International Journal of Civil Engineering (IJCE)
ISSN 2278-9987
Vol. 2, Issue 3, July 2013, 35-40

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

STRENGTH PROPERTIES OF HIGH PERFORMANCE CONCRETE USING BOTTOM ASH AS FINE AGGREGATE

M. PURUSHOTHAMAN & RM. SENTHAMARAI

Department of Structural Engineering, Annamalai University, Chidambaram, Tamil Nadu, India

ABSTRACT

To safeguard the environment, efforts are being made for recycling the industrial wastes and utilise them in value added applications. Advances in solid waste management resulted in alternative construction materials as a substitute to traditional materials like aggregates, cement and etc., This paper reports the results of an experimental program to investigate the effect of using thermal power station bottom ash as a replacement of natural fine aggregate on the properties of High performance concrete (HPC). Totally 10 mixes were prepared for this tests. Out of which five are Bottom ash Concrete (BAC) and five are Conventional Concrete mixes (CC). BAC were prepared for various cement contents ranging from 300 Kg/m^3 to 500 Kg/m^3 by adding 10% of silica fume in the volume of the cement and replacing 40% of the volume of the fine aggregate by bottom ash. BAC mixes were evaluated for compressive, tensile and flexural strengths development for the concrete ages of 7 days,28 days,56 days and 90 days and the results were compared with those of CC mixes prepared for same quantity of cement ranging from 300 Kg/m^3 to 500 Kg/m^3.

KEYWORDS: Bottom Ash, High Performance, Industrial Waste, Mechanical Properties, Silica Fume

INTRODUCTION

Aggregates are considered one of the main constituents of concrete since they occupy more than 70% of the concrete matrix. There is an increase in the consumption of aggregates due to the greater demand by the construction industry. Generally the river sand is used as a fine aggregate in concrete and is obtained by mining the sand from river bed. Increased sand mining not only affects the aquifer of the river bed but also causes environmental problems. In such a situation the construction industry searches an alternative to sand. On the other hand, most of the electrical energy is produced by coal-fired plants. This results in the production of fly ash and bottom ash. The annual ash production is about 380 million tonnes which is more than the rest of all industrial wastes in India and china. Most of the ash has to be disposed off either dry or wet to an open area near the plant or by grinding both the ash and mixing it with water and pumping into artificial lagoon or dumping yards. Such wastes coming out of the industries and factories lead to the pollution of water bodies and soil contamination and thus loss of productive land **(Aggarwal, 2007)**. Although large amount of fly ash has already been utilized in the construction industry as a partial cement replacement and/or mineral additive in cement production, the usage of bottom ash is limited due to its relatively higher unburned carbon content and different structural properties compared to fly ash. Hence use of bottom ash as a replacement of fine aggregates would help the environment and make the sustainable construction industry.

Generally the conventional concrete can have enough strength but not durable. After much research, this problem was overcome by High Performance Concrete (HPC).It is obtained from mineral admixtures and chemical admixtures by partly replacing or adding with the conventional materials. Now a day some industrial waste materials are used as admixtures for making high performance concrete. These admixtures add both strength and durability to the concrete and also make it sustainable **(Tom kuennen, 1998)**. In recent years; the terminology "High performance concrete" has been introduced into the construction industry all over the world. Using HPC in structures today would result in both technical and economical advantage **(Bhikshma, 2009)**. HPC require along with improved compressive strength, high tensile strength, reduced porosity and very high durability. It requires mineral admixtures such as fly ash, silica fume, ground-granulated blast furnace slag, bottom ash used separately or in combination. These mineral admixtures require more water to produce concrete. Therefore the chemical admixtures such as high-range water-reducers are needed to decrease the water demand and to improve the durable property.

In this paper a study was made to evaluate the potential use of Industrial wastes bottom ash by partially replacing the sand and adding silica fume with the cement in the production of High Performance Concrete (Bottom ash concrete).The mechanical properties compressive strength ,split tension strength ,flexural strength and modulus of elasticity were studied for this HPC.

MATERIALS

Industrial Wastes

Bottom ash is one of the Industrial by product and obtained from thermal power plant, Neyveli Lignite Corporation Ltd, at Neyveli, Tamilnadu in India was used in this study as replacement material for Fine aggregates. The specific gravity and fineness modulus of bottom ash was 2.35 and 1.90.

Silica fume is another industrial waste and it is the by-product of the production of silicon and silicon alloys. A densified Silica fume obtained from “Elkem India Private Limited – Mumbai, India, was used as cement replacement material. The specific gravity was 1.93.

