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Pelletized Aggregate for Concrete: Review

[1*]Ajai Adarsan K., [2]Tarun Prakash S, [3]Sri Raksha M S, [4]Ramadevi K

[1,2,3] Undergraduate Students, Department of Civil Engineering
[4] Professor, Department of Civil Engineering
Kumaraguru College of Technology, Coimbatore – 641 049, Tamil Nadu, India
[1*]Corresponding author E-mail d: *ajaiadarsan@gmail.com*
[1*]ORCID id: 0009-0006-3797-7845

ABSTRACT :

In conventional concrete, the weight of concrete is one of the parameters for comparison with the weight of fly ash aggregate concrete. Normally, the density of concrete ranges from 2200–2600 kg/m3. This self-weight will make the process uneconomical to some extent. To produce concrete of the desired density to suit the required application, the self-weight of the components is reduced. Hence, lightweight concrete may serve as a solution to this problem. The use of fly ash has been the subject of numerous studies in the past. The primary focus was on substituting fly ash for cement in concrete; nevertheless, the manufacture of fly ash artificial aggregates facilitates the utilization of a substantial amount of ash in the mixture. Recently, the world has become much more connected because of the widespread use of these materials, which has significantly decreased environmental pollution. The production process of lightweight aggregates employing a pelletizer and cold-bonded curing is the primary topic of this article. Fly ash is utilized in the pelletization process to create an artificial lightweight coarse aggregate. Pelletization is dependent on several process-related factors, including particle size and distribution, wettability, and moisture content. Cold-bonded fly ash products can be utilized to replace aggregates in concrete according to a study that compared the qualities of these aggregates with those of natural gravel. The addition of fly ash aggregates to concrete lowers its compressive strength while maintaining the required durability for use as a structural material, according to research performed on both concrete made with manufactured fly ash rocks and natural gravel.

Keywords: Compressive strength, Pelletization, Fly ash, Cold bond, Artificial aggregate

1. INTRODUCTION :

One of the key indicators of a nation's economic health is thought to be the building sector. Since cement is the primary and most commonly used material within the field of civil engineering, it is reasonable to say that the manufacture of concrete is one of the key contributors to resource consumption and environmental damage. Therefore, to reduce the quantity of cement used and the enormous amount of CO_2 emissions associated with cement production, special attention was given to the incorporation of various byproducts and waste products, such as fly ash, powdered blast furnace slag, and silica fume, as cement substitutes. India's electricity requirements are expanding, and thermal power plants provide 70% of the country's electricity [1]. These facilities pose a threat to the environment because of their particle emissions, water pollution, and lack of land for fly ash disposal. Additionally, the high ash content of Indian coal, due to its poor quality, exacerbates disposal issues. An estimated 154 million tons of fly ash were produced in 2013–2014. Fly ash is now frequently used as a cement substitute, pavement base, or block rather than being dumped in landfills. Applications such as slope fill or aggregate substitute material should be taken into consideration when using fly ash in large quantities. However, as aggregates account for between 70 and 80% of the volume of concrete, there has been much interest in researching the use of artificial aggregates made from scrap and byproduct materials as a substitute for natural aggregates. The protection of natural resources, the reduction in energy used in quarry operations, and the transformation of waste into products with additional value are only a few of the numerous beneficial environmental effects of this movement. The process of exploiting waste and byproduct fine components to produce cold-bonded aggregates (CBAs) begins with agglomeration [4]. This is the process of using stress or non-pressure agglomeration methods to upgrade fines into larger particles. The fines are mechanically compressed to take on the required shape using pressure agglomeration. The pelletization process, a popular and well-known technique for non-pressure agglomeration, causes moistened fines to roll in the pelletizer, as shown in **Error! Reference source not found.**, causing them to collide and coalesce into spherical pellets. Because of this, the pelletizer disc needs to be adjusted to a precise angle and speed to prevent centrifugal or gravitational forces from controlling the flow of fines through the pelletizer. Good collision among fine particles is ensured by adjusting the angle and speed of the pelletizer, which increases production efficiency and can result in pelletized (artificial) aggregates such as pellets, as shown in Figure 2.

