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ARTIFICIAL LIGHTWEIGHT AGGREGATE THROUGH COLD BONDING PELLETIZATION OF FLY ASH: A REVIEW

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Abstract:- *The need for the lightweight concrete has increased with the advances of technology and sophisticated construction applications. Waste materials such as fly ash, ground granulated blast furnace slag, silica fume etc. are used for the manufacture of artificial lightweight aggregate and it has a promising future due to the increasing interest and its need for using as a recycling waste product. Pelletization is a worldwide process used for the manufacturing of artificial aggregates. According to the mechanism of agglomeration and hardening of aggregate, artificial lightweight aggregates can be produced through either a sintering method or cold-bonding method. The cold bonding method is considered to be more conservative due to the utilization of minimum energy, while the sintering method consumes large amounts of energy. In recent years, cold bonding technology was developed as an alternative way of producing Lightweight Aggregate (LWA) with an environmentally-friendly impact the energy resources as well as the nature resources for natural lightweight aggregates became depleted,. This paper deals with a review on the pelletized fly ash light weight aggregate and its effects in concrete.*

Key Words: Lightweight aggregate, Pelletization, Cold bonding, Sintering, Fly ash

1. INTRODUCTION

Lightweight aggregate concrete has been utilized effectively for structural purposes for a long time. They are naturally utilized in structures for which major part of the total load is due to dead load weight of concrete. Commercially available lightweight aggregates, such as expanded clay or shale, and sintered fly ash (FA), are obtained through heat treatment 1000–1200°C. An alternative way of producing lightweight aggregate with an environmental impact and minimum energy consumption is the agglomeration of FA particles by cold-bonding process, where the water is wetting agent acting as coagulant, so that the moist mixture would be pelletized in a tilted revolving pan. Lime and Portland cement (PC) used as binder. By using such aggregates, structural lightweight concrete (LWC) with 28-day compressive strength up to 30 MPa has been produced.

The cost effective production strategies for obtaining alternative aggregates using fly ash can be a real sustainable material for future construction. Pelletization of aggregates is a promising technology that can be adopted for mass aggregate production. Agglomeration process is one mechanism that envisages the formation of pellets from a powder material with more stable spherical balls. The hardened pellets were dried by normal air curing or by heating in hot air oven. The autoclave curing and accelerated curing shows a marginal improvement in the strength properties of aggregate. The agglomeration of the pellets follows three paths due to the thumbing force, excluding the external compaction. Further enhancements of strength of cold bonded aggregates were carried out using sintering process which involves burning at 1000°C in a muffle furnace. The properties of fly ash lightweight aggregate were enhanced with the addition of binder which alters the microstructure of the aggregate. The production of LWA depends on the fineness of fly ash, water added for pelletization and the type of binder. Addition of binder plays an important role in the formation of fly ash aggregates which can lead to ball ability and increased efficiency of production. The physical and mechanical properties of pellets depend on the particle size, shape and porosity of the aggregate.

2. PELLETIZATION 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. 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.

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. In a cold bonded method is to made the increase the strength of the pellet as to increase the fly ash/cement ratio as 0.2 and above (by weight). Moisture content and angle of the disc parameter influence the size growth of pellets. The dosage of binding agent is more important for making flyash balls and the optimum range was found to be around 20% to 25% by the total weight of binders. Initially some percentage of water is added in the binder and then poured in a disc; remaining water is sprayed during the rotating period because while rotating without water in the disc the fly ash powder tends to form lumps and does not increase the distribution of particle size. The pellets are formed approximately in duration of 20 min.

Fig-1: Disc pelletizer machine

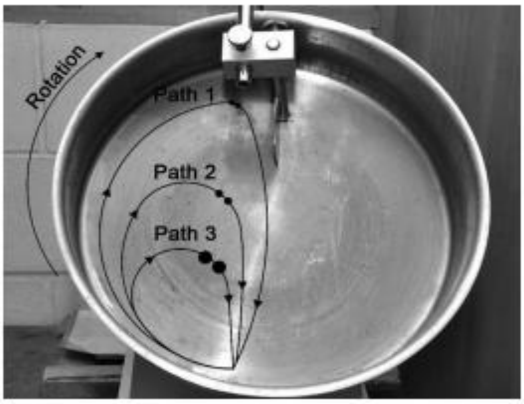

Fig-2: Growing path of pellets

3. METHODS OF PRODUCTION OF LIGHTWEIGHT FLY ASH AGGREGATE

Basically, production of artificial aggregate is using the same principle which is mixing of raw materials, agglomeration, hardening or binding of the particles and then further processing like curing and sintering. Desired size of artificial aggregate is obtained according to the application by agglomerate any raw waste materials during the production process of artificial aggregate. Lightweight fly ash aggregates were produced through various processes such as cold-bonding, autoclaving and sintering.

