Research Journal of Applied Sciences, Engineering and Technology 7(11): 2266-2270, 2014
DOI:10.19026/rjaset.7.525
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: July 1, 2013 Accepted: August 21, 2013 Published: March 20, 2014

Research Article

Studies on Strength and Behaviors of Concrete by using Pond Ash as Fine Aggregate

K. Arumugam and R. Ilangovan
Department of Civil Engineering, BIT Campus, Anna University, Tiruchirappalli, India

Abstract: Common river sand is expensive due to excessive cost of transportation from natural resources. Also large scale depletion of these sources creates environmental problems. In such a situation the pond ash can be an economical alternative to the river sand. Pond ash can be defined as residue and by-product of thermal power plant stations to form fine particles less than 4.75 mm. Usually, Pond ash is used in a large scale for manufacturing of bricks. Use of pond ash as a fine aggregate in concrete mortar draws serious attention of researchers. This study reports the results of some experimental studies on the use of pond ash as Fine Aggregate (FA) in concrete. Super plasticiser is used to increase the workability of concrete with lower water cement ratio. The percentage of pond ash added by weight was 0, 20, 30, 40 and 50, respectively as replacement of FA used in concrete. Experiments were carried out to determine the compressive, splitting tensile and flexural strength with those of conventional concrete made with pond ash as fine aggregate. The various mechanical properties were studied and compared with natural fine aggregate. The test results obtained indicate that pond ash of marginal quantity as partial sand replacement has beneficial effect on the mechanical properties. The strength development for various percentages (0-50%) replacement of fine aggregate with pond ash can easily be equated to the strength development of normal concrete with various ages. The properties of aggregates were also compared. Test result indicates that the workability of pond ash concrete is good and the strength characteristics are comparable to those of conventional concrete.

Keywords: Compressive strength, flexural strength, normal concrete, pond ash, split tensile strength

INTRODUCTION

Use waste and by-products as concrete aggregate is of great practical significance. Because about 75% of concrete comprises aggregate. India power generation has undergone a tremendous growth since independence. Fine aggregate is an essential component of concrete. The most commonly used fine aggregate is natural river sand. It is very high due to the extensive use of concrete. The production of ash from Thermal power plants stations has increased from 17.06 million tonnes during 1990-1991 to 68.82 million tonnes. In 1996-1997 and has crossed 100 million tonnes in year 2000. The ash needs to be managed properly or otherwise it will cause land, air and water pollution. Hence it is a serious concern about utilizing it to the maximum extent. In wet disposal system the pond ash from the boilers and the fly ash from the precipitators are mixed together and pumped off in the form of slurry to lagoons, where water is drained off or Recycled.

This material is being referred as pond ash is available in India, almost free of cost. It was dumped as a waste by product material in almost all thermal power stations. It seemed as river sand while seeing. If the pond ash is not to be used properly or disposed from the power station site there will be more problems

Fig. 1: Neyveli thermal power plant station

(Fig. 1) due to the storage of wastage material. Increase in demand and decrease in the natural resources of fine aggregate for the production of concrete has resulted in the need of identifying new sources of fine aggregate. High volumes pond ash up to 60% replacement of cement has been used for making dry lean concrete as a base course in high ways for contributing towards sustainable construction. The possibility of utilization of thermal power plant by-product pond ash as replacement to the fine aggregate in concrete is discussed in this study.

LITERATURE REVIEW

The consumption of cement content, workability, compressive strength and cost of concrete made with

Corresponding Author: K. Arumugam, Department of Civil Engineering, BIT Campus, Anna University, Tiruchirappalli, India

