durability properties of coal washery rejects concrete with bottom ash as partial replacement of coarse aggregate

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***Abstract* - As the demand of natural coarse and fine aggregates is becoming high day by day in construction industry, attempts are being made to search for alternatives to aggregates. In India, about 70% of electricity is produced by combustion of good quality coal. During coal washing process, large quantities of impure coal so called coal washery rejects (CWR) and coal bottom ash (CBA) are getting accumulated and posing disposal problems. As the construction industry is the feasible application to reuse waste materials, this investigation is mainly intended to introduce CWR as an alternative to coarse aggregate and CBA as an alternative to fine aggregate and study the mechanical properties of CBA based concrete. In this study, coarse aggregate is partially replaced by CWR at various levels (0% - 75%). The optimum replacement level of CWR was found at 40%. CBA based concrete is made with 40% replacement of CWR in coarse aggregate and fine aggregate is partially replaced by CBA at various levels (0%, 25%, 50% and 75%). The rapid chloride permeability, water absorption and drying shrinkage properties were determined at different curing periods and compared to M 25 grade of conventional concrete (CC).**

***keywords* - shrinkage,permeability,absorption,washery,disposal)**

I. INTRODUCTION

Research concerning the use of by-products and industrial wastes to augment the properties of concrete has been going on for many years. In the recent decade, the efforts have been made to use industry by-products such as fly ash, silica fume, ground granulated blast furnace slag (GGBFS), glass cullet, etc., in the civil constructions. According to their chemical composition and particle size the potential application of industrial by-products in concrete as partial replacement for aggregate or as partial replacement for cement. The employment of those materials in concrete arises thanks to environmental constraints, within the safe disposal of those by products.

About 67% of production of electricity in Asian nation is extracted from combustion of coal. The total estimation of coal reserves in world is estimated to be 6,641,200 million tones and the same estimation for India to be 106,260 million tones. The demand of coal is expected to increase at quick rate than it had been within the past because of the increase in the price of crude oil and natural gas. The demand of coal during the first half of last century remained constant more or less and now it is growing in this century. It's the very best linkage impact with thermal power plants, railway locomotives, industry of fertilizers, cement, steel, electricity and a variety of different industries. India is to be continued in sixth largest producer of coal of nearly one hundred million tones with its annual production. The reserves of the low ranking hydrocarbon and lignite coals are more as compared to high ranking coal i.e. anthracite and coking hydrocarbon coals. On the opposite side, the demand of high rank coals is more for metallurgical use and for use as fuel.

The coal because it comes from mines consists of several impurities such as magnesium sulfate, fire clay, pyrites in the form of Sulphur in, and slate. These impurities have higher specific gravity than pure coal and hence, it needs coal washing technique to clean coal before exploitation. Specific gravity of pure coal is1.2 to 1.7 and for impure coal is 1.7 to 4.9. Therefore, coal should be screened to size and it should be cleansed by jigging or by heavy-media separation. When demand grows, society expects cleaner energy with less pollution associate degree an increasing stress on environmental property. The coal industry acknowledges it should meet the challenge of environmental property and in especially it should reduce its greenhouse emissions if it's to stay a neighborhood of property part of energy future. The qualities of coal need to be assessed only then it is often fittingly utilized in completelydifferent industries.

Bottom ash is the coarser material, which drops into the bottom of the furnace in cutting-edge tremendous thermal power plants and represent about 20% of gross ash content of the coal fed in the boilers.

Coal bottom ash is the by-product of coal combustion. The rock detritus filled within thefissures of coal end up separated from the coal during pulverization. In the furnace,carbon, other combustible matter burns, and the non-combustible subject outcome in coal ash.Swirling air contains the ash particles out of scorching zone where it cools down. The boiler fluegas carries away the finer and lighter particles of coal ash. The boiler flue gases passthrough the electrostatic precipitators before reaching the environment. In the electrostaticprecipitators, coal ash particles are extracted from the boiler flue gases. The coal ashaccumulated from the electrostatic precipitators is called fly ash. Fly ash constitutes about 80%of coal ash. During the combustion process some particles of the coal ash accumulate onthe furnace walls and steam pipes in the furnace and form clinkers. These clinkers buildup and fall to the bottom of furnace. In addition, the coarser particles, which might be too heavyto stay in suspension with the flue gases, settle down at the base of the furnace. The ashcollected at the bottom of furnace is called coal bottom ash. Coal bottom ash constitutesabout 20% of coal ash and the rest is fly ash.

