

A review on the effects of artificial light weight aggregate in concrete.

Una revisión sobre los efectos del agregado ligero artificial en el hormigón.

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ABSTRACT

The disposal problem of industrial by-products like fly ash, heavy metal sludge, sewage sludge etc. are increasing day by day. To use by-products in large volume the applications like embankment fill or aggregate replacement material should be considered for sustainable development. This study is focused on properties of artificial light weight aggregate on concrete and the effect of cold bonded light weight aggregate on concrete through partial and complete replacement of coarse aggregates. Artificial Lightweight aggregate can be produced by nodulizing the by-product for example fly ash in a pelletizer with a proportionate quantity of water, cement and further hardened by cold bonding or sintering. Due to the impact of earth quake forces all over the world, the need for light weight structural design is increasing presently, as it reduces mass of the structure. The concrete produced is light weight in nature and has added the benefit of reducing overall cost, especially in transportation and placing etc. it has its own advantages like reduced dead load, and thus economic structures, high sound absorption and good fire resistance.

Keywords—Artificial light weight aggregate, cold bonding, Fly ash, Fly ash aggregate, Pelletization, and Sintering.

RESUMEN

El problema de eliminación de subproductos industriales como cenizas volantes, lodos de metales pesados, lodos de depuradora, etc. aumenta día a día. Para utilizar

subproductos en gran volumen, las aplicaciones como el relleno de terraplenes o el material de reemplazo de agregados deben considerarse para el desarrollo sostenible. Este estudio se centra en las propiedades del agregado ligero artificial sobre el concreto y el efecto del agregado ligero adherido en frío sobre el concreto a través del reemplazo parcial y completo de los agregados gruesos. El agregado ligero artificial se puede producir noulizando el subproducto, por ejemplo, cenizas volantes en una granuladora con una cantidad proporcional de agua, cemento y endurecido adicionalmente mediante unión en frío o sinterización. Debido al impacto de las fuerzas del terremoto en todo el mundo, la necesidad de un diseño estructural liviano está aumentando en la actualidad, ya que reduce la masa de la estructura. El hormigón producido es de naturaleza liviana y ha agregado el beneficio de reducir el costo general, especialmente en el transporte y la colocación, etc. Tiene sus propias ventajas como carga muerta reducida y, por lo tanto, estructuras económicas, alta absorción de sonido y buena resistencia al fuego.

Palabras clave: agregado artificial de peso ligero, unión en frío, cenizas volantes, agregado de cenizas volantes, peletización y sinterización.

INTRODUCTION

Concrete is most commonly used material for construction. Aggregate resources are the world's most commonly exploited natural resources. The need to find alternative aggregates for the manufacture of concrete is vital in the pursuit of sustainable development in the construction sector. Artificial light weight aggregate (ALWA) is manufactured from waste materials like as fly ash (FA), plastics, blast furnace slag, silica fumes, etc. Every day, the issue of disposal of by-products from industries such as fly ash, silica fume, heavy metal sludge etc. is increasing. 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 (P. Priyadharshini et al., 2012). The study of artificial coarse aggregates has a lot of importance in this situation. The density of concrete normally ranges from 2200 to 2600 kg/m³. The need for lightweight structural design is significantly rising due to the effect of earthquake forces all across the world, as it reduces self-weight of the structural element. Artificial aggregates from different waste material have different property because of their origin. The shape and structure of the aggregate affects the new property of the concrete based on origin of materials, properties of binder, manufacturing technique, etc. In general, artificial aggregates are prepared by a

granulation method and followed by a hardening process. Hardening of the pellets is either by cold bonding, sintering, autoclavation or alkali activation.

Sintering is a process that saves time but is energy intensive. The key factors influencing the formation of sintered aggregates are the chemical compositions and LOI of materials, while the temperatures of preheating and sintering can have a major effect on the overall properties of the aggregates. Cold bonding provides an alternate approach in addition to sintering to harden the fresh artificial aggregates by using cement hydration and pozzolanic reaction. Waste materials that contain large quantities of reactive Ca or possess cement properties may also be used in the aggregate system as a main binder. For this reason, possible industrial waste powders may be considered, such as coal fly ash, sewage sludge, paper ash, etc. Overall, this approach is less energy consuming and more efficient.