pond ash were studied by researchers. When pulverized coal is burnt in a dry, bottom boiler, about 80% of the unburnt material or ash is entrained in the flue gas and is captured as fly ash. The remaining 20% of the ash is dry bottom ash that is collected in a water filled hopper at the bottom of the furnace. The lagooned bottom ash is usually combined with fly ash. This fly ash and bottom ash are referred to as pond ash (American Coal Ash Association, 1996). Pond ash is potentially useable but is variable in its characteristics, because of differences in the unit weight of fly ash and bottom ash. The ash deposited within about 100 m of ash slurry discharge point in the pond is coarser ash as compared to the ash deposited away from 100 m in between these two areas is of medium particle size (Mangaraj *et al*., 1994). The type and source of coal, performance of generating facility, variation in collection, disposal, storage methods, temperature of coal burning and few other issues control the properties of pond ash (Ranganath, 1995). The engineering properties of pond ash control its use as a material in construction. The characterization of pond ash in terms of physical, chemical, mineralogical properties play in important role in assessing its suitability as a material in different fields of construction (Ranganath *et al*., 1994). The Grain size Distribution of coal ash reveals that bottom ashes are coarser particles consisting predominantly of sand size fraction with some silt size fraction classifying coal ash sandy silt to silty sand (Leonards and Bailey, 1882). The chemical contents such as toxic elements, heavy metals and levels of natural radioactivity in the coal ashes greatly influence the environmental and ecological system that may arise out of their disposal. Trace metals present as a relatively small fraction in coal ash, can leach out and contaminate soil as well as surface and groundwater resources (Vladimir and Vladimir, 2000; Vimal *et al*., 2005). The workability of concrete decreased with the increase in bottom ash due to the increase in water demand (Aggarwal *et al*., 2007). Sieve analysis conducted on washed bottom ash is more suitable for mortar rather than concreting sand (Mohd Syahrul *et al*., 2010). Experimental investigation carried out to evaluate the effect of fine and coarse bottom ash on the flow characteristics and density of concrete mixture and found that both of fine and coarse bottom ash aggregates had more influence on flexural strength than compressive strength (Kim and Lee, 2011). An investigation was also carried out on the behaviour and long term durability of laboratory made roller compacted concretes containing bottom ash as fine aggregate for the properties like fresh properties and strength, stiffness and deformation characteristics. It was observed that samples containing dry bottom ash offered excellent strength, stiffness and deformation properties, considering the range of cement factors used (Siddique, 2004; Sivasundram and Malhotra, 2004). This study presents the feasibility of the usage of pond ash as a partial replacement for conventional concrete. Tests were conducted on cubes, cylinders and beams to study the compressive, split tensile and flexural strengths of concrete made pond ash for M30 grade proportions and OPC53 grade cement was used.

MATERIALS AND METHODS

Cement: Cement-Dalmiah 53 grade Ordinary Portland cement was used for in this study. This cement is the most widely used one in the construction industry in India.

Fine aggregate: River sand having density of 1720 kg/m^3 and fineness Modulus of 2.51 was used. The specific gravity was found to be 2.69. The maximum size of fine aggregate was taken to be 4.75 mm.

Coarse aggregate: The nominal size of coarse aggregate was taken to be 20 mm size. Natural granite aggregate having density of 1530 kg/m^3 and fineness modules of 6.8 was used. The specific gravity was found to be 2.60 and water absorption as 0.45%.

Pond ash: Pond ash is obtained from (NTPS) Neyveli Thermal power station was used in investigation. The specific gravity of pond ash is 2.16.

Super plasticizers: These are the modern type of water reducing admixtures, basically a chemical or a mixture of chemical that imparts higher workability to concrete. It consists of formaldehyde.

It is the use of super plasticizer which has made it possible to use pond ash as fine aggregate and particularly to give high workability to the concrete. It is widely used all over the word. India is catching up with the use of super plasticizer in the construction of high rise building, long span bridges and the recently become popular ready mixed Concrete technology.

Water: Water is an essential ingredient of concrete since it part in chemical reaction with cement to form a binding paste that fills the innumerable minute surface irregularities of fine aggregate and coarse aggregate and thus bring them into closer adhesion. Water is needed not only to bring about hydration but also to render its easy placing inside the form and around reinforcement. Such additional water should of course be present to the minimum requirement.

Mix design: Since there is No standard method of designing concrete mixes incorporating pond ash as fine aggregate. The mix design proposed by IS method were first employed to design the conventional concrete mixes and finally natural sand was partially replaced by pond ash to obtain the pond ash concrete mixes. The specimens were cast for M30 grade.

Table 1: Chemical composition of pond ash

Sl. No.	Characteristics	Composition (%)
1.	Moisture content % by mass	0.69
2.	Loss on ignition, % by mass	0.71
3.	Silica (as SiO_2) content % by mass	61.85
4.	Aluminum oxide(as Al_2O_2) content % by mass	25.15
5.	Iron oxide (as Fe_2O_3) content % by mass	7.04
6.	Titanium oxide (as TiO_2) content % by mass	NIL
7.	Magnesium oxide (as MgO) content % by mass	1.52
8.	Calcium oxide (as CaO) content % by mass	1.60
9.	Sodium (as Na_2O) content % by mass	0.56
10.	Potassium (as K_2O) content % by mass	0.88

