of cement with 10% fly ash and 15% lime (S2) after 28 days of testing as compare to control specimen. There is slightly decrease in compressive strength for 5% lime and 5% fly ash (S1) each at 28 days than conventional concrete mix (S0).
ii. For the age of 7 days split tensile strength decreases by small value than conventional concrete. The maximum split tensile strength value is obtained for control specimen (S0) (without replacement of materials) after 28 days of testing.
iii. Flexural strength of concrete increases with replacement of cement with 5% of fly ash and 5% of lime (S1) than conventional concrete (S0).
iv. As the percentage of fly ash increases and lime decreases flexural strength increases.

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