3.1 Cold Bonding

In cold bonding process, fly ash and binder are uniformly mixed. This proportion is thoroughly dry mixed in a mixture. After dry mixing, water is sprinkled in a pelletizer and the contents were thoroughly mixed in pelletizer until the formation of fly ash aggregate. This method of formation of aggregates is called pelletization. In cold bonding process the aggregates were allowed for curing for 1, 3 and 7 days in order to achieve green strength.

3.2 Sintering

Once the aggregate is formed in disc pelletizer, it is collected in tray allowed to dry for a day. Finally the aggregates are allowed for sintering for a temperature of 1150°C for half-an-hour duration in order to gain good strength. Sintering of fly ash aggregate was done by down draft sintering method. The raw materials usually are pelletizing by mixing with 20 – 30 % water as a binding agent to get the desire and consistency size and dried at 1100^{0}C. There are different types of palletizer machine that can be used during the agglomeration process by granulation such as disc or pan type, drum type, cone type and mixer type. The plate revolution speeds during pelletize process using rotating disk are also affecting the physical and mechanical properties of the aggregates. These changes are due to increases coalescence process of the particle up to a limit value. The sintering method required high energy, but has high engineering properties depending on agglomerated material properties and process efficiency. There are also fly ash aggregate that using the 2 steps of thermal treatment where the first at 7500^{0}C for 10 -15 minutes and second the expansion step at 11500^{0}C - 11750^{0}C for 10-15 minutes. The two-step of high heat treatment give more porous and property similar to commercial lightweight aggregate compared to one step of heat treatment.

3.3 Autoclaving

This method involves green pellets are then cured in pressurized saturated steam at a temperature of 140°C for 30 minutes. After that they are collected and allowed for dry in 24 hours. This process helps in reducing bonding material in pellet formation and curing time. It seems that the strength property and durability properties of AFA and CFA are very close to each other.

4. LITERATURE REVIEW

Dr. Atluri Sathyam *et al.* (2017) conducted a brief study on M20 Concrete modified with Artificial Cold Bonded Pelletized Light Weight Fly Ash Aggregates. The variables considered are five percentages of fly ash aggregate replacing the conventional coarse aggregate i.e. 0%, 25%, 50%, 75% and 100% with 28 days curing period. From this study, it is concluded that it is possible to produce structural grade concretes from pelletized fly ash aggregate which have been made from pelletization and cold bonding technique. The use of pelletized Fly ash aggregate has exhibited marginal increase in mechanical strength properties of concrete at elevated temperatures. The properties like density, compressive strength, youngs modulus and flexural strength are decreased continuously with increasing fly ash content replacing the natural aggregate. The cost effective and simplified production techniques for manufacturing Fly ash aggregate can lead to mass production and can be an ideal substitute for the utilization in many infrastructural projects. In the near future the depletion of the natural resources for aggregate can be suitably compensated from the manufacture and usage of Fly ash aggregate.

Haydar Arsian *et al.* (2009) investigated the fly ash aggregates produced from fly ash and cement mixing by pelletization method and evaluated engineering properties such as crushing strength, specific gravity, water absorption, particle size distribution, surface characteristics and shear strength properties of the manufactured aggregates experimentally. The experimental investigation showed that these aggregates are a good alternative for wide range of civil engineering applications.

Dr. V.Bhaskar Desai et *al.* (2014) conducted a study on the use of Partial Replacement of Natural Granite Aggregate with Pelletized Fly Ash Aggregate. The concrete produced is light weight in nature and the development of such concrete with cold bonded pelletized fly ash aggregate is to minimize the conventional aggregate, which results in protection of the natural environment. With the partial replacement (0%, 25%, 50%, 75% and 100%) of natural granite aggregate by pelletized fly ash aggregate, the strength properties of concrete such as compressive strength, split tensile strength, flexural strength and young's modulus of elasticity are studied. . From the study it is concluded that the cold bonded pelletized fly ash aggregates are spherical in shape and hence it improves the workability of content mixes with lesser water content when compared with conventional concrete. The compressive strength, split tensile strength, young‟s modulus, flexural strength and density are decreased continuously with the increasing FA aggregate concrete replacing the natural aggregate; and also increased with increasing curing period

P. Gomathi *et al.* (2014) investigated the production of alkali activated fly ash aggregate containing different types of binders such as metakaolin, furnace slag and bentonite. The lightweight aggregate properties are greatly altered with the addition of binder material which can result in good binding properties to the fly ash aggregate. The production of activated fly ash aggregate depends on the type and dosage of binders in the pelletizer. The fly ash aggregates were produced and the effects of various binder materials furnace slag (GGBS), bentonite and metakaolin substituted at 10, 20 and 30% respectively of total binder material for various time duration are studied. From the study, it is concluded that the efficiency and strength of pelletization increases with the addition of binder materials such as bentonite, furnace slag and metakaolin. The addition of alkali activators during pelletization gives a more stable formation of pellets as well as improved the strength properties. An optimum addition of binder (30% slag, 20% bentonite) results in good binding properties as well as strength.