Light weight concrete not always substitute normal concrete but it also offers an ecologically sound waste-management approach. Lightweight concretes with advanced properties matched to those of normal structural concrete were given the suggested production techniques. From an economic point of view, the manufacturing system is sustainable, since it offers an improvement in benefits for industrial sector that uses fly ash as they can transform waste into a resource.

ARTIFICIAL LIGHT WEIGHT AGGREGATES

Artificial Lightweight Aggregate (ALWA) are manufactured from waste materials such as fly ash (FA), Blast furnace slag, Silica fumes etc. By using industrial wastes and by-products as raw material for construction industry is one of the best solutions for waste disposal and management. Manufacturing of artificial aggregates using industrial by product is done by a process called pelletization. Lightweight aggregates can be produced by nodulizing the fly ash in a pelletizer with proportionate quantity of water, and further hardened by adopting sintering, cold bonding or autoclaving. In general, raw materials (fly ash) do not possess any self-bonding capability. The properties of fly ash lightweight aggregate were enhanced with the addition of binder which alters the microstructure of the mixture. The processing of artificial lightweight coarse aggregate using fly ash is by pelletization process and the pelletization along with process-related parameters depends on the size of the particles and their distribution, the wettability of the particles and the moisture content (K.I. Harikrishnan et al, 2006). Result of the studies are as maximum influence on strength of pellet is exerted by speed followed by angle of the pelletizer, the angle and moisture content interaction have considerable influence. The production of LWA depends on the fineness of fly ash, water added for

pelletization and therefore the sort of binder. Addition of binder plays a crucial role within the formation of fly ash aggregates which may cause ball ability and increased efficiency of production. The physical and mechanical properties of pellets depend upon the particle size, shape and porosity of the mixture. The water absorption of sintered fly ash aggregate is predominantly influenced by the speed of the pelletizer and the second important factor is moisture content. The pellets formed after pelletization is shown in Fig 1. The structure and properties of sintered fly ash lightweight aggregate which is modified by heat and polymer treatments to obtain aggregates different in their strength, absorption and pozzolanic activity (R. Wasserman et al., 1997). These properties of the aggregates were accounted for by changes in their microstructure. The strength of concretes of equal effective water/cement ratio prepared from these aggregates was determined at different ages to resolve the influence of the aggregate properties. (C.L. Verma et al., 1998) conducted Techno-commercial perspective study for sintered fly ash light-weight aggregates in India. Annual production of approx. 50 million tonnes of fly ash in India has still limited applications, the large bulk quantity of which remains abandoned as waste. Production of sintered fly ash aggregates has the unique possibility for bulk utilization of fly ash. A techno-commercial feasibility study was undertaken on the production of the light-weight aggregates from fly ash. Being lighter in weight, sintered fly ash light-weight aggregates will reduce the dead weight and material handling cost for multi-storeyed constructions and also due to low modulus of elasticity, the resistance of light-weight concrete to impact forces and vibrations is greater than that of conventional concrete. Artificial light weight concrete from plastic aggregates with five different mixes were built, increasing the amount of artificial aggregate gradually and testing the properties of fresh and hardened concrete, and the amount of artificial aggregate in the concrete increased, the slump and density of the concrete decreased with increase in percentage of artificial aggregates (Enrique del Rey Castillo et al., 2020).



