International Journal of ChemTech Research
CODEN (USA): IJCRGG ISSN: 0974-4290
Vol.9, No.04 pp 566-575, 2016

Experimental Investigation on Strength and Durability Properties of RC Concrete Slabs

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Abstract: India depends on Thermal Power as its main source and there is increase in power requirement every year. Due to increase in the growth of industrial sectors the power requirement of the country is rapidly increasing. Present scenario of our country shows 75 % of country's total installed power generation is thermal of which coal-based generation is 90%. In India around 160 MT fly is produced and only 40% of that is being utilized in different sectors. Balance fly ash is being disposed over land. Currently around 65000 acres of land is occupied by fly ash. It needs one acre of land for ash disposal to produce 1MW electricity from coal. Fly ash and pond ash utilization helps to reduce the consumption of natural resources. Lots of research has been carried out for effective utilization of fly ash in construction industries due to its fine particles and Pozzolonic properties. But little literature is available on pond ash utilization. Pond ash being coarser and less Pozzolonic than fly ash can be used as fine aggregates in concrete by partial replacement of sand.

This paper represents about the experimental investigation of the possibility of using pond ash in varying percentages as fine aggregate substitute in cement concrete. M30 grade concrete was made using pond ash (PA) and Portland pozzolona cement (PPC). Fine Aggregate replaced with pond ash varied as 10%, 20%, 30% and 40%. An attempt has been made to investigate the characteristics of pond ash concrete for various parameters like its compressive strength, flexural strength and durability properties. For this purpose slab elements were cast to test for their flexural behavior.
Key words : P.A - Pond Ash, PA20- 20 % pond ash, PA30- 30 % pond ash,fck - Characteristic compressive strength, HYSD - High yield strength deformed bars, G – Specific Gravity.

Introduction

Use of waste and by products in concrete will lead to green environment and such concrete can be called as "Green Concrete". There are various types of waste materials that can be considered for usage in concrete. The most commonly used waste materials to replace sand and cement in concrete are Fly Ash, Rice Husk Ash, Blast Furnace Slag, Red Mud and Phosphor, gypsum, Silica Fume, Fumed silica, Crushed glass, Eggshells. The waste products used to replace coarse aggregate in concrete are Palm Oil Shell Aggregate for Lightweight Aggregate Concrete, Crushed Ceramic, glass, waste wood, crushed concrete aggregate. The current annual production of coal ash worldwide is estimated around 600 million tonnes. The disposal of fly ash will be a big challenge to environment, especially when the quantum increases from the present level. Hence worldwide research work was focused to find alternative use of this waste material and its use in concrete industry is one of the effective methods of utilization. Increase in demand and decrease in natural resource of fine aggregate for the production of concrete has resulted in the need of identifying a new source of fine aggregate. The possibility of utilization of thermal power plant by-product pond ash as replacement to fine aggregate in concrete is taken into consideration.

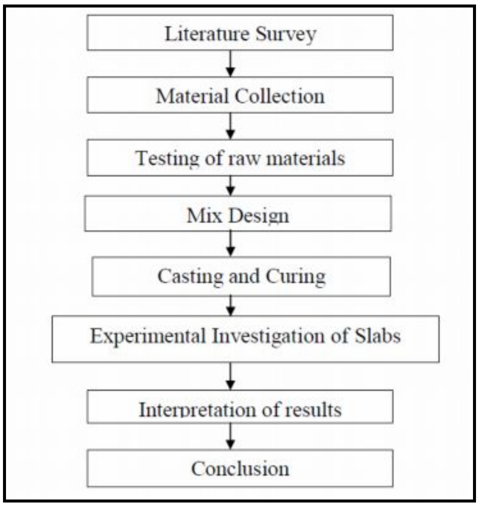
Pond ash Concrete

As a general practice in India, fly ash and bottom ash in thermal power plants are mixed with water and transported to ash ponds. The ash thus deposited in pond is called as Pond ash (PA). Fly ash and pond ash utilization helps to reduce the consumption of natural resources. Lots of research has been carried out for effective utilization of fly ash in construction industries due to its fine particles and Pozzolonic properties. But little literature is available on pond ash utilization. Pond ash being coarser and less Pozzolonic than fly ash can be used as fine aggregates in concrete by partial replacement of sand.

