EXPERIMENTAL STUDY ON CONCRETE BY USING FLY ASH TO ENHANCE ITS DURABILITY PROPERTIES

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Abstract*— *Fly ash is used as a supplementary cementitious material (SCM) in the production of portland cement concrete. A supplementary cementitious material, when used in conjunction with portland cement, contributes to the properties of the hardened concrete through hydraulic or pozzolanic activity, or both. This study was carried out to evaluate the influence of addition of fly ash on concrete permeability. Experimental investigation was carried on fly ash concrete to know the effect of fly ash characteristic performance of the concrete. In the investigation, cubical specimens of size 150x 150 x 150 mm were cast for Permeability test at the ages of 28 days curing with different fly ash % replacement (0%, 3%,6%,9%,12%) for mix M-25. Results of the laboratory investigation conclude that the performance of concrete made up of fly ash is superior to achieve the required strengths at higher ages and improved performance characteristics were observed from durability studies.

***Index Terms*—Concrete, Cubes, Fly ash, Permeability test.**

I. INTRODUCTION

Concrete is a most widely used construction material today. Flexibility, molding ability of concrete material, its high compressive strength and the steel reinforcing and pre-stressing technique in concrete facilitates to improve its strength as against its low tensile strength property and contributed largely for its wide spread use. Many researchers working in the concrete area are trying to understand and modify various concrete properties along with optimizing the cost of concrete.

Concrete is most widely used construction material worldwide. Cement concrete industry is one of the major users of fly ash in structural concrete, mass concrete construction like highways, mortars for building etc. Fly ash in concrete is used for the purpose of economy and at the same time fly ash contributes in better durability, reduced permeability, reduction in W/C ratio, reduction in expansion due to alkali aggregate reaction, and improved long term strength and most importantly reduction in cement content.

In the present scenario, the use of complementary cementing material such as fly ash, slag and silica fume as a partial replacement for Portland cement in concrete presents a viable alternative solution in addition to multiple benefits for sustainable development of concrete industry. The estimated amount is about 170 million MT by the year 2010. Presently 30% of ash is being used in fillings, embankments, construction activities, fly ash hollow block and tiles. Presently majority of the coal ash generated is being handled in wet form and disposed off in ash ponds which are harmful for the environment and moreover ash remains unused for gainful applications. Fly ash has a vast potential for use in fly ash concrete especially due its physico-chemical properties. Detailed studies on the properties of Indian fly ash mix concrete with available local ingredients to use the full potential of this concrete is needed. Experimental investigation was carried on fly ash concrete to know the effect of fly ash characteristic performance of the concrete. Based on the detailed experimental investigation conducted on the various structural elements, it is concluded that high volume fly ash concrete achieves the required durability at higher ages and improved performance characteristics were observed from durability studies.

II. RELATED WORK

Several recent studies showed very low permeability of concrete made with fly ash and superplasticizer (HRWR) (2-10) as compared to no-fly ash concrete. Cement has been replaced with a Class C fly ash (FA) in various proportions from 30 % to 60 %. Durability properties of various self-compacting concrete (SCC) mixtures such as, freezing and thawing and chloride penetration resistance have been investigated by Halit Yazici (2007) besides mechanical properties. Similar tests were carried out with the incorporation of 10 % silica fume (SF) to the same mixtures. Test results indicated that SCC could be obtained with a high-volume FA. Ten percent SF additions to the system positively affected both the fresh and hardened properties of high-performance high-volume FA SCC. Although there is a little cement content, these mixtures have good mechanical properties, freeze-thaw and chloride penetration resistance.

The effects of ASTM Class C fly ash incorporation on mechanical properties and sulfuric acid resistance of concrete has been investigated by Serdar Aydin et al (2007). Cement was replaced with fly ash up to 70 %. Test results indicated that sulfuric acid resistance of steam-cured concrete could be improved significantly by incorporation of fly ash. Under standard curing conditions, the strength values of high-volume fly ash concretes were satisfactory except one day strength. Curing by steam helped to increase the one day strength values. However, long-term strength values decreased significantly for concrete mixtures over 30 % of fly ash replacement levels.

