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A Review on Cold-Bonded Fly Ash Lightweight Aggregates: less costly light weight promising material

KEYWORDS: Lightweight Aggregate, Fly-ash, Bulk, Cementation.

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ABSTRACT This paper mainly focuses on manufacturing procedure of fly ash light weight aggregate by using cold bonding technique. The world is much interested in this part recently due to this large-scale utilization of natural aggregate which also reduces environmental pollution and dwindling of natural resources. Fly ash is one promising material which can be used as both supplementary cementation materials as well as to produce light weight aggregate. The use of cost effective construction material has augmented in recent times due to the increase in demand of light weight concrete for bulk application. In recent times, the addition of artificial aggregate has shown a reasonable cut down in the construction cost and had gained attention due to quality on par with conventional aggregate. The strength property and density of concrete made with artificial fly ash aggregates and natural gravel were also studied which confirms that by adding fly ash aggregate in concrete reduces the compressive strength but meet the required strength to be used as a structural material.

I. INTRODUCTION

Throughout the twenty-first century, the demand for the lightweight concrete has increased with the improvement of technology and the complicated constructions. Presently in India the power sector depends on coal based thermal power station to produces a huge amount of fly ash and estimated to be around 110 million tonnes annually. The utilization of fly ash is about 30% as various engineering properties requirement that is for low technical application such ac construction of fills and embankments, backfills, pavement base and sub base course; intermediate technical application such as in producing blended cement, concrete pipes, pre cast/prestressed product material, lightweight concrete and light aggregate (Baykal and doven,2000). The uses of structural grade lightweight concrete reduce considerably the self load of a structure and permit larger precast units to be handled. One of the common techniques while producing the lightweight aggregate is by agglomeration technique. In agglomeration technique the pellet is formed in two ways either by agitation granulation and compaction. The agitation method is not taking any external force rather than rotating force. With increase in the dosage of water in the binder the cohesive force of the particles increase (Bijen, 1986).As aggregates occupy large volume in concrete, conversion of fly ash into aggregate facilitates high-volume utilization of fly ash and saves depleting natural aggregates. Incorporation of sintered and cold bonded fly ash aggregates in concrete not only reduces the density of concrete but also increases the thermal and acoustical insulation and reduces the autogenous shrinkage (Manikandan and Ramamurthy, 2007).

In this study fly ash aggregates are formed by cold bonded technique. Cold bonding is nothing but normal water curing. This paper is to review on the application of using cold bonding fly ash lightweight aggregate base on cost, mix proportions, strength improving physical and mechanical properties of lightweight aggregate concrete. Lightweight aggregate concrete is used for structurally lightweight structure, it reducing the density of concrete also over weight of structure.

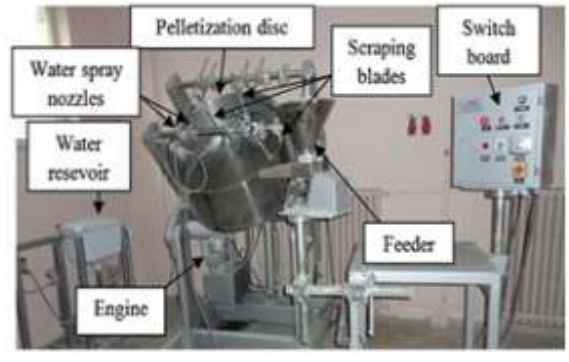


Fig. 1 Disc pelletizer machine (Mehmet, Erhan, Alzeebaree, Kasım 2012)

II. PELLETIZING PROCESS

The desired grain size distribution of an artificial lightweight aggregate is either crushed or by means of agglomeration process. The pelletization process is used to manufacture lightweight coarse aggregate; some of the parameters need to be considered for the efficiency of the production of pellet such as speed of revolution of pelletizer disc, moisture content, and angle of pelletizer disc and duration of pelletization (Harikrishnan and Ramamurthy, 2006). The different types of pelletizer machine were used to make the pellet such as disc or pan type, drum type, cone type and mixer type. With disc type pelletizer the pellet size distribution is easier to control than drum type pelletizer. With mixer type pelletizer, the small grains are formed initially and are subsequently increased in particle size by disc type pelletization (Bijen, 1986). The disc pelletizer size is 570 mm diameter and side depth of the disc as 250 mm, it is fixed in a flexible frame with adjusting the angle of the disc as 35 to 55° and to control for the rotate disc in vertically manner should varying speed as 35 to 55 rpm shown in Figure 1 (Manikandan and Ramamurthy, 2007). The dosage of binding agent is more important for making fly ash balls and the optimum range was found to be around 20% to 25% by the total weight of binders (Bijen, 1986).