Limitations of Pond ash Concrete

The Pond ash concrete has two limitations such as the delay in setting time when high volumes are used and it reduces the workability of concrete. These two limitations of pond ash concrete mix were eliminated by using pond ash in required percentages depending upon the required compressive strength and using super plasticizer to obtain required workability.

Methodology



Objectives of Study

- ✓ In order to minimize the usage of the natural resource i.e river sand, pond ash is being used as an alternative material.
- ✓ Fine Aggregate is replaced with pond ash as 10%, 20%, 30% and 40%.
- ✓ To determine the compressive strength of pond ash concrete.
- ✓ To determine the flexural behavior of pond ash concrete slabs.
- ✓ To improve the flexural behavior of slab elements, weld mesh was used and results were compared with elements without weld mesh.
- ✓ To study the water absorption results and to compare it with conventional concrete and pond ash concrete.
- ✓ To evaluate the durability properties namely corrosion resistance of pond ash concrete with respect to conventional concrete.

Scope of the work

- Reduce the usage of river sand by partially replacing it with pond ash.
- Reduce the usage of cement by making use of Portland pozzolona cement which contains 20% fly ash.

- Look into the feasibility of usage of Pond Ash Concrete in structural elements like slab.
- To reduce the environmental pollution caused by fly ash and pond ash and to produce a “Green Concrete”.

Experimental Investigation

Materials Used

The materials used in this investigation are as follows:

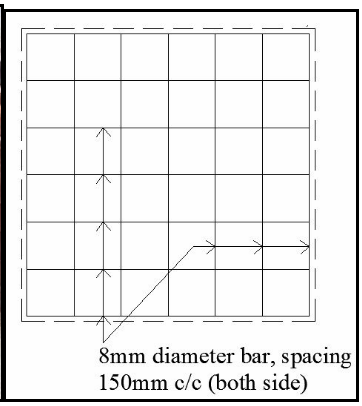
1. Cement
2. Pond ash
3. River sand
4. Coarse Aggregate
5. Water
6. Super Plasticizer
7. Reinforcing Steel

Pond Ash River Sand Super Plasticizer



Shape Size of Specimens

HYSD (Fe415) bars of 8mm diameter.(800mmX800mmX80mm)

Properties of Materials

a. Cement

S.No	Description	Result
1.	Specific gravity	3.15
2.	Initial setting time	110minutes
3.	Final Setting Time	210minutes
4.	Fineness (by Sieve Analysis)	3%
5.	Consistency	32%
6.	Type of Cement	PPC

b. Physical Properties of fine aggregate

S.No	Description	Result
1	Specific gravity	2.69
2	Bulk Density	1644.4 kg/m^3
3	Water absorption	0.52
4	Surface Moisture	Nil
5	Fineness modulus	2.69 Zone-II
6	Fineness modulus with 30% pond ash	2.15 Zone- III

c. Physical properties of pond ash

S. No	Properties	Result
1	Particle Size	(10-50) µm
2	Specific Gravity	2.1
3	Surface area (m2/kg)	350
4	Fineness by sieve analysis	24%

d. Chemical composition of pond ash Parameter

Sl.No	Properties	Experimental Value (%)
1	Sand and Silica	41.24
2	Aluminum Oxide(Al_2O_3)	10.15
3	Iron Oxide(Fe_2O_3)	3.25
4	Magnesium Oxide(MgO)	-
5	Calcium Oxide(CaO)	0.21
6	Loss Of Ignition (L.O.I)	26.78

e. Coarse aggregate

S.No	Description	Result
1.	Specific gravity	2.8
2.	Water absorption	0.617%
4.	Fineness modulus	6.98
5.	Bulk Density	1819.88 kg/m3

Mix Design

Mix design for M30 grade concrete by Indian Standard recommended method of concrete mix design as per design code IS: 10262-2009.