The effect of steam curing on concrete incorporating ASTM Class C fly ash (FA), which is widely available in Turkey, was investigated by Halit Yazici (2007). Cement was replaced with up to 70 % fly ash, and concrete mixtures with 360 kg/m3 cementitious content and a constant water/binder ratio of 0.4 were made. Compressive strength of concrete, volume stability of mortar bar specimens, and setting times of pastes were examined. Test results indicated that, only one day strength of fly ash concrete was low. under standard curing conditions At later ages, the strength values of even 50 % and 60 % fly ash concretes were satisfactory. Steam curing accelerated the one day strength but the long-term strength was greatly reduced. Setting time of fly ash-cement pastes and volume stability of mortars with 50 % or less fly ash content were found to be satisfactory for standard specimens.

More than 88 million Tones of fly ash is generated in India each year. Most of the fly ash is of Class F type. The percentage utilization is around 10 to 15 %. Rafat Siddique (2004) in his experimental investigation evaluated concretes incorporating high volumes of Class F fly ash. Portland cement was replaced with three percentages (40 %, 45 % and 50 %) of Class F fly ash. Tests were performed for fresh concrete properties: slump, air content, unit weight, and temperature. Compressive, splitting tensile and flexural strengths, modulus of elasticity, and abrasion resistance were determined up to 365 days of testing. Test results indicated that the use of high volumes of Class F fly ash as a partial replacement of cement in concrete decreased its 28-day compressive, splitting tensile and flexural strengths, modulus of elasticity, and abrasion resistance of the concrete. However, all these strength properties and abrasion resistance showed continuous and significant improvement at the ages of 91 and 365 days, which was most probably due to the pozzolanic reaction of fly ash. Based on the test results, it was concluded that Class F fly ash can be suitably used up to 50 % level of cement replacement in concrete for use in precast elements and reinforced cement concrete construction.

The durability characteristics of High Performance concrete was studied by Aitcin (2003). The fundamental microstructure difference between cement pastes having a 0.65 and 0.25 w/c ratio concrete pastes were studied. In this study, swelling of chemical origin, such as surface or alkali aggregate reacting was not considered; the only volumetric changes taken into account will be plastic shrinkage and drying shrinkage. Curing method to minimize the shrinkage was studied. Durability of HPC in marine environment was analysed. Abrasion action of sand and floating ice was studied. Rapid chloride - iron test (AASHTO-277) were carried out to study the chloride penetration. High performance concrete was best suited to resist chemical, geometrical, physical and mechanical factors in marine environment. Rapid chloride iron permeability test gave permeability of less than 1000c for HPC containing about 10 % silica fume and W/C ratio of 0.4-0.45.

Rodway and Fedirko investigated permeability of concrete incorporating Class C fly ash for 68% cement replacement. They reported a permeability value of the fly ash concrete of about 3.65 x 10-12 m/sec. Ellis et al. found decrease in permeability of concrete with increase in both either Class C or Class F fly ash contents for a fixed amount of cement content. They further showed that concrete containing Class F was more effective than concrete with Class C fly ash in reducing concrete permeability.

Bilodeau et al. measured water and chloride permeability of concretes having 55 to 60 % cement replacement with various sources of fly ash. They reported coefficient of water permeability of fly ash concretes in the range of 1.6 x 10-14 to 5.7 x 10-13 m/s. The values of chloride permeability (less than 650 coulombs at 91 days) observed in this investigation for fly ash concretes were comparable to that for silica fume concrete. Similar chloride permeability results were also reported by Naik et al.

III. Materials Used For Present Investigation

Cement

The characteristics of cement on water demand are more noticeable in fly ash concrete. Some of the important factors which play vital role in the selection of cement are compressive strength at various ages, fineness, heat of hydration, alkali content, tricalcium aluminate (C3A) content, tricalcium silicate (C3S) content, dicalcium silicate (C2S) content etc. It is also necessary to ensure compatibility of the chemical admixtures with cement. Ordinary Portland cement, 43 Grade conforming to IS: 8112-1989. The results of the tests on cement sample are listed in Table 1.

Table 1 Test results for Ultratech 43 OPC

S.No.	Tests	Results
1	Normal consistency	29%
2	Initial Setting Time	85 Minutes
3	Final Setting Time	195 Minutes
4	Specific Gravity	3.10
5	7 days compressive strength of cement	41.2 N/mm^2

Coarse Aggregate

Aggregates are important constituents of concrete. They form integral structure to the concrete, reduce shrinkage, and affect economy. Aggregates occupy 70 to 80 percent of volume of the concrete. Properties such as crushing strength, durability, modulus of elasticity, maximum size, gradation, shape and surface texture characteristics, percentage of deleterious materials as well as flakiness and elongation indices need special consideration while selecting the coarse aggregate for fly ash mix. The aggregate should be sound, free from deleterious materials, and must have crushing strength at least 1.5 times that of concrete. Locally available (Kakani) Coarse aggregate were tested as per the procedure given in IS 383-1970 and the results are given below in table 2.

