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Effect of sintering and coldbonding techniques onlightweight aggregates fromindustrial waste – a review.

Effect of sintering and coldbonding techniques onlightweight aggregates fromindustrial waste – a review.

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ABSTRACT

Concrete is a building material which consist major portion of hard inorganic materials called aggregates such as crushed stone aggregate. Due to continuous usage of natural resources within a short length of time these get depleted. Production of concreteby using waste materials from industries is important in this era. The production of light weight aggregate from waste material is done by pellatization and hardened by sintering or cold bonding techniques. Depending upon the hardening methods the properties of concrete is also varied. From previous research works it can be concluded that it is possible to produce structural concrete using sintered fly ash aggregate which are spherical in shape having specific gravity varying from 1.33 to 2.35. According to the literature, the specific gravity of these aggregates was 16 to 46 percent lower than that of standard of weight aggregates, and they might be employed as aggregates in structural concrete production depending on the constituent qualities and the production environment. Cold bonded aggregate concretewith compressive strength 48% lesser compared to normal concrete mix, it exceeds the value of 17 MPa that has been fixed as minimum criteria for concrete to be used as a structural material. This paper mainly focuses on review of artificial light weight aggregate from cold bonding and sintering methods and how these methods affect the concrete properties. From different studies, it is concluded that Cold bonding is an energy saving method and Sintered sludge pellets have a stronger aggregate strength, larger porosity, and lower aggregate density than cold bonded aggregates, exhibiting qualities that are superior to those required of building aggregates. Sustainable development is indeed achievable in this developing era and lightweight aggregate in construction sector is key to achieve this.

Keywords-Sintering, Cold bonding, Pelletization, Artificial lightweight aggregate.

RESUMEN

El hormigón es un material de construcción que consiste en una gran parte de materiales inorgánicos duros llamados agregados, como el agregado de piedra triturada. Debido al uso continuo de los recursos naturales en un corto período de tiempo, estos se agotan. La producción de hormigón mediante el uso de materiales de desecho de las industrias es importante en esta era. La producción de áridos ligeros a partir de material de desecho se realiza mediante granulación y se endurece mediante técnicas de sinterización o unión en frío. Dependiendo de los métodos de endurecimiento, las propiedades del hormigón también varían. De trabajos de investigación previos se puede concluir que es posible producir hormigón estructural utilizando agregados de cenizas volantes sinterizados que son de forma esférica y tienen un peso específico que varía de 1,33 a 2,35. De acuerdo con la literatura, la gravedad específica de estos agregados fue de 16 a 46 por ciento menor que la de los agregados de peso estándar, y podrían emplearse como agregados en la producción de concreto estructural dependiendo de las cualidades de los constituyentes y el entorno de producción. Hormigón agregado adherido en frío con una resistencia a la compresión un 48% menor en comparación con la mezcla de hormigón normal, supera el valor de 17 MPa que se ha fijado como criterio mínimo para que el hormigón se utilice como material estructural. Este artículo se centra principalmente en la revisión de agregados artificiales ligeros de los métodos de unión en frío y sinterización y cómo estos métodos afectan las propiedades del hormigón. A partir de diferentes estudios, se concluye que la unión en frío es un método de ahorro de energía y los gránulos de lodo sinterizado tienen una mayor resistencia de agregado, mayor porosidad y menor densidad de agregado que los agregados de unión en frío, exhibiendo cualidades que son superiores a las requeridas de los agregados de construcción. De hecho, el desarrollo sostenible es alcanzable en esta era en desarrollo y el agregado ligero en el sector de la construcción es clave para lograrlo.

Palabras clave: sinterización, unión en frío, peletización, áridos ligeros artificiales.

