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Experimental Investigation on Use of Fly Ash in Concrete for Radioactive Structures for Improved Shielding

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Abstract **- Fly ash as a supplementary cementitious material adds sustainability to concrete. The positive effects of fly ash as a partial replacement of cement on the durability of concrete are recognized through numerous researches; however, the extent of improvement depends on the properties of fly ash. In this study, durability properties of high strength concrete utilizing Class F fly ash have been investigated. Concrete mixtures with fly ash as 20%, 30% and 40% of total binder were used to cast the test specimens. The compressive strength (cube size:150mmx150mm), split tensile (100mm diameter and 200mm height cylinder), pH, sulphate attack (cube size:100mmx100mm), rapid chloride permeability, Scanning electron microscope, radiation shielding of the fly ash and control concrete specimens were determined. The 28-day compressive strength of the concrete mixtures varied from 45 to 55 MPa. Results of mechanical parameters show their improvement with age of the specimens and results of radiation parameters show no significant effect of fly ash substitution on mass attenuation coefficient. The results obtained through this investigation were satisfactory in terms of durability and improved shielding in radioactive structures.**

Keywords – Fly Ash, Fly Ash Concrete For Improved Radioactive Shielding, Fly Ash In Concrete, Durability Of Concrete

1. INTRODUCTION

Ordinary Portland cement is recognized as a major construction material throughout the world and in terms of its per capita consumption, it is second most consumed material in the country, next to water. Rapid increase in construction activities leads to acute shortage of conventional construction materials which results in high cost. During the production of cement, equal amount of carbon-di-oxide is being released into the atmosphere. This causes serious environmental pollution. In view with the global warming, efforts are taken to reduce the emission of carbon dioxide to the environment by replacing the cement with a pozzolanic material such as fly ash. By doing so, the cement and concrete industries could grow together to meet up the demands in construction industry and also help to reduce the environmental pollution. Availability of consistent quantity of fly ash across the country and awareness of positive effects of using fly ash in concrete are pre-requisite for change of perception fly ash from "A waste material" to "A recovery material". At present India produces 225 million tonnes of fly ash as estimated till 2017, its value is expected to reach high within 2020. This project attempted to test if fly ash concrete could be used to improve the shielding effects when used in Radiation structures.

2. REVIEW OF LITERATURES

2.1 Fly ash concrete: A Technical Analysis for compressive strength, Dr S L Patil, J N Kale, S Suman, In this experimental investigation, an attempt has been made to study the techno-economic analysis for the compressive strength of fly ash concrete. The fly ash is procured from Deep nagar Thermal Power Plant. Fly ash is used in various proportions ranging from 10% to 50% by weight of cement in steps of 5%. The fly ash blend is then tested for various preliminary tests that are basically conducted for a cement. There was no increase in compressive strength of the concrete till the 28th day but found to increase and reach the maximum value at 56th day. The strength also noticed to reduce with 50% of fly ash added.

2.2 Effect of Fly Ash on the Durability Properties of High Strength Concrete P. Nath, P. Sarker, In this investigation, they used class F fly ash and has studied the durability properties of concrete for various proportions of fly ash. The aggregates were natural sand and crushed granite. A naphthalene-based super plasticiser was used in addition to normal tap water to enhance workability. The effect of fly ash on the durability of concrete was investigated by using the drying shrinkage, water-sorptivity and chloride ion permeability properties. The percentages at which the fly ash was used are 30% and 40%. The fly ash concrete show less drying shrinkage compared to conventional concrete and was observed that the drying shrinkage value occurred low for 40% than 30%. This test was carried at 28 and 180 days. It was observed that at both the stages the fly ash shows lower resistance. Also, it was noted that at 28 days the chloride penetration was "low" at the same time at 180 days, the Chloride penetration level decreased to "Very Low" for the fly ash concretes.

2.3Assessment of properties and durability of fly ash concrete used in Korean Nuclear power plants

This study describes that TYPE 4 (sulphate resistant cement) was used since 1978 at KOREA for their NPP structures, but upon technology development it was studied that chloride attack is a major factor depending upon which the type of cement was changed from TYPE 4 to TYPE 1 cement mixed with admixtures such as fly ash and slag. The heat of hydration was conducted with the help of adiabatic temperature rise test apparatus. It was noted that with increase in fly ash ratio the heat of hydration reduces. The concrete with 20% fly ash replacement is more advantageous in terms of heat of hydration.

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3 MATERIALS USED

The materials used in this study are cement, fly ash, fine aggregate, coarse aggregate, and water. Cement, fine aggregate, coarse aggregate and water are taken as per standards and the special material used in this study is fly ash which is procured from nuclear power plants.

3.1 Fly ash: The fly ash materials collected from power plants are found to be replaced for cement in concrete making. Fly ash has been used in high performance concrete, fly ash concrete, etc. where in this study attempted to make concrete with improved shielding effects for radioactive structures.

Fig. 1: Fly ash

4. CASTING OF CONCRETE CUBES

The raw materials were taken in the required proportion and the cubes, prisms and cylinders were casted for M_{30} grade of concrete. Cubes, prisms and cylinders were casted with 20%, 30%, and 40% of fly ash as a partial replacement for cement. Mechanical vibrators are used to compact the casted concrete. Curing of concrete done for conventional and partially replaced concrete and tests was conducted on 3rd, 7th and 28th day to check the hardened properties.

