Utilization of Coal Bottom Ash as a Partial Replacement for Fine Aggregate in Concrete.

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Abstract— Environmental Pollution, because of the emission of carbon-dioxide (CO_2),is expanding continuously with each progressive day which make enormous deterioration for environment and is likely to be reduced in any possible manner. Besides bulk of Coal Bottom Waste scattered on the surface is another environmental issue of Pakistan.Through a look, via literature review, at the versatility of concrete this study was based on a suitable replacement of fine aggregate with coal bottom ash and opted to reuse such waste in production of concrete rather than filling it in empty lands which reduced energy requirement and became environment friendly.The fine aggregate forconcrete was substituted partially by weight with CBA-0%, CBA-10%, CBA-20%, CBA-30% and CBA-40%. Results for fresh and hardened states of specimens are communicating that there is a decrease in workability with increase in percentage of CBA on the other hand at 28 days of curing there is an encouraging positive effect on strength parameters i.e. compressive and tensile with increase in percentage of CBA by weight of fine aggregate and increase in proportion of CBA as filler in concrete is also making it more resistive to water absorption.

Index Terms—Coal Bottom Ash, Fine Aggregate, Partial replacement, Compressive and tensile Strength, Water absorption

1 Introduction

Concrete, as a versatile material, possess changeable developments and it has utilization in a wide range of construction works. Use of cementand sand for concrete is expanding continuously with each progressive day which make enormous deterioration for environment. Thus, it is highly needed to utilize some amount of waste material as partial replacements of ingredients for conventional concrete. Evidently, the amount of waste material creating due to the need of growing population is increasing in a considerable rate, consequently environment confronts pollution. The construction industry is being highly competent in developing the infrastructure which ultimately requires the production of concrete in bulk. Therefore, concrete is noted as world's most utilizing fabricated material [1].

1.1. Coal Bottom Ash (CBA)

To ensure the sustainable development with production of environment friendly construction materials, waste material like CBA seems to be a moderated by product for concrete, since last few decades. Encouraging results have been observed by using CBA either as partially or fully replaced with fine aggregate. Despite of delaying in pozzolanic process an obvious enhancement in performance have been noticed in partial CBA concrete than conventional one after 28 days of curing [2].

The most common physical and chemical properties of CBA are tabled below:

Table. 1. Physical properties of CBA [3]

Particular	Properties
Fineness (wt.%) +40μm	24.2
Fineness (wt.%) +90μm	5.6
Fineness (wt.%) +200μm	0.3
Specific surface (cm2/g)	7200
Specific gravity (g/cm3)	1.98

Table.2. Chemical properties of CBA [3]

Particular	Proportions in %age
Silicon dioxide	50.98
Aluminum oxide	14.96
Iron oxide	9.63
Calcium oxide	2.63
Magnesium oxide	4.01
Sulphur trioxide	0.16
Sodium oxide	0.47
Potassium oxide	1.3
Ignition loss	15.7

2. Literature Review

2.1 Coal Bottom Ash

Cristina Argiz et al. (2017) studied that the disposal of coal bottom ash is quite complicated than to use it alternatively in other ways and they investigated the utilization of coal bottom ash in production of Portland cement. Study was also carried out to examines the physical, chemical and mechanical properties of coal fly ash and coal bottom ash to evaluate the potential of these ashes as a constituent for Portland cement to reduce the amount of raw material required for Portland cement from quarry and concluded that the mechanical strength of mortar specimen is decreases gradually for 28 days curing with increase in ratio of coal fly ash and coal bottom ash. The researches also concluded that the results of strength were worst with 35% replacement of ashes which is 32.5 MPa and is lower limit in European standard EN 197-1:2011. Hence suggested to consider it as an upper limit for replacement of coal bottom ash and coal fly ash [4 is 26].

F. Canpolat et al. (2003) had investigated the effects on several properties i.e. Volume expansion, setting time, compressive strength and water consistency of cementitious product by replacing cement with different SCMs i.e. CBA, Zeolite and Fly Ash with different proportions. The modified product was found to be possessed varying mechanical properties from which the zeolite provided the positive changes as SCM with 15% of replacement but the CBA was not succeeded as SCM [5 is 27].

Hans-Joachim Feuerborn (2005) had studied that Coal Combustion products were formed at a large scale as the bulk of energy is required for the world's growing population in the form of electricity. The residuals obtained via combustion i.e. Bottom Ash, Boiler Slag and Fly Ash were considered as wastes which could be a source of environmental pollution if disposed in a ridiculous manner. Thus, those types of wastes should be used in a proper manner to become a source of innovation and advancement in Civil Engineering Materials industries [6 is 28].