Proportion: 70% RIVER SAND + 30% pond ash.

Table 1.Mix Ratio Of M30 Grade Of Concrete Per m^3

Cement	Fine aggregate		Coarse aggregate	Water
	Sand	Pond ash		
370 Kg	558 Kg	239 Kg	1153 Kg	148 Kg
1	2.12		3.11	0.4

Companion Specimens

The RCC slab specimens were cast by the following procedure

1. Batching of specimen
2. Mixing of concrete
3. Casting
4. Demoulding
5. Curing
6. Testing of specimen

Tests of Concrete

The tests on concrete can be made on two stages. For,

- Fresh concrete – Slump (workability test)
- Hardened concrete

✓ Compressive strength test
✓ Split tensile strength test
✓ Flexural strength test

Compressive Strength **Split Tensile Test** **flexural Strength**

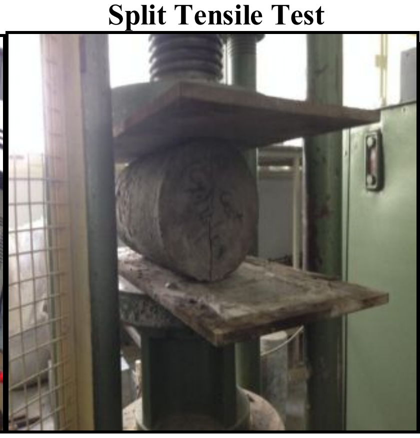


Table 2.Test Results of Companion Specimens

Mix Type	Compressive Strength (Load/Area) N/mm^2	Split Tensile Strength (2P/πdl) N/mm^2	Flexural Strength of Prism (Pl/b d2) N/mm^2
M1 (Control)	31.21	4.60	5.68
M2 (10% P.A)	33.48	5.26	6.20
M3 (20% P.A)	34.26	5.98	6.67
M4 (30% P.A)	30.80	4.50	5.16
M5 (40% P.A)	28.64	3.63	3.42

Corrosion Test

The half-cell potential measurement is an electrochemical technique commonly used by engineers to assess the severity of corrosion in reinforced concrete structures.

Half-Cell Potential Measurement

The simplest way to assess the severity of steel corrosion is to measure the corrosion potential, since it is qualitatively associated with the steel corrosion rate. One can measure the potential difference between a standard portable half-cell, normally a copper/copper sulphate ($Cu/CuSO4$) standard reference electrode placed on the surface of the concrete with the steel reinforcement underneath.

Figure 5.8 illustrates the basics for such a measurement, also called half-cell potential measurement. Copper sulphate solution was prepared by adding 100gms of cupric sulphate in 200 ml of distilled water and stir well until it is saturated. It is then poured into the cylindrical can holding the copper electrode. Figure and Figure 1 shows preparation of copper sulphate solution. The reference electrode is connected to the positive end of the voltmeter and the steel reinforcement to the negative.

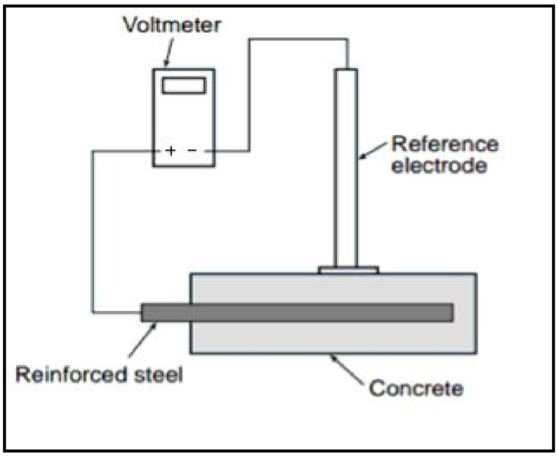


Fig.1. Test Set up for Half-cell potential Measurements

An indication of the relative probability of corrosion activity was empirically obtained through measurements during the 1970s. This work formed the basis of the ASTM standard C876, which provides general guidelines for evaluating corrosion in concrete structures as outlined in Table.