Other Concrete Mix Components

Ordinary Portland cement (OPC) 43 grade confirming to IS 12269-1987(specific gravity 3.08), locally available river sand (specific gravity 2.56 and fineness modulus 2.43) confirming to IS 383-1970 and natural crushed stone aggregate of maximum size 20 mm(specific gravity 2.77 and fineness modulus 6.95) confirming to IS 383-1970 were used.

Super Plasticizer

Use of super-plasticizers becomes essential for designing mixtures to achieve HPC. Super plasticizer by trade name Tec Mix 550, Sulphonated Naphthalene Polymers manufactured at Chennai, India was used as water reducing admixtures to achieve the required workability.

EXPERIMENTAL PROGRAM

The experimental program comprises the following two stages

Stage 1: The optimum replacement percentage of industrial wastes in concrete was evaluated and the isolated effects of silica fume and bottom ash was studied from its 28 days compressive strength.

Stage 2: Knowing the optimum replacement level of replacement materials a mix proportion was developed for making Bottom ash concrete. Tests were conducted on this BAC for its mechanical properties, Compressive strength: Split tension strength: Flexural strength and modulus of elasticity.

In preliminary study, for arriving at the optimum level of mineral admixtures, two mixes were prepared by absolute volume method, one with silica fume at different levels of 0% to 20% designated as CSF. Another one made with bottom ash at different levels of 0% to 60% designated as CBA.

CBA mix was prepared by Keeping the cement, coarse aggregate, and water and SP contents as constant, Fine aggregate content was partly replaced by bottom ash. Six concrete mixtures were prepared with different replacement levels of 10% (CBA10), 20% (CBA20), 30% (CBA30), 40% (CBA40), 50% (CBA50) and 60% (CBA60) bottom ash by volume of fine aggregate. Similarly CSF mix was prepared by keeping fine aggregate and coarse aggregate, water and SP content as constant, the cement content was partly replaced by silica fume. Four concrete mixtures were prepared with different replacement levels of 5% (CSF5), 10% (CSF7), 15% (CSF 15) and 20% (CSF 20) silica fume by volume of cement. Similarly a conventional concrete mixture (CC) was prepared to compare the results. For each concrete mixture, three 100 × 100 × 100 mm cube specimens were used for compressive strength determination. All the specimens were cured under water at 27± 2 ºc for 28 days. Each strength value was the average of the strength of six specimens. Specimens were tested according to relevant Indian Standards. From the preliminary study it was observed that optimum dosage of bottom ash and silica fume were 40% and 10% respectively for making Bottom ash concrete, shown in figure 1 and 2.

HIGH PERFORMANCE CONCRETE MIX PROPORTIONS AND SAMPLE PREPERAION

There are no specific methods of mix design for HPC. The methods adopted for the design of conventional concrete mixes are not directly applicable to HPC **(Kalaiarasu, 2006)**. In this investigation, the mix design for bottom ash concrete was based on absolute volume method by conducting trial mixes. From the number of trials it was observed that the minimum operating water required was 160 litres per cubic meter of concrete.

