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ARTIFICIAL LIGHTWEIGHT AGGREGATE PRODUCTION USING RICE HUSK ASH

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ABSTRACT

The demand of construction materials is increasing nowadays due to the rapid growth of construction industry all over the world. Specially, the aggregates which are incorporated in concrete is collected from natural resources. But, it is known that natural resources are limited. Continuous collection indicate the depletion of these natural resources which would be threat for all lives on the earth. On the other hand, disposal of waste from industry is now major issue in case of sustainable development. To reduce the pollution from these industrial waste, recycling is introduced in many countries of the world. The better sustainable system largely depends on recycling and reducing of waste materials which generated from different types of industry. These waste materials can be utilized by using them in production of new materials like lightweight aggregates. The non-accessibility of natural lightweight aggregate and their demand are going up in worldwide, thus new alternatives on producing artificial aggregate should be developed. The world is tremendously inspired by innovative creation of alternative material in development industry as of late utilizing industrial by products, the huge scale use of these modern side-effects lessens ecological contamination and decreasing the scarcity of aggregates. Subsequently there is a requirement for, the generation of artificial aggregates, which meets present necessity of the industrial business. In this research work, lightweight aggregates was manufactured from industrial waste like rice husk ash and a binding material like cement. Cement and rice husk ash were mixed with respect to volume (1:5, 1:4 & 1:3) with water. The determination of unit weight, specific gravity & water absorption of artificial aggregate were carried out. Also, the aggregate crushing value (ACV) test and aggregate abrasion value test were performed. Different types of mixing ratio showed different values of unit weight, specific gravity, aggregate crushing value and aggregate abrasion value. Unit weight of artificial aggregates was calculated which ranges from 464 kg/m^3 to 850.6 kg/m^3 and the value of specific gravity was laid between 0.752 and 0.953. According to mixing ratio of cement and rice husk ash (1:3) showed the best result. Water-solid (w/s) ratio was observed 0.91, where solid represents the total amount of the cement and ash. The unit weight and specific gravity of artificial lightweight aggregate were found 850.6 kg/m^3 and 0.953, respectively. Water absorption of artificial aggregate was found 33.27%. Aggregate crushing value showed about 15.05% while aggregate abrasion value was found 37.2%. The artificial aggregate properties were compared to the natural aggregates of stone chips and first class brick chips, by which it was clear that the artificial aggregate which was produced from industrial waste of rice husk ash was lightweight. The compressive strength of concrete incorporated with artificial aggregates (1:3) were found 10.26 MPa and 11.34 MPa for the curing period of 7 days and 28 days, respectively. The compressive strength of Concrete incorporated with natural aggregates like stone chips was measured also in same curing period for reference sample. There are wide applications of artificial lightweight aggregate, for structural use, filling and block concrete, insulation purposes and many more. The concrete incorporating with artificial lightweight aggregate results in produce eco-friendly concrete.

Keywords: *Artificial lightweight aggregate, Rice husk ash, Physical properties, Mechanical properties, Compressive strength.*

1. INTRODUCTION

Concrete is a composite material which is used in various types of construction work (Kwek & Awang, 2018). The amount of natural aggregates which are used for production of concrete is about 8 to 12 million tons annually and aggregates take place about 70% of the total volume of concrete (Dash, Patro, & Rath, 2016). As a result, naturally available aggregates are decreasing sharply (B. Durga & M. Indira, 2016). Many researchers (Lura, Wyrzykowsky, Tang, & Lehmann, 2014) are incorporated with the industrial development in investigation of the maintainable artificial lightweight aggregate production as an alternative to natural aggregates. Researchers have produced artificial lightweight aggregate by using industrial waste like fly ash, palm oil fuel ash, paper sludge, water treatment sludge, wood dust, iron ore dust etc. These industrial wastes have a great negative impact on environment which is increasing in an alarming rate.

These days one of the serious issues that should be a worry is to limit and reusing waste materials from industry. The waste materials from industry can be utilized in manufacturing lightweight aggregates. Due to rapid growth of population in Bangladesh, large amount of rice is required for feeding the people. As a result, auto rice mill industry is growing very fast where rice is produced from paddy. During the production of rice, large quantity of rice husk ash is produced in the mill by incineration process of raw rice husk. According to estimation, currently 700 million tons rice is producing in the world. Approximately, 25 Kg rice husk ash is generated from the burning of 100 Kg rice husk (Singh, 2018). Bangladesh is an agricultural country, as a result rice husk ash is largely available in Bangladesh and consider as a renewable agriculture waste from auto rice mill. Rice husk ash contains large amount of silica than other plant residues. Generally, 78% rice and 20% raw rice husk is produced from paddy plant in the rice mill where remaining 2% consider as a lost product during the process. Combustion process in the boiler results in the production (1/5 to 1/4) of rice husk ash from rice husk (Singh, 2018). Rice husk ash consider as an industrial waste because of having no commercial value. Dispose of this ash create many problems in the surrounding environment because its degradation process takes enough time. Also, ash lead to pollution which may create health problems among the people. Rice husk ash can be used as a soil amendment or a filler. Rice husk ash particles can be absorbed large amount of water due to its porous microstructure. Its weight is very negligible compare to its volume, by which it can be considered as a lightweight. Rice husk ash is so fine that it can be served as a material of partial replacement of cement in the construction industry. Since researchers have conducted the manufacture of artificial aggregates by using different types of industrial waste, hence rice husk ash can also be used in production of artificial aggregates which overcome the shortage of natural aggregates as well as reuse of industrial waste.