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Fig.2 Fly ash pellets (after pelletization). (Harikrishnan and Ramamurthy, 2006)

III. HARDENING PROCESS IN LWA

Sintering, autoclaving and cold bonding are three different processes to harden the green pellet (Bijen, 1986). Sintering process can be defined as burning the cold bonded pellet in a muffle furnace at temperature range of 800 to 1200°C. The mineral particles in the binder fuse together to form the crystalline structure (CSH) and results in higher strength of the aggregate.

Autoclave method is less effective to improve the properties of aggregate as compare to normal water curing method. Among accelerated cured fly ash aggregate, autoclaved aggregates has properties closer to the normal water cured aggregate due to the dense microstructure formation. A higher strength of the aggregate can be obtained at 8 to 10 h in autoclave curing (Bekir and Tayfun, 2007).

Cold bonding use is made of the ability of fly ash react with calcium hydroxide at ordinary temperatures to form a water-resistant bonding material, which accounts for the pozzolanic character of fly ash. Lime or Portland cement is the source of calcium hydroxide. The Calcium sulphate, calcium sulphite and alkaline substances may have a positive effect on strength development. CSH-gel is formed and is the main bonding constituent. If calcium sulphate is applied; ettringite (3CaO.Al203, 3CaSO4.32H2O) will be one of the reaction products and will contribute to early strength development while in the presence of calcium sulphite 3CaO.Al203.CaSO3.7H20 will be formed. In case of cement this binder contributes itself to strength development. Heat generated by the hydration of the lime is used to accelerate the hardening of the pellet (Bijen 1986).

Another development is the production of cold bonded synthetic aggregates from the residue of a spray-drying absorption desulphurisation process. Here use is made of a mixture of fly ash, calcium sulphite hemihydrate, gypsum and calcium hydroxide. Fly ash is the major component. This residue is mixed with water and additional lime or cement. The dosage of the latter will depend on the reactivity of the residue itself. The composition is pelletised in a pellet mill. The pellets are cured under moistened conditions for some days after which they can be hardened further at ambient conditions (Bijen 1986).

IV. PHYSICAL PROPERTIES OF LWAC

The physical characteristics of the lightweight aggregate produced by pelletization are given in Table 1 (Bijen, 1986). The moisture content and amount of binder can affect the size of fly ash aggregates thus formed. The fineness of the fly ash (414 m2/kg) gives the better pelletization efficiency compared to the coarser fly ash (257 m2/kg). Therefore finer fly ash needs the addition of the binder material and the addition of clay binder in the coarser fly ash will increase the pelletizing efficiency (Manikandan and Ramamurthy, 2007). The specific gravity of fly ash lightweight aggregate is increase without adding binder and it's a denser structure. The addition of bentonite and glass powder in fly ash is to reducing the specific gravity as compare to lime and cement binder in fly ash (Ramamurthy and Harikrishnan, 2006).

V. MIX DESIGN OF LWAC

Cold bonded artificial fly ash aggregates (AFAs) were used as coarse aggregates for all of the concrete mixtures. AFA used in concrete production was almost in saturated surface dry (SSD) state in order not to affect the proportion of the mixing water due to high water absorption. For this, before mixing, AFAs were presoaked for 30 min to maintain the saturation. Then the AFA was taken out of water and put on a mesh for the outflow of excessive surface water during an extra 30 sec. The extra water on the surface of the pellets was rubbed out manually by a dry towel. This method was reported to be an effective way to provide SSD condition for the cold bonded artificial aggregates (Mehmet, Erhan, Alzeebaree, and Kasım 2012).

The gradation of aggregate with different aggregate grading size distributions are required to improve the engineering properties in the concrete mix(Sari and Pasamehmetoglu, 2005).

The design of lightweight aggregate are followed in two methods; loose volume calculation and absolute solid volume calculation. In mix proportion the LWA are mixed in different status while fully saturated condition, partially saturation condition and dry condition. The lightweight aggregate is pre-wetting before addition of concrete mix. The Polyurethane (PUR) foam waste as a lightweight aggregate were prepare before mixing in a concrete mix while LWA were immersed in water of 24 h to improve the workability of concrete(Amor et al., 2010). A detailed mix proportion of light weight aggregate concrete adopted in different studies is given in Table 2.

VI. STRENGTH PROPERTIES

The compressive strength of cold-bonded aggregate concrete for various percentage of cement replacement with fly ash in concrete is given. Due to slow pozzolanic reaction of fly ash, the early age strength of concrete was lower than that of corresponding control mix. The cement replacement level can be restricted based on the target compressive strength requirement at the desired age (Glory, Ramamurthy 2008).