Omer Ozkan et al.(2007) had taken two of the most commonly partial replacement waste products for ingredients of OPC concrete one of which was from thermal power plant i.e. Coal Bottom Ash (CBA) and other from Iron and Steel plants i.e. Granulated blast-furnace slag (GBFS) and Fly Ash (FA). For evaluating the durability characteristics, the FA was utilized as SCM and CBA & GBFS were utilized as partial fine aggregate replacements. After 7, 28 and 90 days of curing were examined experimentally for unit weight, water absorption capacity and compressive strength. It was recommended to use FA with CBA and GBFS because of decrease in properties when FA was not incorporated with the CBA and GBFS [7 is 29].

I. M. Martins et al. (2010)had studied that the utilization of CBA, a waste product obtained from coal combustion, in construction sector of Europe is 44% among which its addition in concrete is very low. The wastes of Portuguese coal power station were utilized for evaluation of CBA-Concrete in comparison with OPC-Concrete for several properties including compressive strength. Promising results of CBA-Concrete were found with increase in dosages of replacement for making it workable when incorporated with CBA [8 is 30].

A.S. Cadersa and I Auckburally (2014) had chosen the unprocessed CBA (with 11% loss of ignition), from FUEL thermal power station as a partial replacement of fine aggregate with varying percentages of 20%, 30%, 40%, 60%, and 80% respectively, for the structural concrete. The observations had disclosed that the bleeding was increased with decrease in plastic density and workability for the higher fractions of replacement. However, 20% of replacement was considered satisfactory as the results for replacements beyond 20% were not suitable because of decrease in strength parameters i.e. compressive and flexure and suggestion were made to carry out the study on durability of concrete [9 is 33].

Khan R. A. and Ganesh A. (2016), studied the usage of CBA for improvisation of strength and resistance to wear in concrete specimen along with stabilizing the economic and ecological challenges. The study disclosed that the workability decreased in CBA-Concrete with improved strength parameters which was achieved after a considerable time due to slow pozzolanic reaction. Observations exposed that strength of Grinded CBA-10% was increased about 14% than control mix at 56 days of curing. CBA-30% was credible for higher resistance to acid attack but not acceptable where the strength of concrete is primary demand [10 is 34].

Mahdi Rafieizonooz et al. (2016) had observed the wastage of coal ash in tons which mostly comprised of Coal Bottom Ash (CBA) and Coal Fly Ash (CFA) and they opted to reuse such waste in production of building materials rather than filling it in empty lands which reduced energy requirement and became environment friendly. Both the wastes were replaced partially with the ingredients of concrete i.e. CBA with filler and CFA with cement. The research program was designed by replacing 20% of CFA as SCM by weight of cement incorporated with sand replacement by CBA-0%, CBA-20%, CBA-50%, CBA-75% and CBA-100%. Results for fresh and hardened states of specimens communicated that there was a decrease in workability with increase in percentage of CBA on the other hand at 28 days of curing there was zero effect on strength parameters i.e. compressive, tensile and flexural. However, the flexural and split tensile strengths of CBA-75% with CFA-20% was exceeded significantly than the control mix. Finally, the specimen was concluded suitable for diverse structures i.e. foundations, pavement, sub-base etc. [11 is 35].

3. Research Methodology

3.1 Materials

3.1.1. Cement

Ordinary Portland-Cement (OPC) Lucky star [PS-232-2015], having strength class of CEM I 42,5N, was purchased from local vendor as shown in figure 3.1 and has been used during complete research work for all the specimens casted either for control mix or moderate mixes.

3.1.2 Fine aggregate

Hill sand of suitable quality available in the vicinity of Larkana was used as fine aggregate after passing it from 4.75 mm sieve for all the specimens casted throughout the experimental work.

3.1.3 Coarse aggregate

Locally available Crushed aggregate of adequate quality and size of maximum 19mm was utilized for all the moderate and control mixes through the complete experimental work.

3.1.4 Water

Being a most important ingredient needed for chemical reactions in dry mixes for experimental scheme was obtained from ground-water aquifers in Larkana and it was added in dry mixes after confirming unavailability of organic or inorganic constituents in excessive proportions.

3.1.5 Coal Bottom Ash (CBA)

CBA collected from the stock available in Lakhra Coal Powerhouse Jamshoro and utilizedas a partial replacement for fine aggregate for all specimens casted for experimental scheme, after passing from 4.75 mm sieve was used.