Artificial aggregates take place in construction field greatly. In this condition, the present investigation on production of artificial coarse aggregate by using wastes has much significance. The accessibility of raw materials declines significantly which creates many problems in construction field all over the world. Also, deficiency of natural aggregates leads to need of artificial aggregates. The artificial lightweight aggregate has a wide application on construction work (Nor, et al., 2016). As a construction material, the use of artificial lightweight aggregate will provide economic advantages compare to normal aggregates in future (Arioz, et al., 2008).

The main focus of this research is placed on the manufacturing process of artificial lightweight aggregates by using rice husk ash collected from local source. To determine the physical and mechanical properties of artificial lightweight aggregate and compare with the relevant standards.

2. MATERIALS AND METHODS

Artificial lightweight aggregate production was involved basically collection of raw materials, paste of ash and cement, molds of different thickness & different sizes of wire mash for slicing the paste. The size of aggregates are depends on laboratory test, so aggregates were made of two sizes of 1/2" and 3/4". Ordinary Portland cement was mixed with rice husk ash according to volume. Paste was placed in mould of 1’x1’x0.5” and 1’x1’x0.75”. The paste was sliced by wire mashes into small pieces using hand pressure after casting to initial setting time. After hardening, aggregates kept in water chamber for curing.

2.1 Materials

The rice husk, also called rice hull, is the coating on a seed or grain of rice. It is formed from hard materials, including silica and lignin, to protect the seed during the growing season. Each kg of milled white rice results in roughly 0.28 kg of rice husk as a by-product of rice production during milling. Rice husk ash is the remaining by-product after combustion is done. The amount of carbon remaining in ash depends on the combustion performance (i.e., complete or incomplete combustion). Rice husk ash was collected from auto-rice mill industry, then it was sun-dried by spreading it on the floor. For production of artificial aggregate, some binder is needed to bond with rice husk ash and form a hard-solid block. Ordinary Portland cement was used as a binder.

2.2 Mould and Tools

Two wooden frame type moulds were used for artificial aggregate production. The moulds were 1ft x 1ft in size with top and bottom surface open having a depth of 1/2" and 3/4", respectively. Two different sizes of wire meshes having 1/2" square and 3/4" square opening were used for slicing the paste. Wire-mesh generally divided into number of small square blocks.

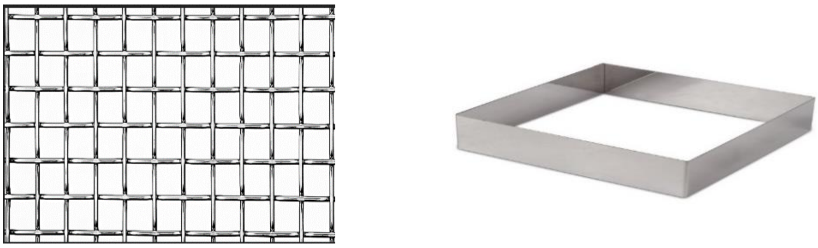

Figure 1: Wire Mesh and Mold

Figure 1 represents the picture of Wire mesh (Each square block of 1/2" & 3/4") and wood mold (1’x1’x1/2” & 1’x1’x3/4”).

2.3 Specimen Preparation

Dry rice husk ash was stirred vigorously to break down any lumps or agglomerates. Then, Cement and rice husk ash were mixed with volume ratios 1:3, 1:4 & 1:5, respectively. After that, water was added the mix to produce a paste. Water & solid (W/S) ratio was 0.91 by mass. Solid was represented by the total mass of rice husk ash and cement. Two moulds were filled with paste and compacted properly to avoid void content. After placement of paste, moulds were kept for some times. Then, mould was removed from surrounding the paste and wire mash was used for slicing the paste before end of initial setting time (45 to 60 minutes). Hand pressure was applied in the wire mash which penetrated into the paste up to the bottom of the mould. As a result, paste was divided into number of small blocks. Then, it was allowed for hardening. After hardening, small blocks were collected and placed in water chamber for curing at 7 days. Then, aggregates were kept in room temperature for one day before performed laboratory test.