Table 3.Probability of corrosion Valve (ASTM Standard)

Corrosion	Potential (C-CSE)
> 95%	More Negative than -350mV
50%	-200 to -350mV
< 5%	More Positive than -200mV

Experimental half-cell potential values

After 28 days of specimen curing, half-cell potentiometer was used to determine the initial corrosion in all the three slabs made of conventional concrete, 20% pond ash and 30% pond ash. After the initialcuring was done the slabs were subjected to curing by salt water solution.

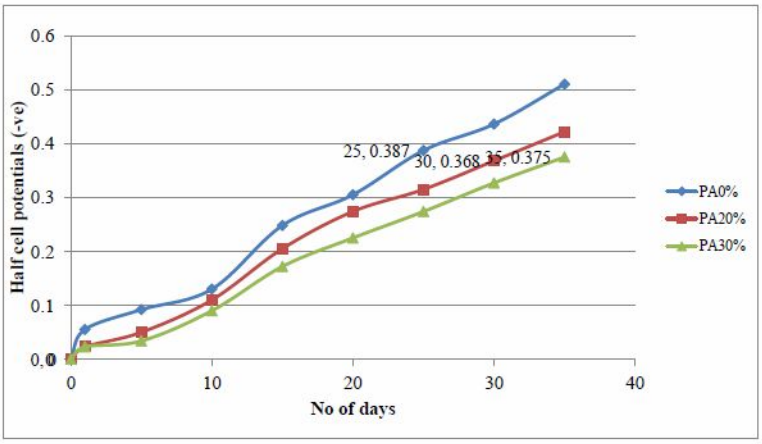



Results & Discussion

Table .4.Experimental half-cell potential readings

No of Days	Conventional concrete (V)	Concrete with Pond Ash 20% (V)	Concrete with Pond Ash 30% (V)
Initial reading	-0.055	-0.023	-0.023
5	-0.092	-0.05	-0.034
10	-0.13	-0.11	-0.09
15	-0.248	-0.205	-0.172
20	-0.305	-0.274	-0.225
25	-0.387	-0.315	-0.274
30	-0.436	-0.368	-0.327
35	-0.510	-0.422	-0.375

In comparison to the values of ASTM C876, the experimental values obtained from the three slabs shows that conventional concrete slab is subjected to corrosion in 20days, 20% pond ash slab in 25 days and 30% pond ash slab in 35 days. Figure 5.9 shows the measurement of half-cell potential in slab. Figure 5.13 shows the half-cell potential reading vs. corrosion activity.



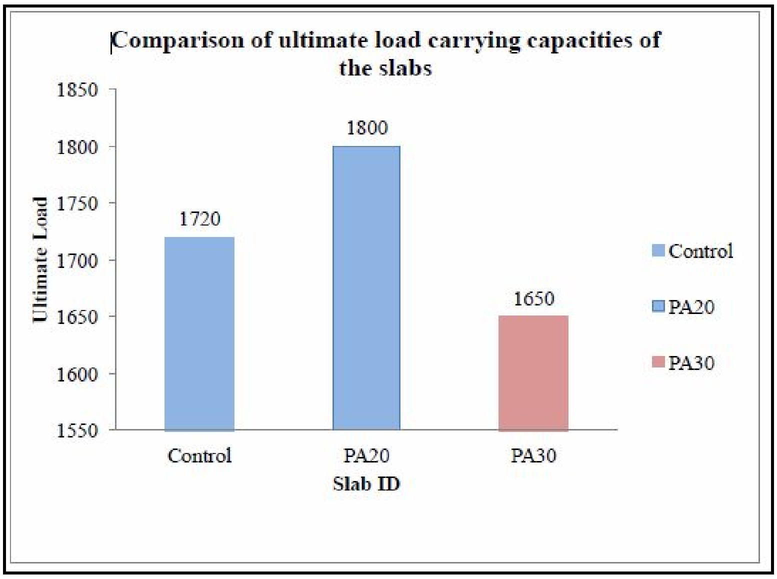
Half-cell potential reading Vs. Corrosion activity