Figure 1. Fabricated Pelletizer

Figure 2. Pelletized aggregates obtained from the pelletizer

2. LITERATURE STUDIES ON PELLETIZED AGGREGATE:

[1] ***K. Ramamurthy and K.I. Harikrishnan (2006)*** observed that the characteristics of aggregates are influenced by the type and dosage of binder, as demonstrated by characterization studies conducted on powdered fly ash aggregates. The addition of bentonite to the powdered fly ash aggregates notably enhanced the 10% particle size and decreased the water absorption. The addition of 20% sodium bentonite produced the best strength (shown by the 10% fine values) and the lowest water absorption properties. While the binders used had an impact on the microstructure of the aggregates, they did not change the chemical composition of the aggregates, which improved their properties.

[2] ***p. Gomathi, a. Sivakumar (2014)*** reported that mixing fly ash with binders, such as GGBS, increased the pelletization efficiency and produced uniformly shaped, round fly ash balls after 15 minutes of pelletization. It was discovered that fly ash aggregates that included GGBS (30S2-100) performed far better than fly ash bentonite particles in terms of water absorption, efficiency, and crushing strength. The absorption of water was lower (13.01%) in the fly ash-GGBS aggregates and greater (21.26%) in the fly ash aggregates treated with alkali. The metakaolin aggregates were found to have a lower bulk density (848.41 kg/m^3), while the fly ash-GGBS aggregates had the highest density (983.44 kg/m^3). GGBS is a more efficient binder than other binders when used in the pelletization of lightweight aggregates.

[3] ***Priyadharshini. P1, Mohan Ganesh. G (2011)*** reported that, in comparison to angular natural gravel, the rounded shape of fly ash aggregates provides superior workability. This was confirmed by an experimental study on cold-bonded fly ash aggregates. The crushing and impact values are significantly below the permitted limits. Despite having a low abrasion value, the material's high-water absorption percentage prevents it from being used as a roadway material. Fly ash aggregate exhibits a 31.8% lower crushing value and a 26.4% greater impact value than natural aggregate, with both types of aggregates displaying crushing and impact values within the 45% range. However, abrasion is almost equal in both situations. Since fly ash occupies a large amount of space in concrete and is used as a substitute for coarse aggregates, it is evident from its low specific gravity when compared with natural gravel that it is a lightweight aggregate material. As a result, the issue of dumping in landfills has decreased overall. The main drawback of fly ash aggregate is that it absorbs water nine times more than natural gravel, a factor that can be overcome with a variety of available treatment techniques, such as treating with water glass. Fly ash aggregates can be used to create concrete with a density of 2150 kg/m^3, whereas a typical concrete mix has a density

of 2580 kg/m^3. Even though fly ash gathers concrete and has a compressive strength that is 48% lower than that of a typical concrete mix, it still surpasses the minimum requirement of 17 MPa for concrete to be utilized as a building material.

[4] ***P. Gomathi and A. Sivakumar (2014)*** noted that the effectiveness of the agglomeration process and the binder content were found to be directly related to the pelletization efficiency. As more binder of any kind was added, fly ash balls started to form much earlier. After seven minutes, the pellets in the disc began to form, and ten minutes later, they were stable balls. A total of 20% was found to be the ideal amount of bentonite binder by weighing fly ash with alkali activation (10 M NaOH). However, when the alkali fly ash concentration was increased to 12 M, the resulting pellets were cohesive and sticky. Therefore, the bentonite binder with a 25% moisture content and 10 M bentonite produced pellets with the highest possible efficiency. The type of binder added to the fly ash and the activator range affect the pellet production efficiency. The efficiency of the fly ash-GGBS (30G2) binders was greater than that of the other two binders. The addition of 30% GGBS (30G2 for 15 minutes) to fly ash improved the production efficiency.