Table 2: Physical properties of pond ash and fine aggregate

Property	Pond ash	Fine aggregate
Specific gravity	2.16	2.69
Bulk density in kg/m^3	740	1720
Fineness modulus	1.25	2.94

Table 3: Physical properties of coarse aggregate

Sl. No.	Property	Value
1	Specific gravity	2.80
2	Bulk density in Kg/m^3	1530
3	Fineness modulus (Aggregate below 12.5 mm-A1)	7.40
4	Fineness modulus (Aggregate above 12.5 to 25 mm)	6.25
5	Water absorption	0.98

Table 4: Sieve analysis of pond ash and fine aggregate percentage of passing

Sieve size	Fine aggregate	Pond ash
10 mm	100	-
4.75 mm	99.60	-
2.36 mm	74.52	100
1.18 mm	55.15	98.76
600 microns	32.84	98.50
300 microns	18.90	60.72
150 microns	10.12	15.45

Table 5: Sieve analysis of coarse aggregate

Sieve size (mm)	A1-aggregate	A2-aggregate
40	100	100
20	40.78	100
10	0.32	81
4.75	0.28	2.2
2.36	-	0.1

Aggregate 1: above 12.5 mm to below 25 mm; Aggregate 2: below 12.5 m - % of passing

- Chemical composition of pond ash (Table 1)
- Physical properties (Table 2)
- Physical properties of pond ash and fine aggregate
- Physical properties of coarse aggregate (Table 3)
- Sieve analysis of pond ash and fine aggregate percentage of passing (Table 4)
- Sieve analysis of coarse aggregate (Table 5)

TEST SPECIMENS AND TEST PROCEDURE

Each and every time 9 cubes of size 15×15×15 cm, 6 cylinders of size 15 cm dia and 30 cm height and 6 beams of size 10×10×50 cm, were casted. For testing at the end of 7 days for analysing compressive strengths 3 nos of cubes are tested. For analysing split tensile strength of concrete 2 nos of cylinders are tested and for analysing the flexural strength of beams 2 nos of beams casted are tested. Likewise at the end of 28 and 56 days the same above testing procedures were followed.

Here the results of compressive strength of cubes, split tensile strength of cylinders and flexural strength of beams at the end of 7, 28 and 56 days, respectively with partial replacement of pond ash for fine aggregate were compared with the same time testing results of the control specimens which were casted with 0% replacement of pond ash for fine aggregate. The pond ash is replaced such as 20, 30, 40 and 50%, respectively instead of fine aggregate and the specimens are tested and compared with the results of the control specimens (Table 6).

Table 6: Concrete mix proportion with 0, 20, 30, 40 and 50%, respectively pond ash

Mix design	Pond ash fraction of F.A (%)	Cement (kg)	Pond ash (kg)	F.A (kg)	C.A (kg)	Water (L)	Super plasticizers (mL)
M1	0	372	0	637	1231	186	1.75
M2	20	372	127.4	509.6	1231	186	1.75
M3	30	372	191.1	445.9	1231	186	2.50
M4	40	372	254.8	382.2	1231	186	2.50
M5	50	372	318.5	318.5	1231	186	2.50

Table 7: Compressive strength of concrete with varying % of pond ash

		Load in N/mm^2		
Mix proportion	% of pond ash added	7 days	28 days	56 days
M1	0	32.81	43.77	57.33
M2	20	33.63	43.18	53.77
M3	30	37.77	41.03	47.11
M4	40	36.74	36.66	40.44
M5	50	21.48	29.85	37.70

Table 8: Split tensile strength concrete with varying % of pond ash

		Load in N/mm^2		
Mix proportion	% of pond ash added	7 days	28 days	56 days
M1	0	1.48	2.37	2.33
M2	20	1.90	2.16	2.30
M3	30	1.80	2.23	2.02
M4	40	2.05	2.44	1.80
M5	50	2.12	2.12	2.22

Table 9: Flexural strength concrete with varying % of pond ash

		Load in N/mm^2		
Mix proportion	% of pond ash added	7 days	28 days	56 days
M1	0	11.25	11.25	10.75
M2	20	9.75	8.37	9.75
M3	30	9.25	10.37	9.25
M4	40	9.25	10.75	8.75
M5	50	10.25	10.50	10.75