K.Venkateswarlu et al. (2018) conducted a study on the strength properties and the behaviour at elevated temperature of light weight aggregate concrete, with Silica Fume pellets is considered. The Silica Fume pellets are prepared by mixing silica fume with lime and cement as binders by using pelletization machine. The variables considered are five percentages of silica fume aggregate replacing the conventional coarse aggregate i.e. 0%, 25%, 50%, 75% and 100% with 28 days curing period. From the study it may be concluded that it is possible to produce structural grade concrete from pelletized silica fume aggregate and cold bond technique. The cube compressive strength, young's modulus has decreased continuously with the increase in percentage of Silica fume aggregate. It is observed that the density decreases with increase of silica fume aggregate. The cost effective and simplified production techniques for manufacturing silica fume aggregate can lead to mass production and an ideal substitute for the utilization in many infrastructural projects. In the near future the depletion of the nature resources for aggregate can be suitably compensated from the usage of silica fume aggregate.

Le Anh-tuan Bui *et al.* (2012) conducted a study on the Characteristics of cold-bonded lightweight aggregate produced with different mineral admixtures. GGBS addition significantly improved the crushing strength of LWA, while there is no effective on crushing strength value of LWA when RHA used. GGBS addition significantly reduced the water absorption of LWA. Conversely, effect of RHA was to increase the water absorption. The 28-day compressive strength of the LWC ranging from 49 to 57 MPa for all mixtures satisfied the strength requirement of ASTM C330 and ACI 318 for structural LWC requiring a minimum 28-day compressive strength of 17.2 MPa. The results of the electrical resistivity and ultrasonic pulse velocity test showed that the LWCs might be considered to be durable concrete.

Sivaiah Kotapati *et al.* (2017) mainly focuses on manufacturing process of light weight aggregates using pelletizer and curing has been done in cold bonded technique. The equity of these fly ash aggregates have been tested and differentiate with natural gravel and the study showed that cold bonded fly ash aggregates can be used as an aggregate replacement material in concrete. The strength property and density of concrete made with artificial fly ash aggregates and natural gravel were also studied which confirms that introduction of fly ash aggregates in concrete decrease the compressive strength but meets the needed strength to be used as a structural material. The rounded shape of fly ash aggregate gives better workability compared to the angular natural gravel. Fly ash aggregates showed results comparable with natural gravel and the natural resource is in the side of depletion, fly ash aggregates can be considered as a replacement material for coarse aggregate. Also, it improves the property of concrete as fly ash is a pozzolanic material. The obtained aggregates can be considered for various applications like wall panels, masonry blocks, roof insulation material, structural load bearing elements etc.

Harilal B. *et al.* (2013) conducted a study on the property of concrete made from cold bonded aggregate from fly ash and quarry dust are studied in this paper. The aggregate are manufactured through polarisation method in different proportion of fly ash and quarry dust with ordinary Portland cement as binder. Three types of artificial aggregate are manufactured for this study and test results of aggregates showed that each have different strength characteristics. The tests carried out in concrete are porosity, compaction factor and compressive strength of 28 days for different water cement ratio 0.35, 0.45, 0.55 and 0.65. The results indicated that the usage of above aggregate in concrete is an alternative for natural aggregate in concrete industry and future practice in concrete also reduces the environmental impact. . Hence, it may be concluded that, cold bond quarry dust aggregates can be used for the production of concrete with appropriate modification in the mix design procedure. The quarry dust aggregate is an alternate potential constituent in concrete industry.

Kadapa Shammad Basha et al. (2017) conducted a study on strength and durability parameters of concrete made using fly ash aggregates. This study briefly presents the compressive strength development of fly ash aggregate concrete at different ages. The split tensile strength and flexural strength of all the concrete mix were investigated at different days of curing. So the replacement of 20% of fly ash aggregate is generally useful for better strength values in m40 grade of concrete

Ana Frankovi *et al.* (2016) conducted a study on lightweight aggregates made from fly ash using the cold-bond process and their use in lightweight concrete. With the addition of Portland cement Aggregates are made from fly ash by means of the cold-bonding process. Cement as a binder at (10, 20, and 30)% of mass fractions, and by pouring the mixtures into moulds. The density, water-adsorption capacity, porosity, compressive strengths, and frost resistance of the samples were determined. Based on the results of the performed investigations, it is concluded that in the case of pouring and crushing, aggregates of higher density and strength are obtained in comparison with aggregates that can be obtained by granulation. In the case of crushing, polygonally shaped aggregates are obtained, which improves the interlocking effect with the cement matrix. The application of such aggregates in concrete has confirmed their usability in the construction sector by the utilization of nearly 80 % of fly ash in concrete. The methodology described in the paper for the use of fly ash is used for other kinds of waste dust that are generated, for example, in the construction industry, in agriculture, and in the refractory industry.