INTRODUCTION

Utilization of industrial waste as a construction material is a key towards sustainable development.The availability of raw materials for the construction is facing many problems in the world.Fly ash is a waste product of coal-fired power plants. If it is not properly disposed of, pollute water and soil, disrupting biological cycles. Coarse aggregates from fly ash and other industrial waste materials with cement as binder can be used in concrete for producing artificial light weight aggregate concrete. Artificial Lightweight Aggregates (ALWA) are manufactured from waste materials such as fly ash (FA), blast furnace slag, silica fumes etc. Manufacturing of artificial aggregates using fly ash is done by a process called pelletization. Lightweight aggregate can be produced by nodulizing the fly ash in a pelletizer with a proportionate quantity of water, and further hardened by adopting sintering, cold bonding or autoclaving.Artificial lightweight aggregates can be produced through either a sintering method or cold-bonding method according to the mechanism of agglomeration and hardening of aggregates. Sintering is the suitable procedure for bulk utilization of fly ash. Sintered fly ash lightweight aggregate is a potential material to replace the natural aggregate. These lightweight aggregates can be used for various structural and non-structural applications. Aardelite, Lytag, Pollytag, Fa-Light are some of the commercially available fly ash LWAs around the world. It was found that the presence of these lightweight aggregates in high strength concrete for the production of off shore structures is highly beneficial [8,6]. The utilization of these waste materials in concrete leads to sustainable concrete and reduces environmental pollution.

BACKGROUND INFORMATION

Reuse of industrial sludge as pelletized aggregate for concrete is one of the best methods to produce artificial light weight aggregates which describes the use of sintered sludge pellets as a complete replacement for regular granite aggregates in concrete. The pelletized sludge was fired to a temperature of 11357ºC at which the sintering process occurs, producing a hard-fused basalt-like mass. In comparison with normal granite aggregates, the sintered sludge pellets display a higher aggregate strength, a higher porosity, and a lower aggregate density that manifests attributes better than that required of construction aggregates. Joo-Hwa Tay et.al (2015) conducted a study on industrial sludge as pelletized aggregate for concrete and the concrete casted with the pelletized aggregates achieved a compressive strength of 38.5 N/mm^2 after 28 days and was comparable to the control specimen. The study indicated that the incinerated sludge pellets obtained by firing to a temperature of 1,1357ºC can be used for complete replacement of regular aggregate in concrete. The pellet concrete has a lower unit weight and hence a higher strength-to-weight ratio. The strength of pellets substituted for regular coarse aggregates in concrete exhibited satisfactory performance with regard to their use as a coarse aggregate.

A study on Bond behaviour between lightweight aggregate concrete and normal weight concrete (LWC) was examined and the bond properties of LWC and normal weight concrete (NWC) based on splitting-tension tests and by considering the relevant factors of LWC, such as its strength grade, interfacial agent, use of steel fibers and interface roughness. Seven concrete mixtures were tested, including six LWC mixtures, with compressive strengths between 40 and 60 MPa and a density range between 1600 and 1800 kg/m^2, and a single NWC mixture, with a compressive strength of 60 MPa. Within these mixtures, three interfacial agents, three levels of interface roughness, and a single type of steel fiber were adopted. The study was conducted by Hua Huang et.al (2019) and the overall results indicate that all of the factors mentioned above significantly influence the bond strength between NWC and LWC.

With the addition of binder material, the lightweight aggregate characteristics are greatly altered, which can outcome in good binding properties for the aggregate of fly ash. The manufacture of fly ash aggregate depends on the type and amount of binders in the pelletizer. Gomathi and Sivakumar A,(2015) shown a study on the production of alkali activated fly ash aggregate containing different types of binders such as metakaolin, furnace slag and bentonite. The fly ash aggregates were formed and the properties of several binder materials furnace slag (GGBS), bentonite and metakaolin substituted at 10, 20 and 30% respectively of total binder material for various time duration are considered. From the learning it is determined that," the efficiency and strength of pelletization increases with the addition of binder materials such as bentonite, furnace slag and metakaolin. A maximum compressive strength of 39.97 MPa and a flexural strength of 4.07 MPa were verified for high volume (62%) sintered fly ash aggregate combined concrete mixes subjected to accelerated curing". During pelletization, the addition of alkali activators provides more stable pellet formation in addition to enhanced strength characteristics. An ideal addition of binder (30% slag, 20% bentonite) results in good binding properties as well as strength.