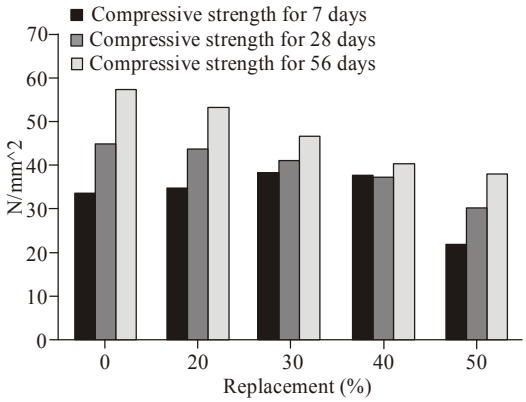

Fig. 2: Compressive strength of concrete for various mixes

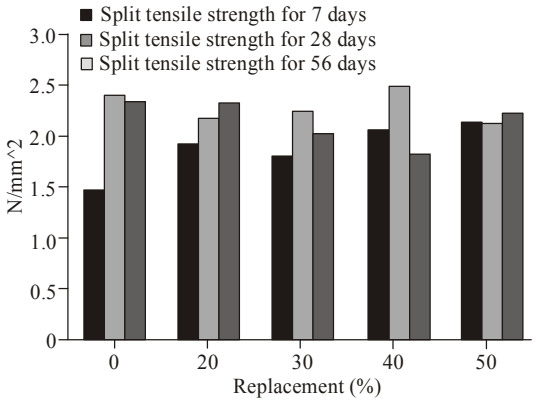

Fig. 4: Split tensile strength of concrete for various mixes

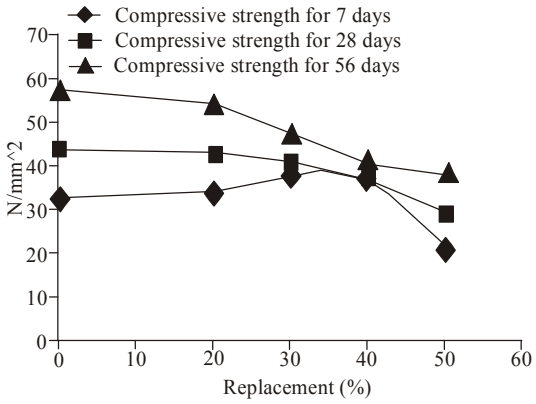

Fig. 3: Compressive strength of concrete with ages

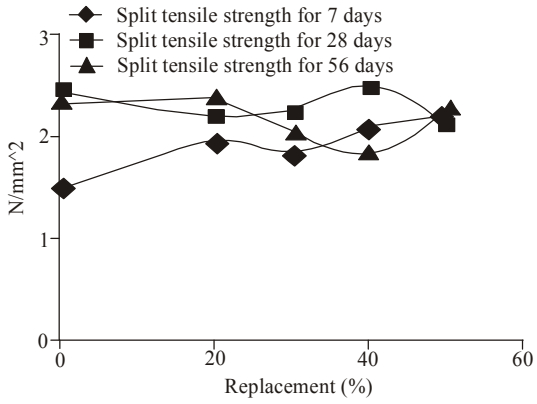

Fig. 5: Split tensile strength of concrete with age

- Compressive strength of concrete with varying % of pond ash (Fig. 2 and 3) (Table 7)
- Split tensile strength concrete with varying % of pond ash (Table 8) (Fig. 4 and 5)
- Flexural strength concrete with varying % of pond ash (Table 9) (Fig. 6 and 7)

RESULTS AND DISCUSSION

- The compressive strength various from 53.77 37.70 N/mm^2 for 56 days and 43.18 to 29.85 N/mm^2 for 28 days and 33.63 to 21.48 N/mm^2 for 7 days. This is the different range of replacement of pond ash.
- The split tensile strength various from 2.22 to 2.3 N/mm^2 for 56 days and 2.16 to 2.12 N/mm^2 for 28 days and 1.9 to 2.12 N/mm^2 for 7 days. This is the different range of replacement of pond ash.
- The flexural strength various from 9.75 to 10.75 N/mm^2 for 56 days and 8.37 to 10.5 N/mm^2 for 28 days and 9.75 to 10.25 N/mm^2 for 7 days. This is the different range of replacement of pond ash.

