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LOW CALCIUM FLY-ASH OPTIMIZATION IN CONCRETE: SUSTAINABLE ALTERNATIVE FOR REPLACING CEMENT AND SAND

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Abstract: In this paper the basic properties viz. workability and compressive strength of concrete with feasibility of optimizing low calcium fly ash as alternative for cement and sand were investigated. Fly ash utilized with varying percentage replacing the cement and filler material. Series of design mixes prepared, cured and tested for compressive strength at 7 & 28 days. The results revealed that the workable flow in range of 30 $\pm$ 5 to 55 $\pm$ 5 mm. The obtained compressive strength increases with age but affected by increasing percentage. The paper demonstrates that; this particular optimizing fly ash concrete complies with the relevant performance requirements of the Indian Standard and thus provides a viable alternative to Portland cement and sand.

Keywords- Fly Ash, Mix proportion, Cement, Fine Aggregate, Compressive Strength

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INTRODUCTION

Concrete is the most widely used construction material and the second most consumed resource in the world [1]. As demand for concrete as a construction material increases the production of Portland cement will also increase. However, production of Portland cement liberates a considerable amount of greenhouse gas as a result of decarbonation of limestone in the kiln during manufacturing of cement and the combustion of fossil fuels. Furthermore, Portland cement is also among the most energy intensive construction materials, after aluminium and steel [2]. Efforts have, therefore, been made to promote the use of pozzolans to replace part of Portland cement [3]. Fly ash is thought to be good candidate for source materials because it is the residue from coal burnt in a thermal power plant and regarded as a waste product. Fly ash has a complex microstructure comprising of a mixture of amorphous and crystalline components. Fly ash replacement of Portland cement; these are environmentally friendly and need only moderate energy for being obtained. In comparison with Portland cement CO2 emission is reduced of about 80% [4]. Whereas Indian standard permit to accumulate the fly ash up to 30 % in concrete mix to replace cement [5]. The use of fly ash as concrete admixture not only extends technical advantages to the properties but also contributes to the environmental pollution control [6]. But the optimization of fly ash in mix proportions for high performance concrete which contain many constituent and are often subjected to several performance constrain, can be a difficult and time consuming task. Statistical experiment design and analysis method have been developed specifically for the purpose of optimizing mixture, such as concrete in which the final product properties depend on the relative proportion of the components rather than their absolute amounts [7]. Statistical mixture experiment was used to optimize a mixture subjected to several performance constraints. The experiment was performed in order to assess the usefulness of this technique for high performance concrete mixture proportioning in general.

This system, the Concrete Optimization, employs a interactive procedure starting with materials selection and working through trial batches, testing, and analysis of test results. The end result is recommended mixture proportions to achieve the desired performance levels. Cost was developed as a tool to introduce the industry to the potential benefits of using statistical methods in concrete mixture proportioning, and to give interested parties an opportunity to try the methods for themselves.

1. MATERIAL AND TESTING

1.1 Cement

Locally available ordinary Portland cement satisfying all the requirements of IS 12269:1987 used for making the concrete [8].

1.2 Aggregate

Coarse aggregate collected from nearby quarry and sand i.e., fine aggregate obtained locally from nearest river passing through 4.75 IS sieve having fineness modulus (F.M)-2.61 and aggregate confirming to zone-III as per IS: 383-1970 was clean and free from impurities [9].

2.3 Fly Ash

The fly ash collected in dry state from the local Power plant located at Paras. The specific gravity of fly ash is 1.31 mg/cubic meter and the test on fly ash are done as per IS: 1727:1967 [10] at Anacon Laboratories Nagpur. The chemical characteristics of the fly ash are given in Table 1.

Table 1.

Chemical Analysis	S_iO_2	Al_2O_3	Fe_2O_3	CaO	SO_3	Na_2o	M_go	LOI
Fly Ash composition (%)	64.23	25.82	4.06	2.03	0.27	0.40	0.78	0.39

2.4 Manufacturing of Concrete

The concrete was designed as per IS: 10262:2010 [5] for a grade of M20 and M25 and slump ranging between 25-75 mm with the maximum water cement ratio 0.50 and 0.45 [11]. The concrete were made using Ordinary Portland cement without any super plasticizers. They mix proportion were prepared for M20, M25 grade and batched by weight with increasing percentage of fly ash added to replace the cement and sand. The mix proportion and the compressive strength tested at 7 and 28 days are shown in Table no. 2.

