International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 04, April-2015

Investigation on the Development of Light Weight Concrete with Sintered Fly Ash Aggregate and Activated Fly Ash in Blended Cement

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***Abstract*— The use of activated fly ash in blended cement and sintered fly ash aggregate in concrete as a partial replacement of granite aggregate has been examined .The concrete so formed is light in nature(upto 40% reduction in unit weight)and development of such concrete minimises consumption of granite rock resulting in the protection of natural environment. Present investigation considers M20 and M25 grade concrete It is observed that with partial (20%,30% and 40% by volume)replacement of natural granite aggregate by sintered aggregate the physical properties of concrete such as compressive strength and Young's modulus of elasticity are retained.**

Keywords—: Light weight concrete(LWC), sintered fly ash(SFA), activated fly ash(AFA), blended cement(BC), coarse aggregate replacement(CAR)

INTRODUCTION

Civil engineering construction involves different types of concrete mixes, comprising of various types of cements and aggregate in it. Different types of Portland cements, slag cements, Portland pozzolana cements are used. The basic materials for above cements are Portland cement clinker normally produced using limestone and clay in the raw mix and the second material in use is slag or any pozzolanic material. Granite aggregate is a vital element in concrete and its extensive use results in destruction of hills causing geological and environmental imbalance. Crushed stone aggregate extraction is already a threat to many parts of country. These impacts include loss of forest, noise, dust, blasting vibrations and pollution hazards. Unplanned exploitation of rocks may lead to weak and steep hill slopes. Fly ash, a by-product of coal based thermal power plants amounts to approximately 60 million tons per year. It is a serious problem so far as availability of land for dumping and pollution hazards are concerned. For disposal of such amount of fly ash about 1,00,000 acres of valuable land will be required in construction of fly ash storage ponds.

Present day investigation have been made to use this waste material in the form of activated fly ash in blended cement and for the preparation of sintered aggregates to be used in concrete.
Aggregate were prepared by sintering the mixture of fly ash, semi-plastic, clay and coke breeze at definite proportion at a sintering temperature of 1200° to 1300° C in Laboratory Chain Grate Sintering System by Down Draft Sintering Technique. These aggregates so prepared were fly ash based light weight aggregates. In order to materialize the direct bulk use of fly ash as blending material in cement and concrete some investigations have been made by mechanical, chemical and thermal means to improve the pozzolanic activities of fly ash .The thermochemical activities of coal fly ash has been increased to a considerable extent by adopting down draft sintering technique. In this technique, activated sintered fly ash aggregates are manufactured by incorporating lime and iron bearing waste materials and sintering in the temperature range of 1300°-1400°C.ASFA contains more high temperature polymeric phases of quartz such as tridymite and cystoballite, calciumalumino silicates and dicalcium silicates. Mulite originally present in fly ash gets transformed to calcium and iron bearing mineral compounds. Presence of polymeric forms of lower elementary silica and other amorphous phases maintain the lime reactivity value of ASFA to as high as 7N/mm^2.Lime reactivity values of Indian fly ash are in the lower side around 4 N/mm^2.On the other hand activated fly ash ,which has high lime reactivity values has been successfully used in high percentage in blending with cement. This clinker gives better strength of cements than inactivated fly ash**.**

MATERIALS AND METHODS

Portland cement clinker and activated fly ash are used as the main ingredient for the preparation of bended cements. Aggregates comprises of sintered fly ash in the pellet form.

COARSE AND FINE AGGREAGATE

During sintering process the ash particles have interacted in the pellet to form ceramic bonding resulting in hard mass. Most of quartz particles have transferred to crystobolite form and alumino-silicate in the form of mullite.The pellet also contains iron in metallic form as shown in X-ray diffraction(XRD)pattern referred to Institution of Engineers (1),CV,Light weight concrete with sintered fly ash: A study on partial replacement with natural granite aggregate.

Chemical composition of sintered fly ash is shown in table 1..The sieve analysis results of normal and sintered fly ash aggregates are shown in table 2.

TABLE-1: Chemical Composition Of Sintered Fly Ash

Major elements	Fly ash	Sintered fly ash
SiO_2	58.80	63.54
Al_2O_3	24.10	24.59
Fe_2O_3	5.18	4.82
TiO_2	1.64	1.35
CaO	1.00	1.32
MgO	0.38	0.38
Na_2O	0.66	0.34
K_2O	0.62	0.42
P_2O_5	0.60	0.44
SO_3	0.25	—
Loss on ignition	6.25	1.84

TABLE -2: Result of sieve analysis of aggregate

Sieve Size	Percentage of mass passing		
	20 mm Size	10 mm Size	sand
80 mm	100	100	100.00
40 mm	100	100	100.00
20 mm	91.6	100	100.00
10 mm	26.25	62.35	100.00
4.75 mm	____	5.75	99.10
2.36 mm	____	____	90.90
1.18 mm	____	____	75.80
600 µm	____	____	39.10
300µm	____	____	10.20
150µm	____	____	1.40