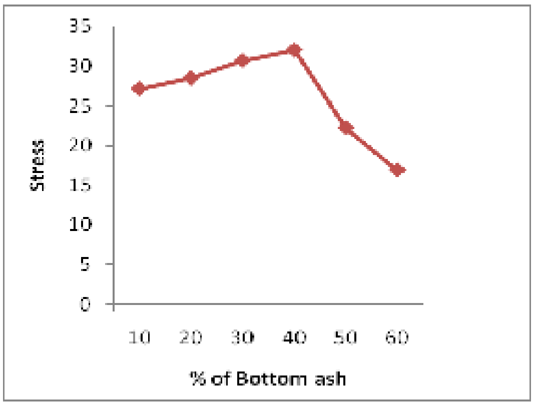

Figure 1: Percentage of Replacement of BA and 28 Days Compressive Strength

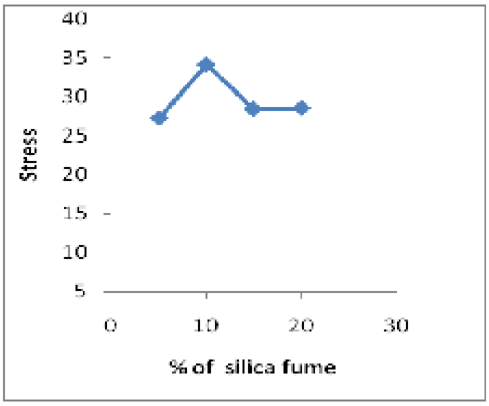

Figure 2: Percentage of Replacement of SF and 28 Days Compressive Strength

Totally 10 mixes were prepared for this tests by volumetric method with different water - binder ratios (1.64,1.41,1.23,1.10,0.99) for various cement contents 300 to 500 Kg/m^3. Out of which five were Bottom ash Concrete mixes (BAC 300, BAC 350, BAC 400, BAC 450, and BAC 500) and five were Conventional Concrete mixes (CC 300, CC 350, CC 400, CC 450, and CC 500). BAC mixes were obtained by adding 10% of silica fume in the volume of the cement and replacing 40% of the volume of the sand by Neyveli bottom ash. The volume of water, super plasticizer and coarse aggregate were kept constant while the volume of cement and sand was varied for all the mixes. In a similar manner, by following the absolute volume method, five conventional concrete mixes were designed. The mix proportions are given in Table.1.

To understand the workability of bottom ash concrete and conventional concrete, slump test was conducted as per IS 7320-1974. A tilting drum type mixer machine was used for preparing the concrete. All the test specimens were cast using steel mould and compacted on a vibrating table. The specimens were de-moulded after 24 hours and cured under water at 27± 2 ºC until the test age. To determine the mechanical properties of bottom ash concrete and conventional concrete, all the tests were conducted as per IS 516-1959.

Test Specimens

For each mix, six cubes of size 100 mm × 100 mm were cast to determine compressive strength, splitting tensile strength; three beams of size 100 × 100 × 500 mm were cast for flexural strength and three cubes of size 150 mm × 150 mm were cast to determine the modulus of elasticity. All these tests were conducted at different curing periods of 7 days, 28days, 56 and 90 days. Therefore 420 HPC specimens and 420 CC specimens, and a total of 840 specimens were cast to conduct the test for Mechanical properties.

RESULTS AND DISCUSSIONS

Compressive Strength

Compressive strength of BAC mixes was determined at 7,28,56,90 days **(IS 516, 1959)** and the test results were compared with the results of conventional concrete specimens and are tabulated (Table 2). BAC mixes showed improved compressive strength than the conventional concrete and shows consistently higher compressive strengths at almost all ages. The sufficient gain in strength is thought to be due to very high pazzolanic reactivity of the two mineral admixtures silica fume and bottom ash **(Arnon, 2007)**.

Table 1: Mix Proportions for HPC by Weight

Mix	Cement Kg/m^3	SF Kg/m^3	FA Kg/m^3	BA Kg/m^3	CA Kg/m^3	Water Kg/m^3
BAC 300	270	19	490	300	1119	160
CC 300	300	-	816	-		
BAC 350	315	22	466	285	1119	160
CC 350	350	-	774	-		
BAC 400	360	25	441	269	1119	160
CC 400	400	-	733	-		
BAC 450	405	28	416	254	1119	160
CC 450	450	-	691	-		
BAC 500	450	31	391	239	1119	160
CC 500	500	-	650	-		

Split Tensile Strength

Split tensile strength of BAC mixes was determined at 7,28,56,90 days **(IS 5816, 1999).** The test results are given in Table 2. The results of BAC were compared with the results of CC specimens.This table indicates that the splitting tension strength of all mixtures showed a similar behaviour to the compressive strength results.

Flexural Strength

Flexural strength of BAC mixes was determined at 28, 56, 90 days **(IS 516, 1959).** The test results are given in Table 2. The results were compared with the results of conventional concrete specimens .The split tensile strength of bottom ash concrete are satisfactory when compared to the conventional concrete mix.

Modulus of Elasticity

The test was carried out confirming to IS 516-1959 to obtain the stress-strain curve and modulus of elasticity of the concrete. The table shows the values of modulus of elasticity.

CONCLUSIONS

The following conclusions are drawn with reference to the material used, test method adopted and the range of parameters studied.

- The industrial waste Bottom ash could be transformed into useful fine aggregate in concrete making. Even partial replacements in volume of cement and sand with silica fume and bottom ash respectively in concrete mixes would lead to considerable savings in consumption of cement and sand and enables the large utilization of waste product.
- The incorporation of 10% silica fume and 40% bottom ash in concrete results in significant improvements in its mechanical properties of BAC compared to the control mix.
- It should be noted that further research work is needed to explore the effect of bottom ash as fine aggregates on the durability properties of concrete.