The scope of the present research work includes the following:

- Characterization of material
- Design of conventional concrete mix
- Preparation of concrete mixtures with varying sand and coarse aggregate replacement levels.

II. LITERATURE REVIEW

Ilangovana et al. (2008) reported the used quarry rock dust as fine aggregate in the preparation of concrete mix. The authors have defined the quarry rock dust as a residue, tailing or other non-valuable waste material after the separation of processing of rocks to converted into fine small particles which are less than 4.75 mm.

Senthamarai and Devadas (2005) used the waste as coarse aggregate in the preparation of normal concrete was collected from an electrical ceramic insulator industry. The material was too big so it was fed into a crushing machine and it therefore broken into small pieces of about 100–150 mm with the hammer. According to the same authors, waste aggregate from ceramic industry has the similar properties as compared to the natural crushed stone aggregate. The specific gravity or bulk density and fineness modulus of aggregate were ranges from 2.45 and 6.88 respectively. The surface texture of the electrical ceramic waste aggregate is found to be smoother than that of crushed stone aggregate. Binici (2007) used ceramic industry waste in the preparation of normal concrete as a partial replacement of fine aggregate about (40–60 %). The bigger waste pieces were crushed into 4 mm or less in size by a procedure similar to that adopted by Senthamarai and Devadas (2005).

Pacheco-Torgal and Jalali (2010) are used four types of different ceramic waste as coarse aggregate and also as the replacement of cement in the production of concrete. These are: white stoneware once fired; ceramic bricks; sanitary ware; white stoneware twice-fired. In these waste types the major oxide constituents present are silica and alumina. In all the waste types contain the major mineral phases are quartz and feldspars.

Siddique (2003a, b) studied the effect of fly ash as fine aggregate replacement in concrete
and observed increase in compressive strength of concrete and decrease in abrasionresistance of concrete with the increase in replacement level of sand with fly ash.

Cyr et al. (2005) observed that MBM bottom ash can be used as replacement of sand in mortars.

Compressive force of mortar incorporating up to 17% MBM bottom ash as replacementof sand did not change. Cyr et al. (2006) observed that on use of rubber sand, the strain ofconcrete improved by 25% but there was a negative effect on compressive strength.

III. EXPERIMENTAL WORK

Constituent materials used to make concrete can have a significant influence on the properties of the concrete. The next sections discuss about the constituent materials used for manufacturing of each conventional concrete (CC) and coal washery rejects (CWR) based concrete. Chemical and physical properties of the constituent materials are presented in this section.

Cement

Ordinary Portland Cement 53 grade (Penna) was used corresponding to IS 12269 (1987). The chemical properties of the cement as obtained by the manufacturer are presented in the Table 3.1.

Table 3.1. Chemical composition of cement

Particulars	Test result	Requirement as per IS:12269-1987
Chemical Composition		
% Silica(SiO_2)	19.79	-
% Alumina(Al_2O_3)	5.67	-
% Iron Oxide(Fe_2O_3)	4.68	-
% Lime(CaO)	61.81	-
% Magnesia(MgO)	0.84	Not more Than 6.0%
% Sulphuric Anhydride (SO_3)	2.48	Max. 3.0% when C_3A>5.0 Max. 2.5% when C_3A<5.0
% Chloride content	0.003	Max. 0.1%
Lime Saturation Factor $CaO-0.7SO_3/2.8SiO_2+1.2Al_2O_3+0.65Fe_2O_3$	0.92	0.80 to 1.02
Ratio of Alumina/Iron Oxide	1.21	Min. 0.66

Summary of physical properties and various tests conducted on cement as per IS 4031(1988) are presented in the Table 3.2.

Table 3.2 Physical Properties of Cement

Physical properties	Test result	Test method/ Remarks	Requirement as per IS

			12269 (1987)
Specific gravity	3.15	IS 4031(1988) – part 11	-
Fineness (m^2/Kg)	311.5	Manufacturer data	Min.225 m^2/kg
Normal consistency	30%	IS 4031 (1988)- part 4	-
Initial setting time (min)	90	IS 4031 (1988)- part 5	Min. 30 min
Final setting time (min)	220	IS 4031 (1988)- part 5	Max. 600 min
Soundness Lechatelier Expansion (mm) Autoclave Expansion (%)	 0.8 0.01	Manufacturer data	 Max. 10 mm Max. 0.8%
Compressive strength (MPa) 3 days 7 days 28 days	25 39 57	IS 4031 (1988)- part 6	27 MPa 37 MPa 53 MPa

IV. RESULTS AND DISCUSSION

In this Chapter, the test results are presented and discussed. The test results cover thestrength properties ofconcrete using CWR as partial replacement of coarse aggregate (0%, 25%, 50%, 75%). The optimum replacement level of CWR was found. Concrete made with the optimum level of CWR. In this concrete, river sand was replaced with coal bottom ash (CBA) at 0%, 25%, 50% and 75% levels.The durability properties of CBA based concrete viz., rapid chloride permeability, water absorption and drying shrinkage were studied at different curing periods.