[5] ***k. Rajendhiran (2019)*** The necessary compressive property of m30 level concrete is achieved by replacing coarse and fine aggregate with m-1 mix (25 percent of fly ash aggregate) and m-3 mix (25% fly ash collects and 40 percent of bottom ash). However, m-2 combines 50% fly ash aggregate as does the m-4 mix (50% fly ash aggregate and 40% BA) resulting in a strength 40% lower than what is needed at the m30 level after 28 days. Flexural strength property: At 28 days, the strength of the m-1 and m-3 mix is approximately 13% less than that of regular concrete, but it still meets the required value for the m30 grade. No mixture exhibited cracks, similar to those of the control concrete. The mixture exhibited good durability when compared to the control mixture (cm). The mean ultimate load of the control beam for the control mix is 63 kN, while that of the m-4 RCC beam is 57.8 kN. When the m-4 beam load-carrying capacity is compared to that of the control beam (CM), the load-carrying capacity decreases by only 8%. The flexural strength improved significantly when fly ash aggregate replacement (50% fly ash aggregate and 40% BA) was used in the concrete. The postcrack behavior of the m-4 mix beam was similar to that of the control beams (RCC beams). It was discovered that the displacement ductility increased for the control concrete beams. When comparing the m-4 mix to the control mix (CM), the ultimate load-carrying capacity and deflection yield favorable results.

[6] ***Mehmet Gesog'lu • Erhan Gu¨neyisi (2012)*** reported that for a pelletizer with an 800 mm diameter and a 350 mm depth, the ideal revolution speed and inclination angle are 42 rpm and 45°, respectively, to achieve the maximum pelletization efficiency. Fly ash-B was used to create the third group of lightweight aggregates, and because of its higher fineness, maximum pelletization was achieved. The pelletization of the slag from the blast furnace produced a significant number of new pellets, which led to the conversion of almost every powdery substance in the disk pan into LWA. When cement is used as a binder in the manufacturing of LWAs, the particular weight of the product increases, and its water absorption decreases. Furthermore, especially for slag aggregates, a higher cement content increases the crushing strength of LWAs. According to the study, class-F fly ash (ASTM C458 fly ash), which lacks any cementitious properties and causes the LMW grains to decompose in water, should not be used to produce cold-bonded lightweight gravel unless Portland cement with similar properties has been added.

[7] ***Dr. M. Vijaya Sekhar Reddy and Dr. M.C. Nataraja (2016)*** demonstrated that when fly ash pellets are used in place of all coarse aggregates, the highest compressive strengths for seven and twenty-eight-day curing periods are 27.73 and 47.45 N/mm^2 respectively. Since fly ash occupies a large amount of space in concrete and is used as a substitute for coarse aggregates, it is evident from its low specific gravity when compared with natural gravel that it is a lightweight aggregate material. As a result, the issue of dumping in landfills has decreased overall. Because fly ash aggregates perform better than natural gravel, they can be considered coarse aggregate substitutes. Additionally, because fly ash acts as a pozzolanic material, it enhances the quality of concrete. The resulting aggregates can be considered for several uses, such as load-bearing structural components, masonry blocks, wall panels, and roof insulation.

[8] ***The specific gravity of the Mr. Abin Joy1, Athul Anilkumar (2021)*** GGBS aggregate was found to be 2. The resultant value for the GGBS material is slightly greater than 1.65, which is the typical particular gravity value of sand from rivers. The average water absorption value for the GGBS aggregate is 4.2%. A value less than 1% is the typical range for fine aggregate water absorption, which is lower than the amount of GGBS generated. For the GGBS aggregate, the bulk density was 1272.66 kg/m3. Fine aggregates typically have bulk densities between 1440 and 1680 kg/m^3, and the amount of small aggregates produced falls within this range. The percentage of voids in the fine aggregates produced by GGBS was 24.69%. The typical range for fine aggregates of voids is 38–43%; however, the number of voids is lower than that of typical fines. The crushing strength of each pellet was 1.13 MPa. Our generated aggregate has a lower crushing strength than typical coarse aggregate, which has a crushing strength of more than 80 MPa. Taken together, these findings indicate that, in most situations, artificial GGBS aggregates made through geo-polymerization cannot be suitable replacements for natural aggregates. Nonetheless, the bulk density and specific gravity values are relatively higher than those of a few other artificial aggregate types that are currently being produced. This suggests that the GGBS aggregates produced can be used for small-scale construction projects in place of typical aggregates.