Table 2: Results of Strength of Different Mixes of BAC and CC

Mix	Compressive Strength MPa				Splitting Tension Strength MPa				Flexural Strength MPa			Modulus of Elasticity in Gpa		
	7 Days	28 Days	56 Days	90 Days	7 Days	28 Days	56 Days	90 Days	28 Days	56 Days	90 Days	28 Days	56 Days	90 Days
CC 300	15	23	24	25	2.21	3.00	3.09	3.16	3.27	3.40	3.54	19.00	21.00	21.11
BAC 300	16	26	28	30	3.42	3.78	3.96	4.34	3.42	3.54	3.71	23.88	25.00	25.71
CC 350	21	29	30	32	2.54	3.36	3.48	3.59	3.70	3.81	4.00	21.11	22.85	23.75
BAC 350	25	32	34	38	3.89	4.22	4.42	4.68	3.81	3.93	4.16	25.71	27.14	28.57
CC 400	24	34	35	37	2.78	3.59	3.68	3.82	4.00	4.15	4.33	22.49	24.44	25.71
BAC 400	29	38	43	45	4.16	4.39	4.73	5.01	4.17	4.32	4.49	27.50	30.00	31.42
CC 450	28	40	42	45	3.11	3.99	4.16	4.38	4.32	4.48	4.67	24.99	26.25	27.77
BAC 450	32	44	49	52	4.36	4.58	4.86	5.22	4.49	4.69	4.96	30.00	31.42	33.33
CC 500	32	46	48	51	3.37	4.28	4.39	4.74	4.55	4.75	5.01	26.67	28.34	30.00
BAC 500	36	50	53	56	4.46	4.73	5.02	5.36	4.74	4.93	5.23	31.42	33.33	35.00

REFERENCES

1. Aggarwal.P, Aggarwal.Y, Gupta S.M, (2007),"Effect of Bottom Ash as Replacement of Fine Aggregates in Concrete", *Asian Journal of Civil Engineering (Building And Housing)* Vol. 8, No. 1 (2007) Pages 49-62.
2. Arnon (2007),"Silica fume: Its role in cement and Concrete technology" International workshop on silica fume, held in Taiwan.
3. B. Bhattacharjee (2010),"Sustainability of concrete construction in Indian context" The Indian Concrete Journal, july 2010, pp 45-51.
4. Bhikshma V, Nitturkar K and Venkatesham Y (2009), Investigations on mechanical properties of high Strength silica fume concrete, *Asian journal of civil Engineering (building and housing)* vol. 10, no. 3 (2009), Pages 335-346.
5. Basu P.C and Amit Mittal (1999), "High performance concrete for Indian Nuclear Power Plants", Transaction of the 15 th International conference on *Structural mechanics in Reactor Technology (SMiRT-15)* held at Seoul,Korea,August 15-20,1999,pages 67 – 74.

6. IS: 516 – 1959, Indian standard code of practice methods of test for strength of concrete, Bureau of Indian standards, New Delhi, India.

7. IS: 5816 – 1999, Indian standard code of practice methods of test for strength of concrete, Bureau of Indian standards, New Delhi, India.

8. KumarMetha.P,(2004),” High Performance, High volume fly ash concrete for sustainable development” proceedings of the International Workshop on *sustainable development and Concrete technology* held at Beiging,China May 20 – 21,2004,Centre for Transportation and research and education , Lowa state University, pp3-14.

9. Kalaiarasu.M and Subramanian.K,(2006),”Properties Of Recycled Aggregate Concrete With Silica fume”, *Journal of Applied Sciences* 6(14),2956 – 2958.

10. Katkhuda.H, Hanayneh.B and Shatarat.N, (2009),”Influence of Silica Fume on High Strength Lightweight Concrete”, *World Academy of Science, Engineering and Technology* 58 , 2009 pages 781 – 788.

11. Khalifa S. Al-Jabri, MakotoHisada, SalemK. Al-Oraimi , Abdullah H. Al-Saidy,(2009),”Copper slag as sand replacement for high performance concrete”, *Cement & Concrete Composites* 31 (2009) 483–488.

12. Revathi,V ,Narashimha V.L.,.jayanthiS,(2009),”studies on the performance of quarry waste in flowable flyash gpsum slurry”,*Modern applied science*,Vol 3.,No 2,-pp 147 – 153.

13. Tom kunnen (1998),”What is High performance concrete”, workshop on durable concrete held at Washington in June 1998.