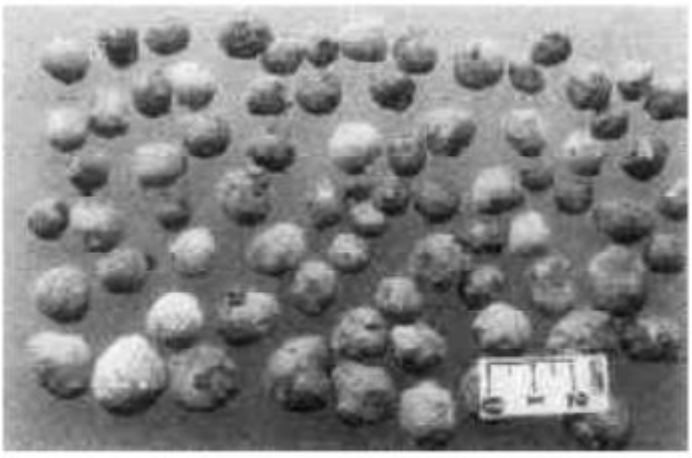

Figure 1 Photograph showing different size fractions and smooth surface of sintered pellets made from flyash

BLENDED CEMENT

It comprised of activated fly ash, cement clinker and by-product gypsum were mixed and grounded in the laboratory all mill to prepare cement.Table -3 shows the pysical characteristics of blended cement with acivated flyash for two concrete mixes.Reference can be made to ICJ ,May 2000.

ACTIVATED FLY ASH

Thermal power plant of Odisha contains a typical distribution of 57.82 per cent SiO_2,24.13 per cent Al_2O_3,5.12 per cent Fe_2O_3,1.49per cent TiO_2 ,0.85 per cent CaO,0.50 per cent MgO,0.67 per cent Na_2O,0.63 per cent K_2O,0.65 per cent P_2O_5 and 7.50 per cent LOI was used to prepare activated fly ash aggregate by agglomeration technique. The powdery fly ash was mixed with 10 per cent lime sludge waste, 10 per cent semi plastic clay and five per cent coke breeze powder. They are granulated in disk granulator using water as binder. Pellets prepared were of size less than 15 mm. The granulated pellets were sintered in a port grate furnace, which operates on the principle of chain grate sintering system is commonly adopted for agglomeration of iron ore fines in steel plants. Solid carbon present in the charge acted as fuel for sintering.

CEMENT CLINKER

Mineralogically cement clinker contained 58 per cent tricalcium silicate(C_3S),23 per cent dicalcium silicate and interstitial phase of tricalciumaluminate(C_3A),tetracalcium alumina ferrite (C_4AF) and glass of 155.Chemically the cement clinker contained 20.6 per cent SiO_2,5.1 per cent MgO,0.3 per cent SO_3,63 per cent CaO,5.6 per cent Al_2O_3 and 0.8 per cent alkalis. This cement clinker is used as control cement, which is prepared by grinding in a ball mill in presence of 3 per cent by-product gypsum.

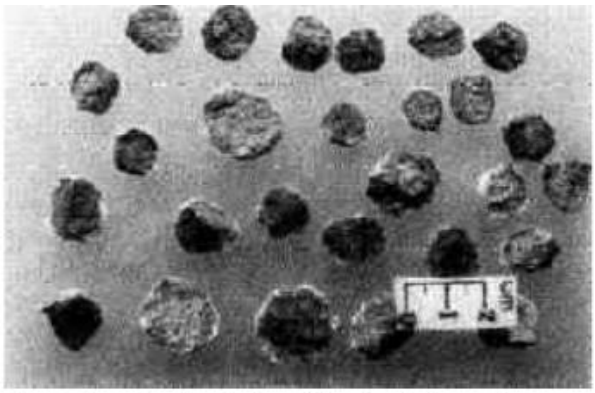

Figure 2 Internal surface showing uniform sintering from surface to core of different size pellets

TABLE-3 Physical characteristics of blended cement with activated sintered fly ash.

Characteristics	Mix 1	Mix 2
1.Percentage of OPC Clinker	77	47
2.Percntage of activated sintered fly ash	20	50
3.Percentage of gypsum	3	3
4.Fineness Sieve Analysis, gm. Blaine's surface analysis,$cm^2/gm.$	Residue 1.7 >3600 29.80	Residue 1.5 >3500 31.0
6.Setting time,hr Initial Final	 0.44 3.9	 1.23 4.28
7.Soundness Le Chateliers expression, mm	Negligible	Negligible
8.Autoclave expansion	Negligible	Negligible

PREPARATION OF CONCRETE MIX

Proportioning Of Ingredients

Ingredient proportioning has been done accurately according to Indian Standard guidelines for M20 and M25 grade. The curve (C),Fig 47 of BIS-SP,23-1982 was referred to arrive at free water cement ratio. These values are 0.465 and 0.425 for M20 and M25 respectively. The ratio of 20 mm down and 10 mm down aggregate were fixed as 60:40 for all in aggregate grading. The qualities of material for the mixes with partial replacement of natural aggregate by 20 per cent,30 per cent,40 per cent by volume of sintered fly ash was done with special attention to water absorption values of sintered aggregates. Four mixes were prepared namely

Mix 1-Concrete with natural granite aggregate
Mix 2-Concrete with 80% natural aggregate and 20% sintered fly ash
Mix 3-Concrete with 70 %natural aggregate and 30% sintered fly ash
Mix 4-Concrete with 60%natural granite aggregate and 40%sintered fly ash.