[9] ***D T Bach, V L Hoang, and N B Nguyen (*****2020)** The research findings led to the following conclusions: the mixture composition that worked best had been FA: C: W= 85: 15: 21 by weight; pelletized fly ash particles were successfully produced. Upon reaching 28 days of age, the fly debris aggregate exhibited a 3.1 MPa breaking strength, 1450 kg/m3 bulk dry specific weight, and 22% water absorption. At 28 days, the environmentally friendly concrete with fly ash particles had a density of approximately 2000 kg/m^3 and a compressive strength ranging from 17.5 to 46.3 MPa. To create ACOTEC wall panels that meet the TCVN 11524:2016 requirements, the aggregates could be completely replaced with a mixture of fly ash and bottom ash aggregates.

[10] ***Dickson Ling Chuan Hao,1 Rafiza Abd Razak (2022)*** reported that to reduce the dead load of a structure, lightweight aggregates with a density of less than 2.0 can be used extensively in lightweight concrete. The kind of substance and binder used will primarily determine the specific weight of the lightweight aggregate. Furthermore, compared to regular aggregates, artificially produced lightweight aggregates exhibited reduced water absorption. When geopolymer is utilized in the production of vacuum impregnation or coating, the water absorbed by the lightweight aggregate is enhanced. By applying additional treatments, the characteristics of lightweight aggregate can be further enhanced. For example, microstructures can contain fewer continuous pores and a wider range of internal aggregate holes. Conversely, a key element influencing the compressive strength of concrete is the interfacial zone (ITZ) between the paste and coarse aggregate. Therefore, additional research on the chemical bonding mechanism between stones and the concrete matrix is crucial. Additives, such as synthetic fibers, can increase the compressive strength of lightweight aggregate concrete. Lightweight aggregate can be used to achieve higher compressive strength, which is beneficial when building lightweight structural elements that can withstand earthquakes.

[11] ***Fahad K. Alqahtani a, Idrees Zafar (2020)*** characterized processed lightweight aggregates and found that the manufactured aggregates were analogous to natural and commercially available lightweight aggregates. The density and compressive strength of the concrete decreased as the replacement percentage of PLA increased. A constant relationship was observed between the density and compressive strength of the processed lightweight concrete irrespective of the replacement ratio. The decreases in density and compressive strength can be related to the hydrophobic nature of the plastic in the processed lightweight aggregate matrix, which prevents good bonding between the cement and aggregates. The processed lightweight aggregate concrete exhibited an increase in Poisson's ratio compared to that of the reference mixes. An increase of 9–41% was observed when the replacement level was increased from 25 to 50% compared to that of the natural lightweight aggregate concrete. Increasing the replacement content to 100% yielded an increase of 144% in the Poisson's ratio values compared to those of the Lytag aggregate concrete.

[12] ***Haydar Arslan Gokhan Baykal (2006)*** reported that there is a serious need for the recovery and reuse of industrial waste. Agglomeration by the pelletization method can alleviate the problems associated with fly ash. The objective of this study was to evaluate the material properties of manufactured aggregates produced from fly ash and cement mixed by the pelletization method. The engineering properties of the manufactured aggregates were evaluated experimentally. The crushing strength, specific gravity, water absorption, particle size distribution, surface characteristics, and shear strength properties of the manufactured aggregates were evaluated. For all practical purposes, the study showed that manufactured aggregates are a good alternative for a wide range of civil engineering applications.

[13] ***Gokhan Baykal and Ata Gu¨rhan Doven (2000)*** observed that the addition of mineral additives increases the crushing value of artificial pellet by 12 to 200% during the 7-day curing period and by 175 to 319% during the 28-day curing period. The cement addition provides a greater increase in the first 14 days of the curing period, whereas the lime addition provides greater strength due to the increase in strength in the long term. The efficiency of the pelletization process depends on the physical properties of the agglomerated material, the mechanical parameters, and the moisture content of the fines. The physical properties of the fly ash, cement, and lime used in the study were within the range of the physical properties of similar materials used in the pelletization process, as stated in the literature. The grain size distribution and surface texture of the material influence the efficiency of the pelletization process, and possessing a wider range results in higher engineering performance of the final product. The main mechanical parameters of the pelletization process were the operation tilt angle and disc speed, which were 43° and 45 rpm, respectively. Examining Fig. 8, it may be concluded that the values determined for these parameters are within the scope of pelletization theory. However, the ratio of the applied disc speed to the critical revolution speed is 0.82 (ncritical= 55 rpm), whereas the advised ratio is 0.75.