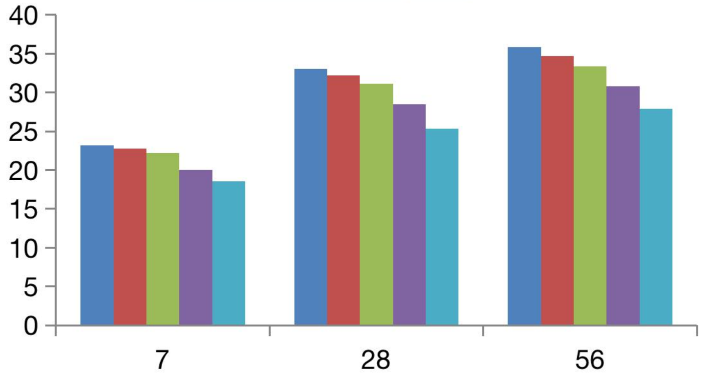
Compressive strength of CWR based concrete

This section discusses the compressive strength of both CC and CWR based concrete mixesat different curing periods.Table shows the compressive strength values of concrete with partial replacement of CWR.

Table Compressive strength of CWR concrete

Mechanical property	Age (days)	Mix type			
		CWR_0	CWR_25	CWR_50	CWR_75
Compressive strength, f'c (MPa)	7	22.20	21.76	21.18	20.02
	28	32.06	31.20	30.14	28.53
	56	34.84	33.68	32.39	30.81

From the results it is seen that the concrete mixes withpartial replacement of CWR have attained lower values of compressive strength at all ages as compared to that of conventional concrete (CWR_0) as shown in Fig.4.1.



concrete. Shrinkage strains decreased with the increase in coal bottomash content in concrete.Thereduced shrinkage strain exhibited by bottom ash concrete mixtures was probably due tolower free water-cement ratio. The porous particles of dry coal bottom ash absorbed part ofwater internally during the mixing process. It is also believed that, the porous coal bottomash particles released the water during drying of specimens. This resulted in lessershrinkage strains on drying of bottom ash concrete mixtures. Earlier investigations reported that concrete containing coal bottom ash exhibited greater dimensional stability as compared toconventional concrete

V. CONCLUSION

Based on the test results, the following conclusions are drawn:

1. The 28-day compressive strength of the concrete mixes CWR_20 and CWR_30 are comparable to that of M 25 grade of CC.

2. The further increase in replacement of CWR decreased the strength properties significantly as in the case of the concrete mixes CWR_40 and CWR_50.
3. Hence, it can be recommended to use CWR at 30% partial replacement of coarse aggregate in order to attain the desired values of CC.
4. The compressive strength values of CBA_30 are comparable to that of M 25 grade of CC and CBA_0 at all ages.
5. The further increase in replacement of CBA decreased the compressive strength values significantly as in the case of the concrete mix CBA_40.
6. At 28 days of curing age, the total charge passed through CBA based mixes were higher than CC and CBA_0 concrete mixes. After 90 and 180 days of curing age, the total charge passed through bottom ash concrete specimens were lower than that through CC and CBA_0 concrete mixes.
7. At 28 days of curing age, the water absorption values of CBA based mixes were higher than CC and CBA_0 concrete mixes. After 90 and 180 days of curing age, the water absorption values of CBA based concrete specimens were lower than that through CC and CBA_0 concrete mixes.
8. Drying shrinkage strains decreased with the increase in coal bottom ash content in concrete.
9. It can be concluded that 30% replacement of CWR in coarse aggregate and 30% replacement of CBA in fine aggregate can be recommended in the manufacturing of M 25 grade of concrete.

5.1. Future work

Based on the investigation of this project, the future work includes:

- Study on durability properties of CBA based concrete mixes viz. sorptivity, acid attack resistance.
- Conduct non-destructive tests on CBA based concrete mixes.
- Keeping in view of the availability of natural resources and environmental aspects, it is recommended to replace some percentage of sand with CBA and slag in CBA based concrete mixes and study all hardened and durability properties.
- Study on micro level properties of CBA based concrete mixes.

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