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Strength Analysis of Fly Ash Replacement in High Alumina Cement

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Abstract: The rising cost of construction materials in developing countries has necessitated research into the use of alternative materials in civil engineering construction. Concrete mix design is a process of proportioning the ingredients in right proportions. Though it is based on sound technical principles and heuristics, the entire process is not in the realm of science and precise mathematical calculations. This is because of impreciseness, vagueness, approximations and tolerances involved. In this study concrete mix of M35 was used as control, while fly ash was used to replace high alumina cement by volume. Eighty cubes ere produced and the weight and compressive strengths were evaluated at 1st day, 3rd days, 7th days, 14th days and 28th days. This paper also presents the development of a novel technique for approximate proportioning of standard concrete mixes as suggested in IS: 10262-2003 and IS456-2000. The results in terms of quantities of cement, fine aggregate, course aggregate, water and fly ash obtained through the present method for various grades of standard concrete mixes are in good agreement with those obtained by the prevalent conventional method. Details of the system model are described and comparative graphs are presented.

Keywords: Concrete Mix Design, Compressive strength, Fly ash (FA), High alumina cement (HAC).

I. INTRODUCTION

Concrete is the most widely used construction material in civil engineering world. Due to the development of recent new technologies, many materials are used as valuable inorganic and organic resources to produce various useful and value added products. Now a day in civil engineering industry supplementary cementitious materials are playing a great role. The concrete industry is constantly looking for different supplementary cementitious material with their objectives of reducing the solid waste disposal or by product problems i.e. fly ash (FA), silica fume, natural sand with quarry sand etc. The disposal of fly ash is one of the important issues for environmentalists as dumping of fly ash as a west product may cause different environmental hazards/problems. Cost saving result can result when industrial by products are used as partial replacement of or the energy intensive cement.

Calcium Aluminates Cement or Aluminous Cement or High Alumina Cement was developed in France in 1908 by Bied of the Pavin de Lafarge Company as a result of search for a cement offering sulphate resistant and later it was used as a refractory material to resist high temperature that means mainly used in industry.

High Alumina Cement is rapid hardening cement made by fusing at 1500 to 1600 degree Celsius, a mixture of bauxite and limestone in a electric furnace or in a rotary kiln. This is special type of cement that has high rate of strength development, refractoriness and possesses high chemical resistant. About 80% of its ultimate strength is achieved within 24hrs. Even if 6-8hrs is sufficient for the High Alumina Cement is generally used in side formwork.

High Alumina Cement (HAC) gets strength at low temperature as compare to Portland cement. High Alumina Cement is often used as a bonding material for refractory casteless because it forms ceramic bonds at high temperature and maintain its strength even after cooling. With accurate selection of aggregates, it is possible to produce refractory casteless capable of resisting a maximum temperature of 1600 degree Celsius.

As the cost of HAC is very high, fly ash is used in different percentage by the replacement of cement as a supplementary product.

A. Composition of high alumina cement

The chemical composition is presented in Table 1 as supplied by the Lafarge Aluminous Cement Company Limited.

TABLE I CHEMICAL COMPOSITION OF HIGH ALUMINA CEMENT

Composition (%)	High Alumina Cement
Al_2O_3	73.5
CaO	25.0
Fe_2O_3	0.40
SiO_2	0.20
Others	less than 1.0

B. Design mix

The term "Design Mix" is world-wide common but the sense of design is completely different from structural design process. Over the years numerous attempts have been made to develop mix proportion equations based on observe influences of various factors. Such relations, or models, inevitably represents averages of behaviour and yet in every particular case of behaviour of concrete is affected by properties of ingredients which cannot be or cannot yet be expressed mathematically. Thus selecting mix proportion is not just a rule based process. It is also worth adding that some of the more elaborate methods involve numerous interaction terms, but there is a little value in including factor which is subject to unpredictable variation during construction. In the meantime, the selection of mix proportion must be best on preliminary calculations or experiences, followed by trial mixes of deciding relative proportions of ingredient of concrete to achieve the desire properties in the most ecumenical ways, by necessary adjustments. So it can easily say that mix selection requires both knowledge of the properties of concrete, experimental data (Trial mixes) and experiences. That means selection of mix proportion is an art as much as science. Due to variations in atmospheric conditions, ambient temperature, transporting distance, moisture content, aggregate grading, shape impart a great effect on concrete that's why proper field correction is required during production.

EXPERIMENTAL STUDY

C. Material properties

In this study, High Alumina Cement (HAC) of 35 grade used having specific gravity 3.10 along with bulk density 3.03 g/cc. Natural river sand of zone II was taken as per IS: 383-1970 with specific gravity 2.67, fineness modulus 3.03 and water absorption 2.95%. Natural coarse aggregate passing through 20mm and confirming to IS: 383-1970(RA 2007) of specific gravity 2.67, water absorption 0.30% and fine modulus 7.00. In this study, two types of coarse aggregates were used. Fly ash (FA) is used as replacement of HAC from 0%, 10%, 20%. FA used to make good workability condition of the mix. FA is generally used for excellent durability, high water reduction, high flowing. Here the following Table 2, Table 3 and Table 4 represented the gradation of coarse aggregate (20mm, 12.5mm) and fine aggregate respectively. The figure 1, figure 2 and figure 3 shows the grading curve for coarse and fine aggregates respectively.