The reduction in density of concrete with an increase in replacement of cement is due to lower specific gravity of fly ash as compared to that of cement.15cm x 15cm x 15cm concrete cubes were tested as per IS 516-1959. The test was conducted in 120 tonne compression testing machine. The load was applied at the rate approximately140kg/cm2/min until the failure of the specimen. Concrete cylinders of 15cm diameter and 30 cm height were tested for Split tensile strength as per IS 5816-1976. The specimen was placed horizontally between the loading surfaces of the compression testing machine and the load was applied without shock until the failure of the specimen (Shanmugasundaram, Jayanthi, Sundararajan, Umarani, Jagadeesan 2010). According to literature compressive strength, modulus of elasticity and splitting tensile strength of the concretes are presented in Table 3.

VII. CONCLUSIONS

Fly ash aggregates are formed by cold bonded technique which does not require energy for curing of artificial aggregates.

Cost effective construction practices with alternate construction materials are most desired in terms of huge savings in construction cost. Fly ash is not a waste and can be effectively used in concrete either as aggregate fillers, replacement for fine aggregates or as a fly ash brick material.

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Using cement as a binder in LWA production increases the specific gravity of LWA and decreases the water absorption.
The workability of cold-bonded fly ash aggregate concrete increased with partial replacement of cement with fly ash, while it decreased when sand was partially replaced with fly ash.
Cold bonded (CB) and sintered (S) aggregates were produced with water absorption values of 16.5% and 11.7%, respectively.

The workability of cold-bonded fly ash aggregate concrete increased with partial replacement of cement with fly ash, while it decreased when sand was partially replaced with fly ash. Cold bonded pellets however prefer low carbon fly ash.

The water absorption of cold bonded fly ash aggregate is 9 times higher than that of natural gravel which is the major disadvantage which can be eliminated by various treatment methods that are available like treating with water-glass etc.

In the near future the depletion of the nature resources for aggregate can be suitably compensated from the fly ash aggregate.

Table No. 1 Physical characteristics of LWCC aggregates from various literatures

Authors	Type of LWA used	Specific gravity of LWA	BD (Kg/m3)	Voids (%)	Water absorption (%)	Crushed strength of pellet (Mpa)
Priyadharshini, Mohan and Santhi 2011	LWCC	2.12	936	41	13.23	2.27
Mehmet and Erhan 2012	LWCC	2.04	-	-	16.5	5.80
Ramamurthy 2006	LWCC	1.83	850	-	15.8	-

LWCC = light weight cold bonded concrete

Table No. 2 Mix proportion of LWCC ingredients studied from various literatures.

Author	Concrete type	w/c ratio	Cement content (kg/m3)	Fine aggregate content (kg/m3) Natural	crushed	Lightweight aggregate content (kg/m3)	Admixtures (kg/m3) SP
Mehmet and Erhan 2012	LWCC	0.5	400	560.7	239.2	686.9	2
Priyadharshini, Mohan and Santhi 2011	LWCC	0.31	311	737		1293	2.4
Mehmet, Turan, Erhan 2006	LWCC	0.35	550.4	627.8		624.8	5
Glory, Ramamurthy 2008	LWCC	0.39	405	851		510.6	4.66
Erhan, Mehmet, Kasım 2013	LWCC	0.35	495	395	219	715	6
Mehmet, Erhan, Swara, Hatice, Kasım 2012)	LWCC	0.35 0.55	450 192.5	566.9 656.3	199.2 281.25	766.1 562.5	8.5 0.5
Erhan, Mehmet, Kasım 2013	LWCC	0.35 0.55	550 400	401 419	223 232	690 721	8.25 0
(Mehmet, Turan, Erhan 2006)	LWCC	0.35 0.55	549.5 399.4	603.2 631.0	258.5 270.4	486.5 508.9	11 2.5

LWCC = light weight cold bonded concrete

Table No. 3 Mechanical properties of lightweight aggregate concrete from various literatures

Authors	Concrete type	Comp strength (Mpa)	Split tensile strength (Mpa)	Modulus of elasticity (Gpa)
Mehmet, Turan, Erhan 2006	LWCC (fly ash A) LWCC (GGBSS) LWCC (fly ash B)	36.9 49.7 60.2	2.86 3.26 3.31	20.0 25.1 28.5
Shanmugasundaram, Jayanthi, Sundararajan, Umarani, Jagadeesan 2010	LWCC(15:85) LWCC (Control con.)	23.71 20.80	5.56 4.84	22.5 20.7
Niyazi and Turan, 2011	LWCC	42.3	3.7	19.6

LWCC = light weight cold bonded concrete

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