[14] ***Alberto Ferraro a, Vilma Ducman (2023)*** investigated the performance of a cold-bonding pelletization process for the production of lightweight aggregates (LWAs) from municipal solid waste incineration (MSWI) fly ash (FA) by including multiple waste materials in the aggregate mixture. Before pelletization, FA was pretreated by washing with water, which led to a decrease in the chloride (66.79%) and sulfate (25.30%) contents. This was further confirmed by XRF and XRD analyses, which showed a decrease in chloride content and the content of chlorine crystalline phases. The pelletization process was carried out using both single- and double-step methods. For single-step pelletization, all the mixtures contained 80% FA combined with various compositions of cement (5, 10, and 15%) and granulated blast furnace slag (GBFS) (5, 10, and 15%). For the double-step pelletization, 30% cement and 70% marble sludge (MS) were added to each of the previous mixtures. The apparent density of all the aggregates varied between 1.60 and 1.87 g cm^{-3}, suggesting that these aggregates are suitable for classification as LWAs. Aggregates produced from double-step pelletization showed improved characteristics, with water absorption capacity and open porosity generally lower than those of the corresponding aggregates from single-step pelletization. The best compressive (crushing) strength (approximately 11 MPa) was observed for the double-step pelletization aggregates with an initial cement: GBFS mixture of 15%:5%.

[15] ***P. Tang a and M.V.A. Florea (2017)*** observed that municipal solid waste incineration (MSWI) bottom ash fine particles (0.2 mm, BAF) are potential building materials, but their possible environmental risk and poor physical properties hinder their application scale. In this study, the coldbonded pelletizing technique was applied to produce artificial lightweight aggregates using BAF and other industrial waste powders as a way of recycling BAF. The properties of the produced aggregates were determined and compared with those of other artificial aggregates. Moreover, the growth mechanism of the pellets with BAF and the effect of BAF on pellet strength were investigated. The leaching properties of these aggregates were evaluated according to environmental legislation. In addition, this aggregate is used as a natural aggregate replacement in concrete to investigate its influence on concrete properties.

Table No. 1 Mix proportions of the LWAC ingredients studied in various studies

Author	concrete type	w/c ratio	Cement content	Fine aggregate content		Lightweight aggregate content	Admixture (SP)
				natural	crushed		
K. Ramamurthy, K.I. Harikrishnan (2006)	LWCC	0.39	405	851		510.6	0.46
K. Rajendhiran	LWCC	0.45	333	754	967.5	232.2	0.35
Mehmet Gesoglu erhan Guneyisi	LWCC	0.5	400	560.7	239.5	649.5	0.5
Priyadharshini Mohan, Santhi (2011)	LWCC	0.31	311	737	-	1293	0.4
D. M. V. Reddy, Dr. M. C. Natarajan	LWCC	0.35	350	896	-	745	0.05

Table No. 2 Mechanical properties of LWAC materials from various studies

Authors	concrete type	compressive strength (MPA)	split tensile strength	modulus of elasticity
Niyazi and Turan (2011)	LWCC	42.3	3.7	19.6
K. Rajendhiran	LWCC	38.13	6.06	Nil
Mehmet Gesoglu Erhan Guneyisi	LWCC	41	3.26	25.1
Priyadharshini Mohan, Santhi (2011)	LWCC	21.8	Nil	7.38

3. Conclusion:

A review of the literature on lightweight aggregates and pelletizer aggregates has been conducted. Pellets and cold bonding have been used to create fly ash aggregates. The resulting aggregate properties were compared to those of natural gravel, and the results were comparable. The use of fly ash particles can be thought of as a substitute for coarse aggregates because they exhibit a performance that is comparable to that of natural gravel and because natural resources are running low. Additionally, because fly ash is a pozzolanic material, it enhances the quality of concrete. The resulting aggregates can be considered for several uses, such as load-bearing structural components, masonry blocks, wall panels, and roof insulation.

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