Fig.1. Pellets formed after pelletization

The mixture that was most acceptable to the specifications of the analysis in terms of density and compressive strength was then selected for further investigation in stage two. In the optimal mix, fifteen percent of the natural aggregate was substituted by weight, which corresponds to more than thirty-seven percent of the volume given the lower density of the artificial aggregate relative to the natural aggregate. The findings showed that plastic aggregates were produced after shredding; it is possible to obtain lightweight concrete (1800 kg/m^3) using palletisation and extrusion processes while providing reasonably good compressive strength (20 MPa at 28 days). The strength properties and behaviour of light weight aggregate concrete with silica fume pellets at elevated temperatures (K. Venkateswarlu. et al., 2018) was tested. The silica fume pellets are prepared by means of a pelletization system by mixing silica fume with lime and cement. Here, cement as a binder is used. The replacement of coarse aggregate with artificial aggregates by 0 %, 25 %, 50 %, 75 % and 100 % with 28 days of curing. It is concluded that structural grade concrete can be developed from the pelletized silica fume aggregate and cold bond technique. Young's modulus and the compressive strength of the cubes have decreased continuously with the rise in the percentage of silica fume aggregate and the density of concrete decreases. In the near future, the exhaustion of natural resources for aggregates can be appropriately offset by the use of silica fume aggregates. Characteristics of cold-bonded lightweight aggregate produced with different mineral admixtures and GGBS addition pointedly enhanced the crushing strength of LWA, while when Rice husk ash (RHA) is used, there is no effective on the crushing strength value of LWA (Le Anh-tuan Bui et al, 2012). The addition of GGBS significantly reduced LWA's water absorption. In contrast, the effect of RHA was to improve the absorption of water. 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 findings of the test for electrical resistivity and ultrasonic pulse velocity showed that the LWCs could be regarded as durable concrete. Geopolymer concrete is an advanced material that blends the advantages of lightweight concrete with the advantages of geopolymer concrete (Priyanka M et al, 2020). Geopolymer concrete is zero percent cement concrete. Geopolymer lightweight aggregate concrete with Lightweight Expanded Clay Aggregates (LECA) and the strength of fly ash based geopolymer concrete with Lightweight Expanded Clay Aggregates (LECA) are observed. To get an acceptable mix design for LWGPC, twenty concrete mixes were prepared. As an alkali activator, an 8-molar mixture of sodium hydroxide and sodium silicate was used. The variables in the study include alkaline to binder ratio and percentage of LECA to produce concrete of densities 1800 kg/m^3 and 2000 kg/m^3 . As the percentage of LECA increased the density and the

compressive strength are decreasing. Durability of lightweight concretes with lightweight fly ash aggregates and the influence of properties of four aggregates (sintered lightweight fly ash aggregates, cold bonded lightweight fly ash aggregate and normal weight aggregate) on mechanical and durability properties of concrete is studied (Niyazi Ugur Kockal et al., 2011). Experimental results showed that using sintered or cold-bonded lightweight fly ash aggregates, high strength air-trained lightweight concretes can be produced with equal results to that of normal weight concretes. The use of lightweight aggregates (LWA) instead of normal weight aggregates in concrete production decreased the strength and stiffness due to the higher porosity and lower strength of the aggregate included in the concrete. However, permeability of sintered fly ash aggregate lightweight concretes was comparable and slightly lower than normal weight concrete whereas permeability of cold-bonded fly ash lightweight concrete was greater than the others. The result obtained from the accelerated corrosion test was consistent with comparative results of chloride ion permeability and water permeability test. Manufacturing process of light weight aggregates using pelletizer and curing has been done in cold bonded technique and 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 (Sivaiah Kotapati et al., 2017). 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. Property of concrete made from cold bonded aggregate from fly ash and quarry dust are studied (Harilal B. et al., 2013). The aggregates 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. 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 (Ana Frankovi et al., 2016). 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, polygonal 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.

HARDENING METHODS FOR LIGHT WEIGHT AGGREGATES

After pelletization the aggregates should be cured properly to achieve required strength. These curing can be done by a method called cold bonding or sintering. The sintering method let the pelletized aggregates be heated in a rotary kiln at a temperature near 1200°C so that the aggregates will be expanded. Those particles become ready-used aggregates after they cool down. On the contrary, the cold-bonding method let the pelletized aggregates be cured at an ambient temperature or be stored in an indoor space with steam-curing until their strengths are suitable for concrete. The cold bonding method is considered to be more economical due to the minimum energy consumption, while the sintering method consumes large amounts of energy and creating environment problems had to be shut down. It is observed that from pelletized fly ash aggregate after cold bonding techniques structural grade concretes can be produced (Dr. Atluri Sathyam et al., 2017). M20 Concrete modified with Artificial Cold Bonded Pelletized Light Weight Fly Ash Aggregates replacing the conventional coarse aggregate by 0%, 25%, 50%, 75% and 100% with 28 days curing period. Thereby reduce the use of natural resources by the manufacture of artificial aggregate by pelletization process using fly ash as a by-product of thermal power plants. The use of pelletized fly ash aggregate has demonstrated slight improvements at elevated