Table. 3. Details of mix proportions

Mix Code	**Partial Replacement**		**Constant Parameters**	
	Sand (% age)	**CBA (% age)**	**C.A. (% age)**	**W/c (ratio)**
Control Mix	100	0		
CBA10	90	10		
CBA20	80	20	100	0.5
CBA30	70	30		
CBA40	60	40		

3.2 Curing of Specimens

After hardening, the concrete specimens were extracted from molds gently and kept in containers full of water at a temperature of 26oC – 34oC for 28 days at normal room temperature before taking to the testing laboratory.

3.3. Laboratory Testing of Concrete

All the tests were performed using British Standards Manual after curing of concrete. Whereas, the workability, as it is a property of freshly mixed concrete, was tested after mixing. The procedures are elaborated below;

3.3.1 Workability of Concrete

As per BS EN 12350-2:2009; Slump test method was opted to examine the workability of freshly mix concrete.

3.3. Compressive Strength

As per BS EN 12390-3:2009; Compressive Strength test of casted cubes of size 100mm x 100mm x 100mm (according to BS EN 12390-1:2000) by applying the load at a specified rate. The maximum load applied on the specimen was noted down after crushing occurred and the strength (i.e. maximum load (F) per unit surface of the cube (Ac) at which the load was applied) of specific batch mix was determined by average value of five results.

3.4 Split-Tensile Strength

As per BS EN 12390-6:2009; Tensile splitting Strength test of casted cylinders of size 100mm diameter x 150mm height (according to BS EN 12390-1:2000) by applying the load at a specified rate. Then the maximum load applied on the specimen was noted down after crushing occurred and the required strength was obtained by following formula:

$$ft = [(2P) / (\pi LD)]$$

where: P= Maximum load at crushing;
L= Length of Cylinder; and
D= Diameter of Cylinder.

Finally, an average value for five specimens of specific batch mix was determined as result of that batch.

3.5 Water Absorption Test

As per BS 1881-122:2011; Water absorption, commonly defined as the amount of water to be penetrated in the concrete body in submerged condition, was evaluated for this experimental scheme. In which the cylindrical specimens were kept in an oven at a temperature of 1050C + 50C for 48 + 2 hours and weighed (W1). Secondly, the specimens were immersed in water for 100 + 10 minutes and weighed (W2). Thirdly, the percentage of water absorbed by the cylindrical specimen was evaluated by following formula:

$$[(W2 - W1) / W1]$$

where: W1= Weight of cylindrical specimen in dry state;
& W2= Weight of cylindrical specimen in wet state.

Finally, an average value for three specimens of specific batch mix was determined as result of that batch.

4. Results and Discussion

4.1.Workability with CBA

Results for workability, with CBA as a supplementary filler material in concrete, are illustrated below:

Table. 4. Workability with CBA

Mix	**Slump in*[mm]***	**Degree of Workability**
Control Mix	110	High
CBA10	98	Medium

ISSN 2229-5518

CBA20	85	Medium
CBA30	65	Medium
CBA40	40	Low
CBA40	40	Low

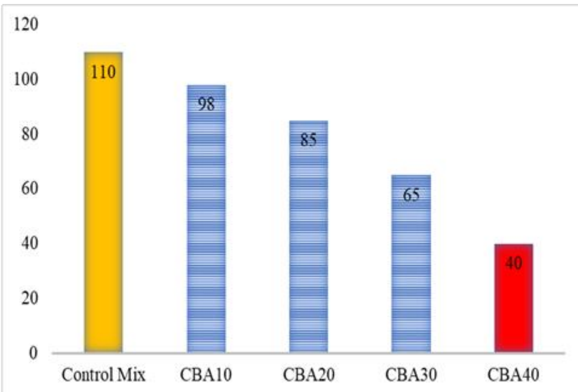

Figure. 1. Workability with CBA

Diagram in fig. 1. shows that the workability is also decreasing with increase in percentage of CBA as compared to the workability of control mix concrete, but the least value of workability with maximum percentage (i.e.40%) of replacing CBA with sand possesses low degree of workability which ultimately indicates more requirement of water for it.