TABLE II INDIVIDUAL GRADATION OF COARSE AGGREGATE (20MM)

IS Sieve Size	% of passing	Specification of Zone II as per IS: 383-1970 (RA 2007)
40mm	100	100
20mm	85.30	85-100
10mm	0.45	0-20
4.75mm	0.15	0-5

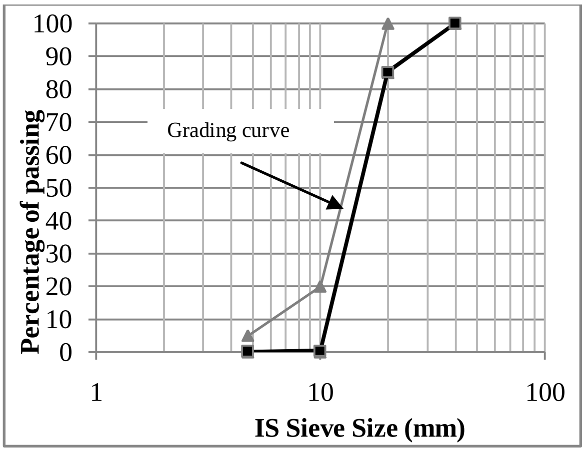

Fig. 1. Grading curve for coarse aggregate (20mm)

TABLE III Individual gradation of coarse aggregate (12.5mm)

IS Sieve Size	% of passing	Specification of Zone II as per IS: 383-1970 (RA 2007)
20mm	100	100
12.5mm	97.28	90-100
10mm	71.38	40-85
4.75mm	0.77	0-10

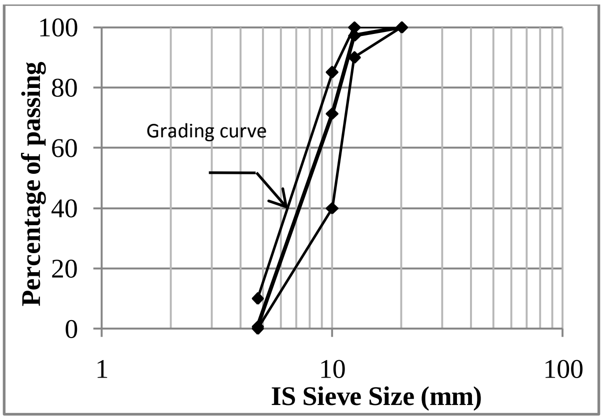

Fig. 2. Grading curve for coarse aggregate (12.5mm)

TABLE IV INDIVIDUAL GRADATION OF FINE AGGREGATE (SAND)

IS Sieve Size	% of passing	Specification of Zone II as per IS: 383-1970 (RA 2007)
10mm	100	0-100
4.75mm	96.60	90-100
2.36mm	91.68	75-100
1.18mm	75.60	55-90
600micron	47.55	35-59
300micron	9.43	08-30
150micron	0.95	0-10

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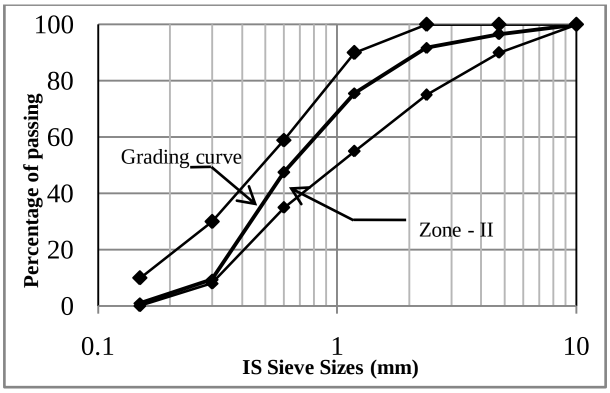

Fig. 3. Grading curve for sand

D. Mixture proportion

The grade of concrete M35 was designed according to standard specification IS: 10262-2009. The mix proportions were taken for this experiment with w/c ratio of 0.36. The different mixes of concrete mixtures were by replacing 0%, 10% and 20% of HAC with FA. Different weight of cement is used in this study. Several trial proportions were prepared.

II. TEST PROGRAM

Laboratory experiment investigation on compressive strength of HAC at different casting for M35grading concrete has been conducted. The concrete cube samples have been prepared and cured. The curing has been done properly to achieve the target strength. The compressive strength as obtained are reported at 1 day, 3 days, 7 days, 28 days interval. The following figure 4 shows the compressive strength test for concrete.