These mixes were casted in 150 mm side cubes and 150 mm by 300 mm cylindrical test specimens .These specimens were covered with wet burlap at the casting site for 24 hours. These were transferred to curing tank. These cubes were tested for 7 days and 28 days. Table 6 gives the strength and Young's Modulus of the casted concrete.Table 5 shows the mix proportioning weight of various aggregate present in the concrete mix. Cylindrical specimen were tested at 28 days to arrive at the Secant Modulus of Elasticity.

(1)

TESTING PROCEDURE

To determine percentage size fractions of sintered materials sieve analysis was done. The physical properties of the blended cements such as normal consistency, setting time ,Le Chatelier's expansion, autoclave expansion and compressive strength has been determined following BIS specification. Lyca make heating microscope was used to determine refractiveness of different sintered products containing alumina.

TABLE-4:Mix proportioning weight(cement :sand: coarse aggregate)

Grade of mix	Mix	Mix proportioning Weight			Unit Weight kg/m^3
		Cement	Sand	Coarse Aggregate	
M20	1	1.449	3.317	3.317	2317
	2	1.449	2.965	2.174	2174
	3	1.449	2.789	2.105	2105
	4	1.449	2.613	2.613	2040
M25	1	1.307	2.981	2.981	2326
	2	1.307	2.664	2.664	2187
	3	1.307	2.505	2.505	2115
	4	1.307	2.348	2.348	2052

TABLE-5: Compressive strength and Young's Modulus of Elasticity of concrete mix

Grade of concrete	MIX	7 day concrete strength,N/mm^2	28 day concrete strength,N/mm2	Young's modulus of elasticity
M20	1	21.53	30.42	29600
	2	21.01	30.05	29550
	3	21.10	29.83	28800
	4	20.79	29.67	28680
M25	1	24.10	35.38	32520
	2	24.13	35.16	31640
	3	24.06	35.16	31455
	4	23.91	35.01	31200

RESULTS AND DISCUSSION

Blended cement of different composition have been prepared replacing cement clinker by 50 per cent,40 per cent ,30 per cent,20 per cent respectively by activated fly ash. Three per cent gypsum has been used as set retarder in all the samples. The control cement prepared from clinker contains 97 per cent clinker and 3 per cent gypsum. It is observed that normal consistency and setting time of blended cement increases with increase of activated fly ash from 20 to 50 per cent. Compressive strength of blended cement cubes in 1:3 mortar ratios has been determined up to 90 day intervals, of curing. With increase of activated fly ash from 20 to 50 per cent the strength gradually decreases. The blended cements achieve 16.5, 17.65, 19.5, 20.5 N/mm2 in 3 days and 31, 33.5, 35, 36.5 N/mm2, in 28 days. But it is interesting to note that all the blended cements show remarkable increase in strength after 60 and 90 days of curing. Figure reference can be taken from ICJ,MAY 2000,Fig.2.Investigation on the development of blended cement using activated fly ash. It can also be seen that the strength values achieved in direct fly ash blended cements with 40 per cent activated fly ash is more than that with 20 per cent fly ash blended cement. Activated fly ash contains lime activated silicate phase which induces better hydraulic property than the normal fly ash.

On comparing normal aggregate with sintered fly ash and activated fly ash in blended cement with ordinary Portland cement the compressive strength was found to be slightly less. The difference is less than 1 %.These values are however, well above target strength of M20 and M25 grade of concrete.

The deformation characteristics of sintered fly ash concrete show that the Young's Modulus remains same. The results confirm to the specified values as per BIS 456-2000.The use of sintered fly ash aggregate with activated fly ash in blended cement reduces the self-weight of structures.

CONCLUSION

From the present investigation following conclusions :

- Presence of lime bearing complex silicate impart better pozzolanic property than those due to the presence of crystalline quartz and mullite phases.
- In activated form flyash can replace cement clinker up to 50 percent in blended cement preparation which gives similar strength to the blended cement with 20 per cent normal fly ash
- Sintered fly ash with blended cement is not only characeterised by light weight characteristics but also possess strength and deformation similar to natural granite aggregate with ordinary Portland cement.
- Preparation of blended cement using activated fly ash and sintered fly ash aggregate would potentially be a major attempt in waste utilisation programme.

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