Table: 2 Sieve Analysis Test results for Big size aggregate

No.	Sieve Size	% passing	According to IS 383-1970 % passing for 20 mm single size Aggregate
1.	40 mm	100	100
2.	20 mm	89.68	85-100
3.	10 mm	0.7	0-20
4.	4.75 mm	0.04	0-5

The above result confirms coarse aggregate of 20-mm single size aggregate and specific gravity 2.65 and voids content 45%.

Fine Aggregate

Fine aggregate used for fly ash concrete showing high performance characteristics should be properly graded to give minimum void ratio and be free from deleterious materials like clay, silt content, and chloride contamination etc. Fly ash concrete contains large quantity of fine cementitious materials. Hence, the grading of fine aggregate is relatively different from that of conventional cement concrete. Properties such as void ratio, gradation, specific gravity, fineness modulus, free moisture content, specific surface, bulk density, etc. have to be assessed to design a dense fly ash mix with optimum cement content and reduced mixing water. Locally available river sand were tested as per the procedure given in IS 383-1970 and the results are given below in table 3.

Table 3 Sieve Analysis Test results for fine aggregate (sand)

No.	Sieve Size	% passing	from table IS 383-1970 for Zone II% Passing
1.	4.75 mm	96.4	90-100
2.	2.36 mm	91.2	75-100
3.	1.18 mm	73.5	55-90
4.	600 micron	52.4	35-59
5.	300 micron	30.7	8-30
6.	150 micron	9.8	0-10
7.	Pan	0.0	-

Above sieve analysis conforms to fine aggregate of zone II and specific gravity 2.42 and voids content 26%.

Fly Ash

Fly ash is an inorganic, non-combustile by-product of coal-burning power plants. As coal is burnt at high temperature, carbon is burnt off and most of the mineral impurities are carried away by the flue gas in the form of ash. Fly ash is a pozzolanic material which possesses no cementitious value but which will, in finely divided form and in the presence of moisture, alumino-silicates within the fly ash react with calcium ions to form calcium silicate hydrate. In today's construction industry there is a general trend to replace higher levels of Portland cement with fly ash in concrete is due to the three main aspects i.e. economic, environment and technical benefits. Fly ash sample is collected from Suratgarh Thermal Power Plant.

Water

Potable water was used for concreting and curing for the entire investigation.

Plasticizers

Plasticizer are used in this study is BASF.

IV. CONCRETE MIX DESIGN

Design Mix M-25

As per IS 10262 and SP (23)-1982 and IS 456-2000

Target Mean Strength of Concrete

For a tolerance factor of 1.65 as specified in IS 456-2000 and the standard deviation 5.0 N/mm2 (as given in table 1, IS-10262), target mean strength of concrete:

F_{tms} = 25+5*1.65

F_{tms} = 33.25 N/mm^2

Selection of W/C ratio

Selected W/C ratio for the desired target mean strength = 0.45

Selection of water and sand content

Water per cubic meter = 170 kg/m3
Sand as percentage of total aggregate by absolute volume = 0.35 or 35%
Cement required = 170/0.45= 380kg/m3
Determination of coarse and fine aggregates
Volume of concrete- 1m3
Volume of cement- 0.121m3
Volume of water- 0.170 m3
Volume of plasticizer- 0.0025m3
Volume of all in aggregate- 0.7065 m3
Mass of fine aggregate- 598 Kg/m3
Mass of coarse aggregate- 1220 Kg/m3

0.75% Admixture (Plastisizer) by weight of cement (for coarse aggregate mix proportion as 60% for 20 mm size aggregate and 40% for 10 mm size aggregate).

V. Test Program And Procedure

The permeability of concrete is related to durability of concrete in terms of its resistance against progressive determination under exposure to sever climatic conditions and leaching due to prolonged seepage of water. The permeability is measured in terms of coefficient of permeability, by permeability test apparatus in accordance with Indian Standards. To find coefficient of permeability of hardened concrete a cube specimen of size 150 x 150 x 150 mm for each of eight mixes were casted. The specimens were subjected to a known hydraulic pressure from one side in a permeability test apparatus after 28 days of curing.