3. EXPERIMENTAL PROGRAMS

3.1 Physical Properties of Aggregate

Unit Weight of coarse aggregate was performed according to ASTM C29 test method in laboratory. Specific Gravity and Absorption of coarse aggregate was conducted in the laboratory according to ASTM C127 test method.

3.2 Mechanical Properties of Aggregate

The Los Angeles test was performed according to ASTM C535 to observe the resistance to degradation against abrasion and impact.

BS 812 test method was followed in the laboratory to conduct the Aggregate Crushing Value (ACV) test.

3.3 Concrete Mix Proportion

Design compressive strength of concrete (fc′) at 28 days was 20 Mpa. Ordinary portland cement was used as binder. River sand having fineness modulus of 2.60 was used as the fine aggregate. Mixing ratio of 1/2″ and 3/4″ artificial aggregate was 1:1 in the concrete mix. Water-cement ratio was 0.69. Target slump value of concrete was taken 75-100 mm and concrete mix ratio (by weight) was 1: 1.1: 1.87. All of the aggregates were presoaked in water and made saturated surface dry (SSD) condition before incorporating in the concrete mix.

3.4 Compressive Strength of Concrete

Cylindrical specimens (Diameter 4” & Height 8”) were made to determine the compressive strength of concrete. Concrete was made incorporated with both Artificial aggregate and Natural aggregate (stone chips). For both types of specimen, curing period was 7 days and 28 days. After curing, compressive strength of both type of cylindrical specimen was determined and then comparison of compressive strength of concrete was done. Compressive strength of cylindrical concrete specimens was conducted according to ASTM C39.

Figure 2: Artificial Aggregate and Concrete Incorporated with Artificial Aggregate

Figure 2 shows the artificial aggregates after curing for 7 days in water and cylindrical specimens incorporated with artificial aggregate. Cylindrical specimens were cured for 7 days and 28 days in water to determine the compressive strength of concrete.

4. RESULTS AND DISCUSSIONS

Table 1: Physical Properties of Artificial Aggregate

Properties	1:3	1:4	1:5	**Brick Chips (1^{st} Class)**	**Stone Chips**
Specific Gravity	0.953	0.897	0.752	1.95	2.55
Unit Weight (Kg/m^3)	850.6	630.5	464.0	991.3	1485
Water Absorption (%)	33.27	61.17	91.28	16.79	1.89

Table 1 shows the variation of specific gravity of artificial aggregate. Specific gravity is increasing significantly with mix proportion of increasing of binder and decreasing of rice husk ash. But, finally specific gravity of artificial aggregate (0.953) shows the lower value than the natural aggregate like stone chips (2.55) and brick chips (1.95). According to other research (Kwek & Awang, 2018), lower value of specific gravity compared to natural aggregate can be considered as a lightweight aggregate. Table 1 illustrates the change in unit weight of artificial aggregates which ranges from 464 to 850.6 Kg/m^3. The 1:3 mixing ratio shows the highest (850.6 Kg/m^3) value of unit weight. Overall, the unit weight of artificial aggregate is comparatively lower rather than Brick chips (991.3 Kg/m^3) and natural aggregate of stone chips (1485 Kg/m^3). According to ACI code, there are three (3) types of lightweight aggregte based on unit weight. Among them, lightweight aggregate for insulation purposes should have unit weight less than 1000 Kg/m^3. This experiment values were satisfied these criterion.

Table 1 demonstrates the variation of percentage (%) of water absorption of artificial aggregate with change in mix ratio. Water absorption of coarse aggregate contributed mostly by open and close pore space of aggregate (Nor, et al., 2016). Cellulose structure of artificial aggregates lead to consume more water rather than normal coarse aggregates. According to ASTM C127 and ASTM C128 procedure, the water absorption of structural lightweight aggregate varies from 5% to more than 25% by mass of dry aggregate. The mix ratio of 1:3 shows the 33.27% of water absorption which relatively larger than brick chips (16.79%) and stone chips (1.89%). The deviation of water absorption percentage from standard value was occured due to high proportion of rice husk ash which was turnrd into large amount of void space in the aggregtae.

Table 2: Mechanical Properties of Artificial Aggregate

Properties	1:3	1:4	1:5	**Brick Chips (1st Class)**	**Stone Chips**
Crushing Value (%)	15.05	15.38	17.20	26.81	14.05
Abrasion Value (%)	37.20	43.70	45.80	33.10	16.20

Table 2 shows the variation of crushing value and abrasion value of artificial aggregate. For structural purposes, the recommended Aggregate crushing value (Equal to or not greater than) is 30% and Aggregate abrasion value (Equal to or not grated than) is 50%. Artificial aggregate (1:3) shows the crushing value of 15% and abrasion value of 37% which lies within the recommended limit.