4.2. Compressive Strength with CBA

Results for Compressive Strength, with CBA as a supplementary filler material in concrete, are positive up till the maximum percentage (i.e. CBA-40%) of replacement made in this experimental scheme as illustrated below:

Table.5. Compressive strength with CBA

Mix	**CS in[MPa]**	**Increase / Decrease [Percentage]**
Control Mix	26.6	0.00
CBA10	27.53	3.50
CBA20	28.19	5.98
CBA30	29.06	9.25
CBA40	30.68	15.34

Figure. 2. Compressive strength with CBA

Diagram in fig. 2. shows that the compressive strength is maximum with maximum percentage of replacement (i.e. 40%) of CBA with sand. Whereas, the value of CS is least for control mix concrete. Hence, there is no regret for replacing CBA with sand.

4.3. Tensile Strength of CBA

Results for tensile strength, with CBA as a supplementary filler material in concrete, are positive up till the maximum percentage (i.e. CBA-40%) of replacement made in this experimental scheme as illustrated below:

Table. 6. Tensile strength with CBA.

Mix	**TS in[MPa]**	**Increase / Decrease [Percentage]**
Control Mix	3.62	0.00
CBA10	3.72	2.76
CBA20	3.8	4.97
CBA30	3.89	7.46
CBA40	4.01	10.77

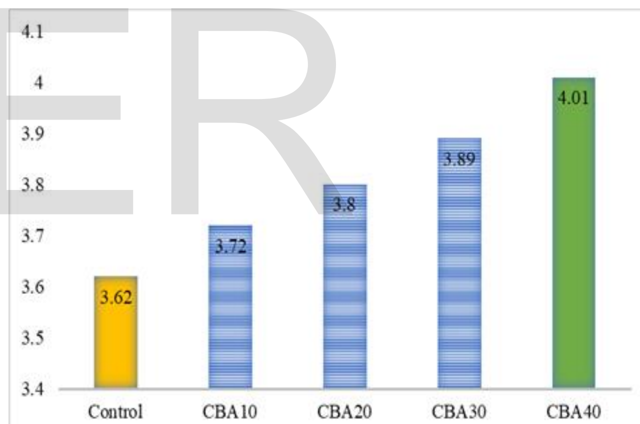

Figure. 3. Tensile strength with CBA

Diagram in fig. 3. shows that the tensile strength is maximum with maximum percentage of replacement (i.e. 40%) of CBA with sand. Whereas, the value of TS is least for control mix concrete. So, it is encouraging to replace CBA with sand.

4.4. Water Absorption of CBA

Results evaluate a negative graph for water absorption of CBA-Concrete with increase in percentage of CBA as supplementary filler material up till the maximum percentage (i.e. CBA-40%) of replacement made in this experimental scheme as illustrated below:

Table. 7. Water absorption with CBA

Mix	WA in[Percentage]	Increase / Decrease [Percentage]
Control Mix	8.03	0.00
CBA10	7.64	-4.86
CBA20	6.58	-18.06
CBA30	5.41	-32.63
CBA40	4.39	-45.33

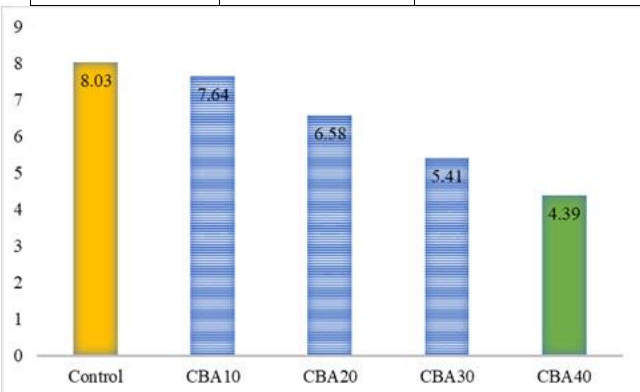

Figure. 4. Water absorption with CBA

Diagram in fig. 4. shows that more water is absorbed by the specimen with 10% replacement of sand by CBA and is also less than the result evaluated for control mix. However, the minimum water absorption is evaluated for maximum percentage of replacement (i.e. 40%) in this experimental scheme.

5. Conclusion

In this paper, we studied the problem of environmental hazard causing by improper disposal of coal bottom waste and utilized it as a partial replacement for fine aggregate in concrete. Workability of concrete incorporated with CBA was decreased and modified mix was found to require more water or a chemical admixture for making it workable. However, the values for compressive and tensile strength were increased from 0% – 40% replacement of fine aggregate with CBA as shown in fig. 2. and fig. 3. respectively. Along with this, CBA-Concrete was found efficient in resistance to water penetration in it. Hence, the study encourages us to take it to a wider range with increase in percentage of CBA in concrete ingredients and study for more parameters of modified CBA-Concrete i.e. Density and Flexural Strength.

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