To determine Durability properties of concrete at different fly ash replacement level as 0%,3%,6%,9%, and 12%, for mix M-25. One cylinder of size 150x150 mm for each mix was casted and by water permeability testing machine Coefficient of water permeability is obtained. After 28 days of curing cylinder specimens are taken out and after surface dried condition results are obtained as in table 4.

Table 4 Coefficient of water permeability for mix M-25 after 28 days curing

S.no	% of fly ash	Identification mark	Average Coefficient of water permeability, K(cm/sec)x10^{-10}
1	0 %	M1	15.26
2	3 %	M2	11.74
3	6 %	M3	9.56
4	9 %	M4	6.78
5	12 %	M5	6.36

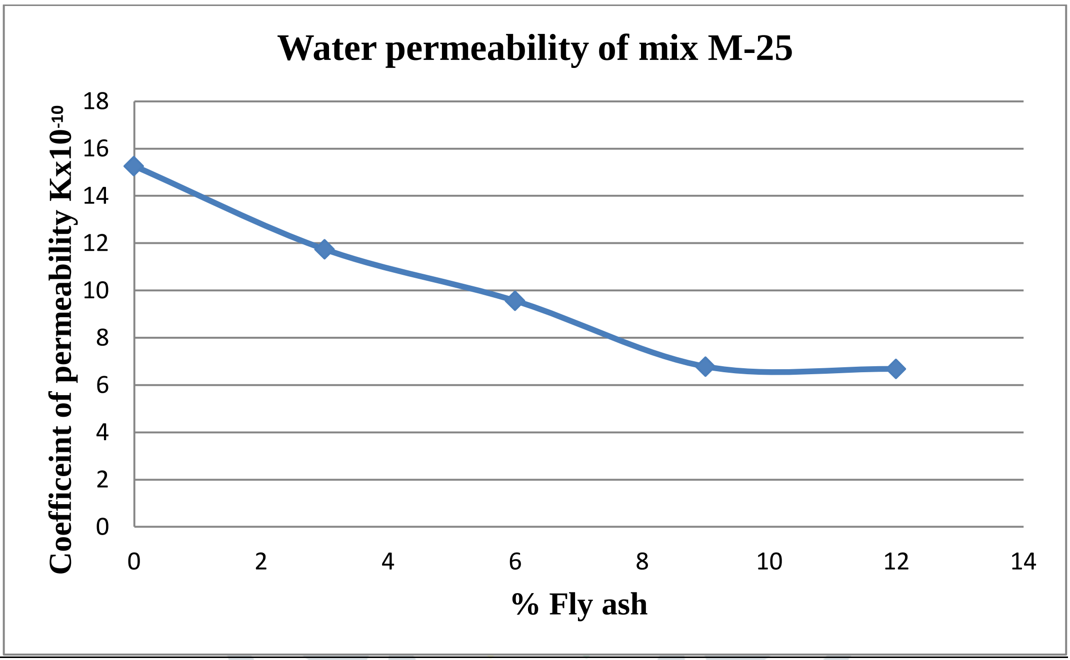

Figure 1 Water Permeability of fly ash concrete mix M-25

Above results show for mix M-25 that with increase in fly ash content, there is decrease in water permeability. Fig.1 show that water permeability is between 9% to 12 % is minimum, after that water permeability increases with increase in fly ash content.

VI. Conclusions

In this investigation we have used Fly ash mix concrete with available local ingredients to utilize the full potential of this concrete is needed. Experimental investigation was carried on fly ash concrete to know the effect of fly ash characteristics performance of the concrete. In this investigation, five specimens (5) cubical specimens were cast for Permeability test. This sample is having Mix of M-25 (with fly ash % as 0, 3, 6, 9, 12). Conclusions are presented on the basis of results show that for mix M-25 that with increase in fly ash content, there is decrease in water permeability. There is minimum of water permeability is in between the 9% to 12 %, after that water permeability increases with increase in fly ash content. The present study can further be investigated for other mix proportion and grade of concrete i.e. M-30, M-40, M-50 etc. and fly ash based mix design of concrete and its effect on durability properties. Experimental studies can be conducted with Fly ash content with addition of silica fume and fibers. The water permeability study can be carried out with the different age of concrete & also with concrete containg high volume of the fly ash (HVFC). Also the study can be done with the different water quantities, fine to coarse aggregate ratios.

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