Utilization of waste clay bricks as coarse and fine aggregates is one of the methods for preparation of lightweight aggregate concrete. An experimental study was carried out to evaluate the feasibility of preparing lightweight aggregate concrete with waste clay bricks by testing the properties of prepared lightweight aggregate concrete (Yasong Zhao et.al,2018). The results indicate that the dry densities of all mixtures are about 1700 kg/m^3~1850 kg/m^3, meeting the standard requirement for lightweight aggregate concrete (≤ 1950 kg/m^3), the 28-day compressive strength could reach up to 40 MPa, and corresponding static elasticity modulus is about 26 GPa. Moreover, both freeze-thaw resistance and carbonation resistance of all mixtures could satisfy the service requirements of Chinese standard (JGJ 51), and the chloride migration coefficient varies from 5.0×10-12 m^2/s and 19.0×10-12 m^2/s, corresponding with chloride penetration resistance of concrete from high to low. It has been proved that consuming waste clay bricks by preparing lightweight aggregate concrete with waste clay bricks as coarse and fine aggregates is a promising way and has application potentials.

Joseph and Ramamurthy [8] studied the influence of high volume of fly ash in concrete containing cold bonded fly ash aggregate.Fresh and hardened properties of concrete made by using cold bonded fly ash aggregate and the cement content of 250 and 450 kg/m^3 is used for the preparation of concrete. It is found that the density of concrete reduces with increase of in volume fraction of cold bonded fly ash aggregate. The workability of concrete is found to be controlled by content of cold bonded aggregate. The test results indicate that the strength of the concrete increases with increase cement content. The failure of concrete is found to be controlled by aggregate fracture. It is reported that workability of concrete is influenced by volume fraction of cold bonded fly ash aggregate. The failure of concrete is explained by the failure of mortar phase or aggregate phase. The test results indicated that cement content in concrete influences the failure of mortar phase. The strength of concrete decreases with increase in volume fraction of cold bonded aggregate. The moisture movement from aggregate to the paste in the matrix is evaluated at different ages.

PELLETIZATION

The pelletization process is used to manufacture lightweight coarse aggregate. Some of the parameters needed to be considered for the efficiency of pellet production are speed of revolution of pelletizer disc, moisture content, angle of pelletizer disc and duration of pelletization. Different types of pelletizer machines used to make the pellets are 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.

The formation of pelletization involves the wet mixing of raw materials, due to the rotary motion the wetted fly ashparticles forms a small seed, with the increase induration, the size of aggregate increases due to agglomeration, and the pellets grow into larger size due to gain in mass and aredischargefrom the rotating disc.

The selection ofmoisture content was moreimportant for the formation of pellet (Bijen, 1986). Howeveradditional moisture content and prolonged pelletization duration beyond optimum valueresults in the undesirable formation of bigger size balls.

COLD BONDING AND SINTERING

The method of manufacture of artificial lightweight aggregate can be divided intosintering and cold-bonding. The chemical composition of raw materials is subjected to precise conditions in order to make sintered lightweight aggregates. The pellets must sinter at a high temperature of 1100 to 1200°C to allow gases to escape from the raw materials and the gases were kept inside the sintered pellets until they cooled. The pellets were subsequently transformed into a lightweight aggregate with porous features. Huang (2013) used the granite waste sludge as raw materials and successfully produced the lightweight aggregate by high temperature sintering process. Sintering method has to demand higher energy. Cold-bonded lightweight is a porous spherical particle made from the powdery materials and binder materials.The method of production of cold bonded aggregate is simple and energy saving. Many scholars show that the using Pozzolanic materials successfully produce lightweight aggregates by cold-bonded technology. The aggregates were permitted to be cured for 1, 3 and 7 days in the cold bonding process to achieve green strength. The method of cold bonding allows the pelletized aggregates to be treated at an ambient temperature or be stored with steam in an enfolded space. Curing until its strengths are appropriate for concrete. This technique requires medium technical ability with least energy consumption.