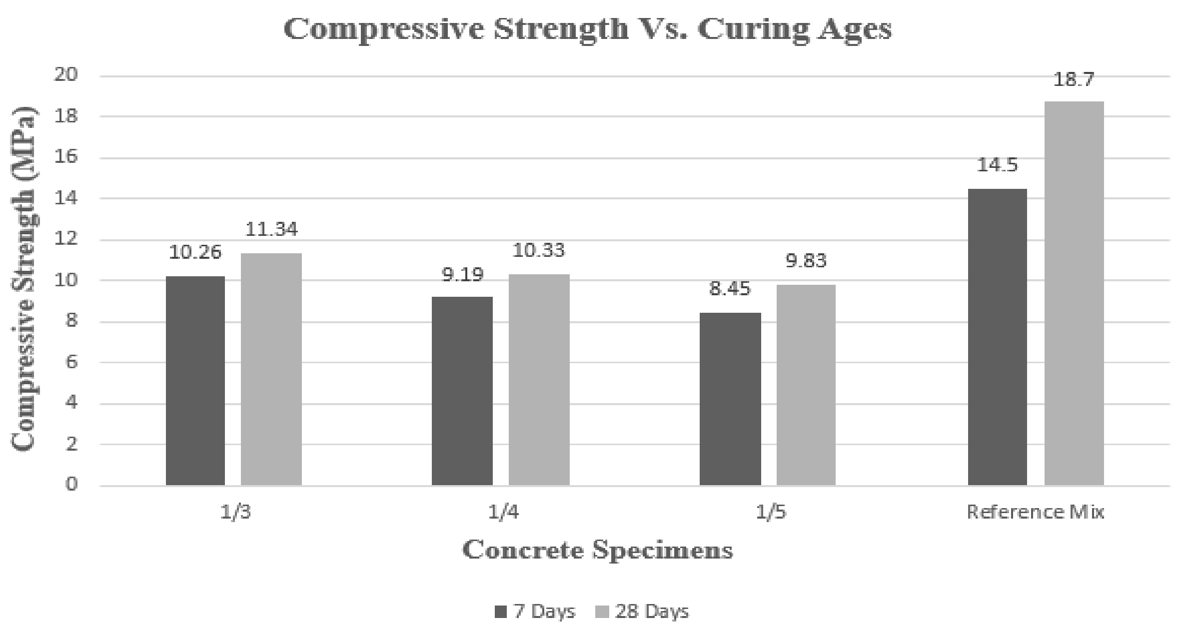

Figure 3: Compressive Strength of Concrete Specimens at Different Curing Periods

Figure 3 represents the compressive strength (MPa) of concrete specimens incorporated with artificial aggregate and reference mix (stone chips) at curing age of 7 days and 28 days. Among three (03) mix ratios, 1:3 shows the highest compressive strength of 10.26 MPa and 11.34 MPa for curing period of 7 days and 28 days, respectively. In case of artificial aggregates compressive strength increased very small amount (about 1.08 MPa) from 7 days to 28 days curing period while compressive strength of reference mix was rose up significantly (above 4 MPa). According to ACI code, lightweight concrete can be used in two (02) purposes based on their compressive strength at 28 days. Compressive strength equal or above 17 MPa can be considered as structural lightweight concrete and compressive strength less than 17 MPa can be considered as a non-structural lightweight concrete.

5. CONCLUSIONS

According to current study and result analysis, artificial lightweight aggregates can be manufactured from rice husk ash. The properties of artificial aggregate obtained compared with normal aggregates. Conclusions about this study can be stated as –

- According to other research study (Kwek & Awang, 2018), lower value of specific gravity of artificial aggregates compared to natural aggregates indicates it can be served as a lightweight coarse aggregate material.
- Water absorption (%) of artificial lightweight aggregate is deviated slightly from ASTM C 127 and ASTM C 128 standard value where recommended value is within 25%.
- ACI code recommends the density of lightweight concrete generally lies between 500 and 1850 Kg/m^3. In this experiment, the density of concrete incorporated with artificial aggregate was obtained 1383 Kg/m^3 which satisfies the practical range stated in the ACI code.
- According to ACI code, if compressive strength of lightweight concrete at 28 days is less than 17 MPa then it can be considered as a non-structural lightweight concrete. Since the compressive strength of experimental lightweight concrete (11.34 MPa) is less than this recommended value so this concrete can be served as a non-structural lightweight concrete.
- Considering low density and compressive strength of concrete based on ACI code, this type of artificial lightweight aggregate can be used in insulation purposes.
- Artificial lightweight aggregate used in construction can reduce the total construction cost which treat as alternate source of natural coarse aggregate.

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