Hasan Yıldırım *et al.* (2013) studied the mechanical properties of lightweight concrete made with cold bonded fly ash pellets. The compressive and splitting tensile strengths, modulus of elasticity and steel rebar-concrete bond strength of lightweight aggregate concretes (LWAC) produced at 0.40 w/c with sand and mixture of crushed stone and lightweight fly ash coarse aggregates are presented. Lightweight fly ash aggregates, plain and reinforced with 0.1% and 0.5% crumb rubber and0.1% polypropylene fiber are utilized. Test results revealed that the compressive strength of all LWAC conformed to the limitation for structural use whereas a reduction in density up to 20% was achieved. Whereas the mechanical properties decreased with the use of lightweight aggregates, some increases were observed for the steel-concrete bond strength

A. Sivakumar *et al.* (2012) conducted a review on Pelletized fly ash lightweight aggregate concrete as a promising material. Fly ash is one promising material which can be used as both supplementary cementitious materials as well as to produce light weight aggregate. Artificial manufactured lightweight aggregates can be produced from industrial by-products such as fly ash, bottom ash, silica fume, blast furnace slag, rice husk, slag or sludge waste or palm oil shell, shale, slate, clay. The potential applications of light weight aggregate are more phenomenal in terms of the usage as new construction materials. 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. The overall studies conducted showed that the fly ash aggregate produced by pelletization can be an effective aggregate in concrete production. The cost effective and simplified production techniques for manufacturing fly ash aggregate can lead to mass production and can be an ideal substitute for the utilization in many infrastructural projects. In the near future the depletion of the nature resources for aggregate can be suitably compensated from the fly ash aggregate.

P. Priyadharshini *et al* (2012) conducted a study on Artificial Aggregates made out of various waste materials. In the current situation, the disposal problem of industrial by-products like fly ash, paper pulp, heavy metal sludge, marine clay, palm shell, paper sludge, pet bottles, sewage sludge, steel slag, bottom ash etc., has become an environmental issue due to the pollution caused. Artificial aggregate can be made out of these materials that are considered waste and pollutants of environment. On the other side, shortage of natural aggregates in the growing infrastructure industry, creates problem of depleting natural resources which builds the need for artificial aggregates. This paper mainly throws light on the manufacturing process, properties and strength aspects and applicability of these categories of aggregates in civil engineering industry. Consequently, the production of artificial aggregates solves two problems, conserves environment from pollution and prevents natural resource from depletion, thereby giving way to sustainable development.

A.Siva Kumar *et al.* (2011) conducted a study on pelletized fly ash lightweight aggregate concrete. Crushed aggregates are commonly used in concrete which can be depleting the natural resources and necessitates an alternative building material. Fly ash is one promising material which can be used as both supplementary cementitious materials as well as to produce light weight aggregate. The use of cost effective construction materials has accelerated in recent times due to the increase in the demand of light weight concrete for mass applications. This necessitates the complete replacement or partial replacement of concrete constituents to bring down the escalating construction costs. In recent times, the addition of artificial aggregates has shown a reasonable cut down in the construction costs and had gained good attention due to quality on par with conventional aggregates. The cost effective and simplified production techniques for manufacturing fly ash aggregate can lead to mass production and it is an ideal substitute for the utilization in many infrastructural projects.

J. M. J. M. Bijen *et al.* (2011) conducted a study on the manufacturing processes of artificial lightweight aggregates from fly ash. Agglomeration techniques and hardening methods are described here. A division is made according to the method of hardening: sintering, autoclaving or cold bonding. It is concluded that sequence the bond between the fly ash particles in general diminishes; this effect, however, can be compensated by improving the degree of compaction of the green aggregates. Sintering processes can accept fly ash with fairly high carbon contents, whilst the other processes prefer low carbon fly ashes.

5. CONCLUSION

The potential applications of light weight aggregate are more phenomenal in terms of the usage as new construction materials. 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. The overall study showed that the fly ash aggregate produced by pelletization can be an effective aggregate in concrete production. Also, the efficiency of pelletization depends on the speed of the pelletizer, angle of the pelletizer and the type of binder added along with the fly ash. The cost effective and simplified production techniques for manufacturing fly ash aggregate can lead to mass production and can be an ideal substitute for the utilization in many infrastructural projects. In the near future the depletion of the nature resources for aggregate can be suitably compensated from the fly ash aggregate.

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