Fig. 4. Compressive strength of cube specimen after failure

III.RESULT AND DISCUSSION

Compressive strength tests for each cement was carried out after 1 days, 3 days, 7days, 14 days, and 28 days of curing. After the curing period is over specimens were taken out from the curing chamber. Excess water was wiped out from surface using dry jute before placing in the compressive testing machine. It is observed that the maximum compressive strength is attained at 18 degree centigrade. As per previous researches and concrete codes, the high alumina cement gives maximum compressive strength at curing environmental temperatures between16 to 20°C. As temperature increases, the compressive strength rapidly decreases. In this study 400 kg and 420 kg of HAC are taken in to consideration as HAC1 and HAC2 respectively. HAC1FA0 indicate 0% FA with 100% HAC1, HAC1FA10 indicate 10% FA with 90% HAC1 and HAC1FA20 indicate 20% FA with 80% HAC1. HAC2FA0 indicate 0% FA with 100% HAC2, HAC2FA10 indicate 10% FA with 90% HAC2 and HAC2FA20 indicate 20% FA with 80% HAC2. For each mix three different cubes are prepared and final values of compressive strength is calculated which is shown in Table 4.

TABLE IV TEST RESULT OF COMPRESSIVE STRENGTH FOR HAC1

Days	**0% FA**		**10% FA**		**20%FA**	
	Compressive strength in kN		**Compressive strength in kN**		**Compressive strength in kN**	
1	37.78	850	42.67	960	35.11	790
3	41.34	930	43.12	970	37.78	850
7	43.12	970	44.45	1000	44	990
14	44	990	45.33	1020	44.45	1000
28	49.33	1110	50.22	1130	47.11	1060

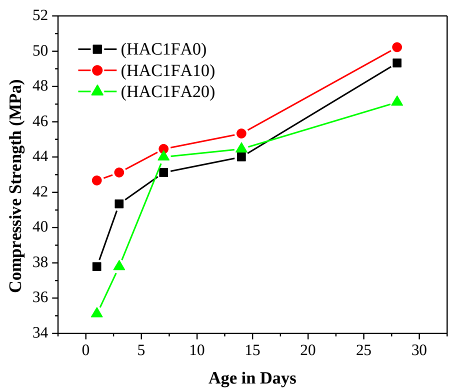

Fig. 5. Compressive strength of concrete versus age in days

TABLE V TEST RESULT OF COMPRESSIVE STRENGTH FOR HAC2

Days	**0% FA**	**10% FA**	**20% FA**
	Compressive strength in kN	**Compressive strength in kN**	**Compressive strength in kN**

1	36.89	830	39.12	880	30.23	680
3	38.67	870	40	900	34.23	770
7	40.44	910	41.34	930	37.78	850
14	43.55	980	44.88	1010	41.77	940
28	47.55	1070	48.88	1100	45.77	1030

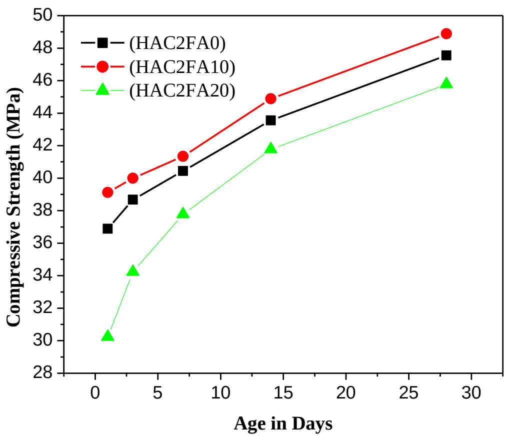

Fig. 6. Compressive strength of concrete versus age in days

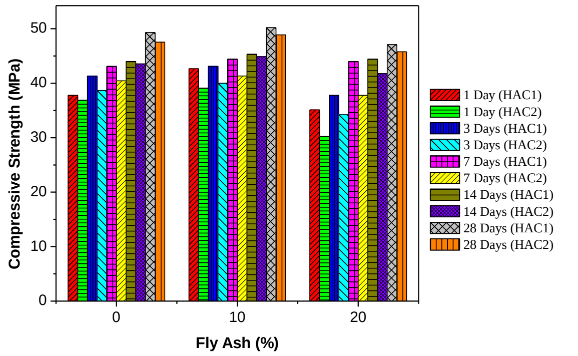

Fig. 7. Comparison of compressive strength for HAC1 and HAC2

IV. CONCLUSION

Based on the experimental program the following conclusions can be drawn:

- Addition of 20% of FA with HAC, the compressive strength reduces as compared to control specimen.
- But while adding 10% of FA with HAC, the strength increases as compared to other specimens.
- HAC2 indicates lowest compressive strength as compared to other concrete mix after 1 day of curing.
- HAC1FA10 provides highest strength as compared to HAC2FA10 after 28 days of curing period.
- Highest compressive strength was observed after 28 days curing period. The test result indicates that the increase in the curing period increases the strength.
- So, we conclude that up to 10% FA replacement in HAC provide better results as well as which is economical and helpful for construction of low cost RCC structure.

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