Compared to cold bonded aggregates the mechanical properties of sintered aggregates were found to be higher and a maximumcrushing strength of 20.62 MPa was obtained.Cold bonded aggregates cured in hot air oven showed improvedmechanical performance due to effective polymerization processoccurring in hot environment which accelerate the earlyhardening of aggregates.Compressive properties of concrete were affected with theincrease in volume of aggregates as well as the type of aggregateused in concrete. Compared to cold-bonded aggregates, the sintered fly ash aggregate exhibited the highest compressive strength [Gomathi and Sivakumar A, 2015].

Fig.1 showsthe compressive strength properties of different types of fly ashbentoniteaggregate concrete at maximum volume fraction of flyash aggregates. Test results signified that the maximum substitution (62%) of sintered aggregates showed animprovement in strength compared to cold bonded aggregates.However, a highest compressive strength up to 39.97 MPawas obtained for sintered fly ash aggregate subjected to hot water curing. Most notably, strength gain of steam cured concrete specimens was comparativelyhigher than hot water cured concrete mixes in the case ofcold bonded aggregate substitution. Test results also indicated thatthe compressive strength of concrete increased with the cement content (430.34 kg/m^3).Compressive strength of the flyash aggregate concrete mixes tested depends upon the volume ofcoarse aggregate and type of curing method adopted.

Table 1 shows the compressive strength of cold bonded artificial light weight aggregate concrete. With the increase in percentage of cold bonded light weight aggregate in concrete there is decrease in strength of concrete.

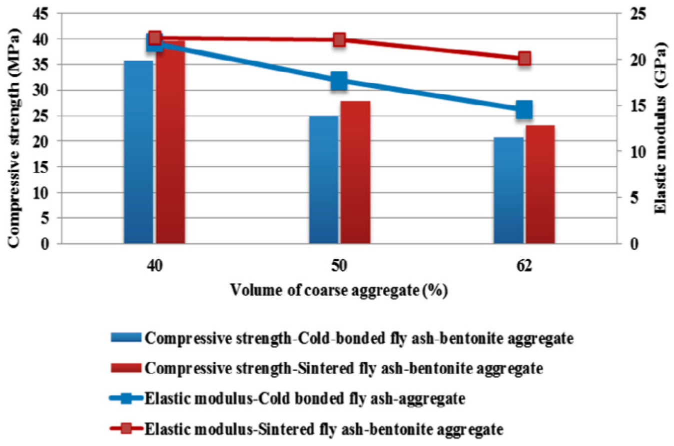

Fig. 1. Compressive strength and elastic modulus of various types of aggregatesubjected to steam curing. [Source: Gomathi and Sivakumar A, 2015]

Table 1. Compressive strength result of Cold bonded aggregate concrete. [12. Sathyam Det.al, 2017]

Cold-bonded light weight aggregate concrete	Compressive strength (MPa) (Replacing natural aggregate with artificial light weigh aggregate)				
	0%	25%	50%	75%	100%
	41.95	35.85	33.65	32.65	24.20

As conclusion, it is concluded that the artificial light weight aggregate pellets can be effectively produceddepending onthe type of binder added as well as the duration of pelletization. Compressive strength properties of concrete were affected with theincrease in volume of aggregates as well as the type of aggregateused in concrete. Compared to cold-bonded aggregates, the sintered fly ash aggregate exhibited the highest compressive strength. The optimum time of pelletization and moisture content can result in higher pelletization efficiency and economical production. Compared to cold bonded aggregates the mechanical propertiesof sintered aggregates were found to be higher and a maximumcrushing strength of 20.62 MPa was obtained.Reduction in concrete strength properties were reported forhigher substitution of fly ash aggregates.Concrete with density 2150 kg/m^3 can be achieved using fly ash aggregates whiledensity of normal concrete mix goes up to 2580 kg/m^3.Though compressive strength of Fly ash aggregate concrete is 48% lesser compared to normalconcrete mix, it exceeds the value of 17 MPa that has been fixed as minimum criteria for concrete to be used as a structural material.

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