Test Setup For Ultimate Load

All slabs were tested to an ultimate load in uniform loading over a simple supported span of 900 mm. The load was applied by means of loading frame which is of 28 T capacity. The load was applied in increments of 50kN until the tensile reinforcement yielded. Deflection control, in which the load step up corresponds to a specified increase in deflection, was used when the slab entered the plastic range. The mid-span deflection was recorded at each load step using a dial gauge. The test set up is shown in the Figure.

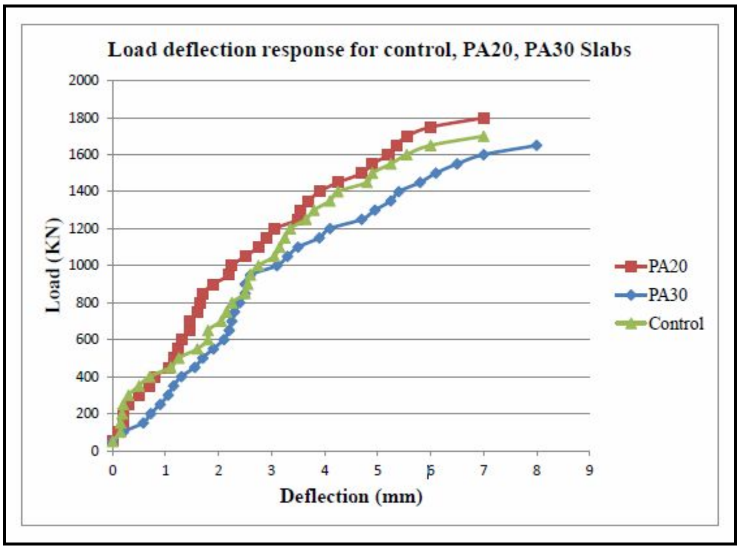
Table. 5 Ultimate load

Slab ID	First crack Load(kN)	Ultimate load (kN)	Gain in ultimate load (%)
Control	1150	1720	-
PA20	1300	1800	4.65
PA30	900	1650	-4.06



Load deflection response

In load deflection response the deflection values of slab increases for 30% pond ash slab with respect to the control slab. 20% pond ash slab gives the maximum load. It is shown in Figure.



Conclusions

- The compressive strength was found to be maximum in 20% PA concrete and it increased by 9.77% than the conventional concrete.
- The split tensile strength was found to be maximum in 20% PA concrete and it increased by 30% than the conventional concrete.
- The flexural strength was found to be maximum in 20% PA concrete and it increased by 17.43% than the conventional concrete.
- The compressive strength, split tensile and flexural strength results increased with 10% & 20% PA and started to decrease with 30% PA.
- The ultimate load carrying capacity of the slab increased for 20% PA by 4.65% and for 30%PA the ultimate load was reduced by -4.06% than the control slab.
- The corrosion activity in reinforcement of slab shows that with increase in pond ash content the corrosion is reduced. Here for 30% pond ash concrete the maximum time of 35 days was taken to reach 90% probability of corrosion according to ASTM C876.

- Increasing pond ash reduces workability which can be overcome by making use of super plasticizer and increasing pond ash in concrete gives better durability.

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