temperatures in the mechanical strength properties of concrete. The properties like density, compressive strength, young's modulus and flexural strength are decreased continuously with increasing fly ash content replacing the natural aggregate. Four light-weight artificial aggregates of cold-bonded and sintered pellets based on either mechanically activated or non-activated low-calcium fly ash and water glass were developed by the experimental study and an improvement in concrete strength due to the increase in the fineness of ash has been observed (Anja Terzica et al., 2014). Mechanical activation also had an effect on the sintering time of the pellets and the reduction of the sintering temperature. The 28- and 56-day lightweight concrete samples showed properties that matched the standards for concrete of normal weight. Finally, the ideal combinations of production parameters and properties of ash pellets were developed that gave the light weight concrete behaviour corresponding to that of standard concrete. The pelletization efficiency increased by up to 98 % with finer fly ash which is obtained through mechanical activation treatment. Light weight concretes with 28-day compressive strengths ranging from 28.87 to 52.64MPa, flexural strengths in 2.62–4.45MPa range, porosity decreasing from 26.25% to 17.55% were successfully produced with cold-bonded and sintered fly ash aggregates. Concretes produced with cold-bonded fly ash aggregate showed relatively low performance due to the existence of the large number of voids in the aggregates.

COMPRESSIVE STRENGTH OF ARTIFICIAL LIGHT WEIGHT AGGREGATES

The compressive strength obtained from researches is listed in table 1. Where the compressive strength obtained by replacing natural aggregates by artificial aggregate with different percentages are also shown in table. From the result it is concluded that fly ash light weight aggregates give more compressive strength than that of silica fume light weight aggregates.

Table 1. Compressive strength result

Replaced natural aggregates with	Compressive strength (MPa)				
	0%	25%	50%	75%	100%
Silica fume Wasserman (R, A. Bentur, 1997)	32.62	29.02	20.95	15.67	11.16
Fly ash (Sathyam D, Srikanth K, Dr. Desai B V, 2017)	40.85	34.80	32.74	31.87	22.93

ARTIFICIAL LIGHT WEIGHT AGGREGATES AS A SUSTAINABLE CONSTRUCTION MATERIAL

The importance of sustainable development in construction sector is increasing every year. To find an alternate material for construction which will match the properties of original material is a challenging one. There are different methods available for the production of artificial aggregates. This paper discussed mainly about sintering technique and cold bonding technique. In addition to protecting the environment from landfill pollution, the recycling of solid waste into artificial aggregates also helps to reduce the depletion of natural resources caused by growing infrastructure, thus contributing to sustainable development. Regarding that many solid wastes, such as coal-fired fly ashes, foundry silica fume and recycled concrete fines, are generated in the form of fine particles, granulation is a desirable method of using these powder wastes and converting them into real worth building materials. The production of artificial aggregates from solid waste is regarded as an eco-friendly process of production. With regard to the sintered aggregate, many advantages were noted. The high mechanical strength, low-bulk density and water absorption and relatively short period of production time. Cold bonding is a prevalent technology with the advantages of being energy saving and easy in terms of operation for aggregate production. The main limitation is that the need for longer hardening time, as the cold bonded aggregate typically has to be cured for 28 days before discharging and used as building materials. Lightweight concretes with advanced properties matched to those of normal structural concrete were given the suggested production techniques. From an economic point of view, the manufacturing system is sustainable, since it offers an improvement in benefits for industrial sector that uses fly ash as they can transform waste into a resource.

CONCLUSION

In addition to protecting the environment against landfill emissions, artificial aggregates often help to reduce the depletion of natural aggregates caused by growing utilities, thereby contributing to sustainable growth. Sintered aggregates have many advantages were high mechanical performance, low bulk density and water absorption, as well as the good ability to encapsulate most heavy metals. Its high production efficiency has been assured by a relatively short production time, including the sintering process. Cold bonding is one of the less energies consuming and more efficient method. It is necessary to select highly reactive waste or binders for cold-bonded aggregates to produce aggregates of good quality. Thru the addition of binder and alkali activator, which predicted stable aggregate formation as well as improved strength properties after adequate curing, manufacture of fly ash aggregates in the disc pelletizer was found to be

efficient. By increasing the percentage of artificial light weight aggregates in concrete the compressive strength is found to be decreasing, therefore the replacement of ALWA with conventional aggregate is limited up to an optimum value.

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