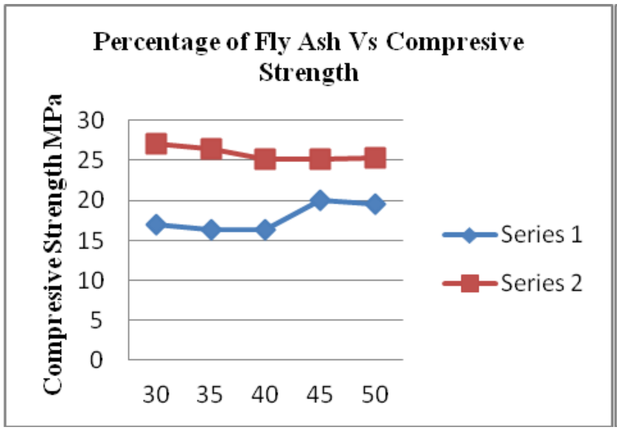
Table No. 2

Grade	Cement (Kg)	Replace (%)	Actual cement (Kg)	Sand (kg)	Replace (%)	Actual sand (kg)	Workability (mm)	Compressive strength(N/mm^2)	
								7 days	28 days
M20	372.33	30	260.631	564.70	0	564.70	30	16.96	27.05
M20	372.33	30	260.631	564.70	5	536.46	35	16.37	26.52
M20	372.33	30	260.631	564.70	10	508.23	35	16.36	25.22
M20	372.33	30	260.631	564.70	15	479.995	45	19.99	25.11
M20	372.33	30	260.631	564.70	20	451.760	56	19.48	25.33
M25	404.35	30	283.045	556.04	0	556.04	30	20.18	26.22
M25	404.35	30	283.045	556.04	5	528.238	35	19.85	30.22
M25	404.35	30	283.045	556.04	10	500.436	45	16.44	27.40
M25	404.35	30	283.045	556.04	15	472.634	50	18.56	26.74
M25	404.35	30	283.045	556.04	20	444.835	55	13.33	24.14

3. RESULT AND DISCUSSION

3.1 Compressive Strength

The compressive strength of concrete is one of the most essential design parameter of concrete. The concrete develop the strength with continuous hydration but with it can be reduced through replacement of part of cement with fly ash. The rate of gain strength increases with start and rate gets reduced with age. This series tested which determine the strength attained by concrete whose cement and fine aggregate replace with varying percentage of fly ash from 0 to 50 %. The fly ash replaced cement up to constant 30 % and sand with increasing percentage from 0 to 20 %. The compressive strength test carried out according to IS 516:1959 [12]. The results plotted on graph below the average value of three cubes tested at each 7 and 28 day. As the fly ash added to the concrete, a decreases the strength gain is observed shown in Fig. 1 and Fig.2. Fly ash affects the early strength gain probably due to free limit that is still reacting during curing process.



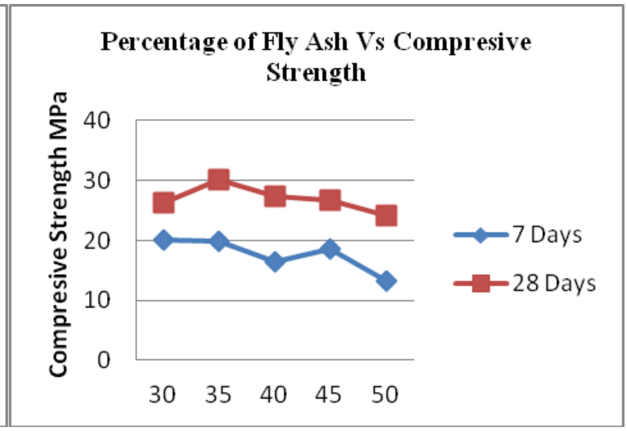
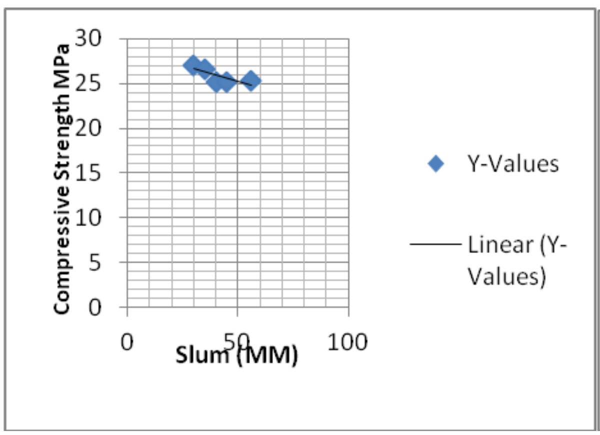


Fig. no.1 M20 Grade **Fig. no.2 M25 Grade**

3.2 Workability

The fine glossy pozzolonic material, in spite of increasing surface area, offer better lubricating effect for giving better workability, but increasing the percentage of fly ash flow increases. The workability and strength gain has been plotted for understanding the durability of concrete shown in Fig. no.3 and 4



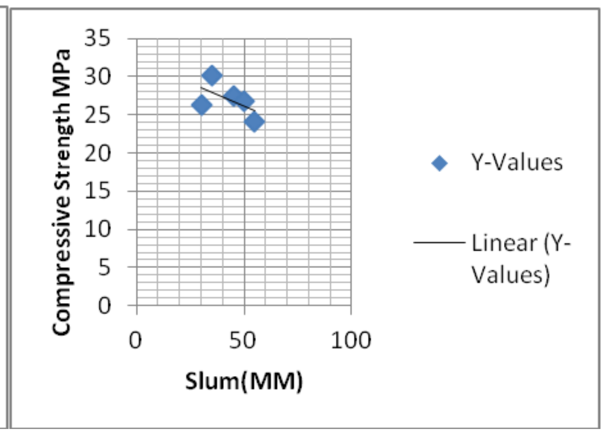


Fig. no.3 M20 Grade **Fig. no.4 M25 Grade**

CONCLUSION

Based on the obtained data, it can be concluded that, the replacement of fly ash reduces the strength gain of concrete but as per results it can also possible to replace the sand also as age of 28 days the concrete getting required strength. A 30 - 40 % fly ash replacement provides the most optimal (best possible) strength results. Beyond 40 % fly ash replacement, the rate of gain of compressive strength decreases at 7 days maintains also increasing the percentage of fly ash in concrete, increases the chances of flow ability in concrete.

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