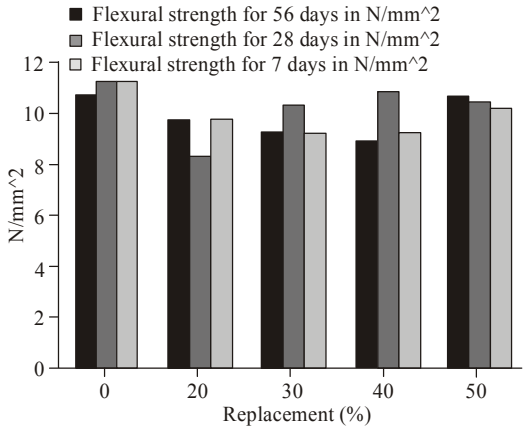

Fig. 6: Flexural strength of concrete for various mixes

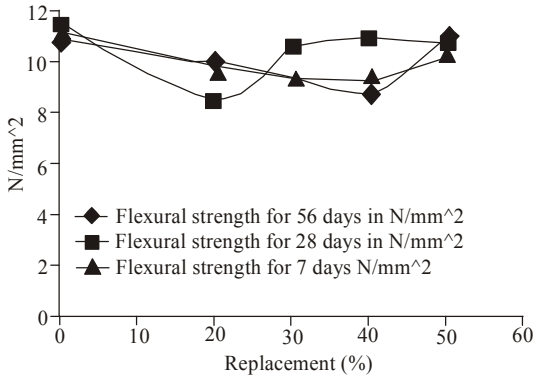

Fig. 7: Flexural strength of concrete with age

CONCLUSION

The following conclusions are drawn from the observations of the compressive strength test, Split tensile test and Flexural Strength test made by using the pond as partly replacement for fine aggregate from 0 to 50%.

The density of concrete reduces with the increase in the percentage of pond ash:

- The compressive strength of concrete with pond ash increases with increased curing period
- The Split tensile strength of concrete with pond ash increases with increased curing period
- The Flexural strength of concrete with pond ash increases with increased curing period
- While pond ash is used the workability is reduced. For obtaining the required workability the super plasticizers are added while preparing the concrete
- The more pond ash adds the more super plasticizers are required to be added for obtaining the required workability
- With increasing replacement of fine aggregate with pond ash, the average density of concrete shows a linear reduction due to its lower specific gravity
- Strength gets increased by increasing the days of curing
- The test result shows that the replacement has beneficial effects in improvement of properties mainly at M3 and M5
- As the compressive and tensile strength of pond ash result values is good

REFERENCES

Aggarwal, P., Y. Aggarwal and S.M. Gupta, 2007. Effect of bottom ash as replacement of fine aggregate in concrete. Asian J. Civil Eng. Build. Housing, 8(1): 49-62.

American Coal Ash Association, 1996. Coal Combustion Product-production and Use. Alexandria, Verginia.

Kim, H.K. and H.K. Lee, 2011. Use of power plant bottom ash as fine and coarse aggregates in high strength concrete. Constr. Build. Mater., 25: 1115-1122.

Leonards, G.A. and B. Bailey, 1882. Pulverized coal ash as structural fill. J. Geotech. Eng. Div., 108: 517-531.

Mangaraj, B.K. *et al*., 1994. Use of ponded fly ash as part of replacement of fine aggregate in mortar and concrete. ICJ, pp: 279-282.

Mohd Syahrul, H.B.M.S., M. Fadhluhartini and M. Zulkifli, 2010. The properties of special concrete using washed bottom ash as partial sand replacement. Int. J. Sustain. Constr. Eng. Technol., 2: 65-76.

Ranganath, R.V., 1995. A study on the characterization and use of ponded fly ash as fine aggregate in mortar and concrete. Ph.D. Thesis, Report 1995, IITD, Delhi.

Ranganath, R.V., B. Bhattacharjee and S. Krishnamoorthy, 1994. Influence of size fraction of ponded ash on its pozzolanic activity. Cement Concrete Res., 28(5): 749-761.

Siddique, R., 2004. Performance characteristics of high volume class fly ash concrete. Cement Concrete Res., 33(3): 487-493.

Sivasundram, V. and V.M. Malhotra, 2004. High performance high volume fly ash concrete. Indian Concrete J., Nov(2004): 13-21.

Vimal, K., M. Mukesh, S.S. Shashank and D. Sagar, 2005. Fly ash: An environment saviour. Fly Ash India 2005. Fly Ash Utilization Programme, TIFAC, DST, New Delhi.

Vladimir, K. and B. Vladimir, 2000. Environmental Impact of heavy metals contained on fly ash emitted from the Thai lignitefired power plant. ASC Div. Fuel Chem., 45(1): 83-87.