Fig. 2: Curing of Concrete

5. TEST RESULTS

5.1 Strength Test: The concrete cubes were casted and cured to obtain the 3rd , 7th and 28th day results of compressive strength. It was found that the strength increased gradually as the days increased. Also it was observed that there was increase in strength upto addition of 40% of fly ash.

Table 1: Comparison of compressive strength obtained on 3rd, 7th, and 28th day for M30 grade concrete

Replacement %	Average flexural strength (N/mm^2)		
	3rd Day	7th Day	28th Day
0	23.31	25.06	30.50
20	28.51	36.60	53.04
30	27.70	38.82	51.51
40	18.84	31.80	45.59

5.2 Durability Test: In the durability study, the rapid chloride permeability test was performed as per ASTM C 1202-97, to determine the electrical conductance of the three different percentages of fly ash concrete.

The test method consists of monitoring the amount of electrical current passed through 50 mm thick of 100mm nominal diameter of a cylindrical specimen for duration of six hours.

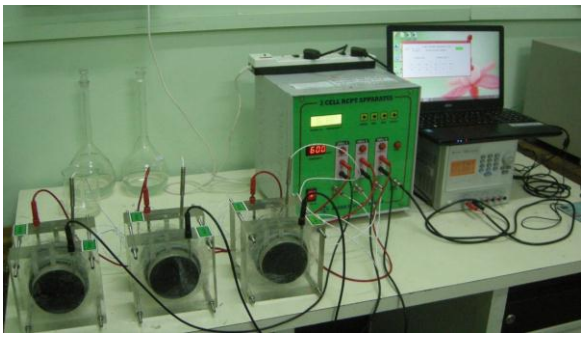

Fig. 3: RCPT Experimental setup

Table 2: RCPT values at three consecutive days after curing

S.no	Percentages	Chloride ion penetrability value (Coulombs)	Chloride ion penetrability as per ASTM C 1202-97
1	0	1314.10	Low
2	20	985.02	100 – 1000 very low
3	30	666.48	
4	40	680.80	

The above table shows that the electrical conductance is very low when the percentage of fly ash is higher. This indicates that the addition of fly ash in concrete proves to be satisfactory in shielding from radiation effects.

5.3 Sulphate attack Test: Sulphate attack on concrete is a chemical breakdown mechanism where sulphate ions attack components of the cement paste. The compounds responsible for sulphate attack on concrete are water soluble sulphate containing salts, such as alkali-earth and alkali sulphates that are capable of chemically reacting with components of concrete.

It combines with the C-S-H gel and destroys the paste that holds the concrete together leading the formation of crack and further deterioration.

Fig 3: Deteriorated cubes on 3rd day after immersion

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Table 3: Weight loss of FAC in 5 % of Sulphuric Acid

Age of Specimen in days	Age of specimen in sulphate solution in days	Average weight loss in Fly ash Concrete		
		20%	30%	40%
25	3	31.5	20.25	13.5
25	14	172.5	112	42

We can observe the difference in weights of the cubes after immersion in the sulphate solution. We can also observe that the weight loss is higher in 20% FAC and it reduces tremendously at 40% FAC. This indicates that 40% of FAC resists deterioration to greater extent compared to that of 20% and 30% FAC.

5.3. Scanning Electron Microscope: Scanning electron microscope is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons.

The collected samples were carbon coated and analysed using a scanning electron microscope in the back scattered electron mode. The SEM image of the C+20% fly ash has been observed to possess good densified concrete. This justifies the higher compressive strength of 20% fly ash added concrete (Refer table:1).

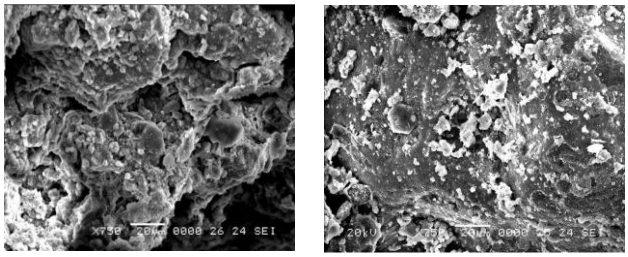

Fig 4: SEM images of conventional concrete and 20%FAC

6 CONCLUSION

From the undertaken experimental investigation, the following conclusions can be drawn.

• Fly ash can be used in concrete for improved shielding effects in radioactive structures. Due to lack of time and testing equipment availability a few test like radiation tests were not performed. This could have helped to confirm the shielding effects to almost 80%.

• The fly ash concrete is highly resistant to sulphate attacks and had very good compressive strength after the immersion in suphuric acid. The positive effect of FA on acid resistance may arise from pozzolanic reaction between FA and calcium hydroxide liberated during the hydration of cement.

• This study proves that fly ash can be successfully used in the cement concrete in minor amount as an additive. Considering the intangible cost of disposal problem of fly ash and hidden cost of environmental protection, the methodology appears to be indeed successful. Fly ash is a solid waste and priceless. If it can be used for any purpose then it will be good for both environment and economy. Use of fly ash as a raw material in Portland cement is an effective means for its management and leads to saving of cement and economy consequently. Hence it is a safe and environmentally consistent method of disposal of fly ash. Though the rate of strength development is less, yet the results are satisfactory. It can be concluded that power plant waste can be extensively used in concrete as a partial replacement for cement and a mineral admixture.

• It can also be concluded that there was only slight variation in the attenuation values with partial replacement of fly ash for cement in concrete.

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