ARTIFICIAL STONE FOR ROADS WITH ENVIRONMENT FRIENDLY APPROACH

Jafor Ahmed Limon*[1], A R M Kamruzzaman[2], Rajiv Ahmed[3], Md Aminul Islam Joynul[4] and Md Ayub Ali[5]

[1] *Assistant Professor, Leading University, Bangladesh, e-mail: jaforlimon@lus.ac.bd*
[2] *Lecturer (Adjunct), Leading University, Bangladesh, e-mail: kamruzzaman021998@gmail.com*
[3] *Student, Leading University, Bangladesh, e-mail: ce_2012069025@lus.ac.bd*
[4] *Student, Leading University, Bangladesh, e-mail: rjjoynul100@gmail.com*
[5] *Student, Leading University, Bangladesh, e-mail: ayubsumon11@gmail.com*

ABSTRACT

In Bangladesh, an extensive number of ceramic constituents transform into wastage from construction locations and production industries particularly during building, shipping and establishing structures due to its breakable characteristics. The potentiality of ceramic waste in artificial stone manufacturing is massive. The use of this application will contribute to environmental protection as well as environmentally sound surroundings by lowering natural stone use and reducing ceramics dumping volume. Artificial stones were created from cement, sand, and tiles, and its source is more sustainable than natural stones. The crushed waste ceramic tiles were used in concrete as a replacement for natural fine aggregates with 0%, 5%, 10% and 15% of substitution under the ratio of 1:1 to manufacture stones. Flakiness Index (FI), Elongation Index (EI), Los Angles Abrasion (LAA) and Aggregate Impact Value (AIV) tests were conducted in order to find out the most effective combination for stone manufacturing process. All physical properties were checked by taking curing periods of 7, 14, 21, and 28 days. Artificial stones created by the research can be used in road construction as all the values of FI, EI, LAA and AIV were much below than the standard value of 30%.

Keywords: *Recycling, ceramic tiles, artificial stone, environment kindly, construction materials*

1. INTRODUCTION

In these industrial conditions, if earth's future environment wants to protect then environmental sustainability must be ensured, especially for constructions materials. For that purpose, users must focus on not only the materials development but also, should try to refrain from using natural items, such as aggregate. Manufacturers can use waste materials and at the same time the waste volume will be reduced. Moreover, using waste on construction as materials will be a high solution for enhancing the balance of environmental resources. Aggregate is very important in the manufacture of concrete since it modifies the qualities and performance of the concrete, ceramic waste has been discovered as an appropriate replacement for both fine and coarse aggregates in the making of concrete (Adekunle, Abimbola, & Familusi, 2017). Crushed stone and sand generated from natural aggregate, made up of crushing bedrock or occurring naturally as unconsolidated sand and gravel, serve as critical components in asphalt and concrete, which are required for the construction of various infrastructure such as streets, highways, railroads, bridges, buildings, sidewalks, sewers, power plants, dams, to name of a few—representing virtually every aspect of the built environment. As the world's leading nonfuel resource, aggregate is unrivaled in terms of both volume and value, with over 20 billion tons produced worldwide in 1998, valued at around 120 billion Euros (Wellmer & Becker-Platen, 2002). Worldwide consumption is predicted to grow at a 4.7% annual rate (Bleischwitz & Bahn-Walkowiak, 2006). The supply of excellent in quality aggregate for building usage has decreased significantly and global aggregate production was 21 billion tons in 2007 and 40 billion tons in 2014 (Peduzzi, 2014). The negative environmental effects of the increased reliance on natural aggregate in construction, particularly the geological implications of coarse aggregate mining, highlight the importance of researching alternative materials that have the potential to replace traditional aggregate application.

Sustainability can be described as addressing current demands while not risking future generations' capacity to meet their own requirements (Le, 2017). The model of inconceivable elongation, unrestrained exploitation of natural resources, and unregulated contamination of the environment is a formula for universal self-harm in a finite world (Odion, 2019). As indicated by the rising unavailability of natural aggregates in towns and cities, the current usage of aggregate is unsustainable. Artificial stone would have a lower environmental effect, boost production, and better utilization of ceramic waste materials. Artificial aggregate saves virgin aggregate, decreases landfill effect, and reduces energy usage, all of which contribute to the sustainability of the aggregate resource.

Following are the objective of experimental study:

➢ To produce artificial stones and compare the properties of stones as Coarse Aggregate with the specifications of RHD and LGED

2. METHODOLOGY

This section illustrates the experimental program and methodology used to evaluate the durability (water absorption) and hardened properties (density and compressive strength) of concrete mixes made with varying percentages of sand, tiles, and a partial substitution of natural sand with tiles materials. The physical qualities of crushed stone produced from cement concrete are also assessed and compared to RHD and LGED standards. Physical testing processes for the basic materials needed to manufacture concrete: cement, natural sand, and tiles waste. Cement, sand, and tiles were used to produce artificial stone. The ratio was considered as 1:1 for cement and (tiles + sand). To make stones, crushed waste ceramic tiles were utilized in concrete as a replacement for natural fine aggregates in the ratios of 0%, 5%, 10%, and 15%.

Figure 1: Created cube

Figure 2: Curing

2.1 Cement Testing

All concrete mixes utilized Seven Rings Cement Limited's Portland Composite Cement of Grade 42.5 (PCC 42.5). The assessment of the cement's physical properties, including fineness, initial and final setting time, followed the procedures specified in ASTM Standard specifications. The fineness of the cement was determined by employing a 90-micron sieve, as per the outlined procedure in BIS 4031(Part 1): 1996. Standard consistency, initial and final setting times were tested using the Vicat apparatus, in accordance with ASTM C191. It is essential that all physical properties of the cement adhere to the requirements specified in BIS 8112:1989.

2.2 Natural Sand

Construction involved utilizing local natural sand, with the assessment of its physical properties following ASTM standard specifications. The evaluation included sieve analysis, specific gravity, water absorption, bulk density, and Maximum Dry Density (MDD). The natural sand underwent sieve using ASTM C33 guidelines to obtain the sieve analysis and calculate the fineness modulus. Additionally, specific gravity, water absorption, bulk density, and MDD were determined using methods outlined in ASTM C128, C29, and D1557, with the specific gravity calculated using the pycnometer method.

2.3 Methodology flow chart

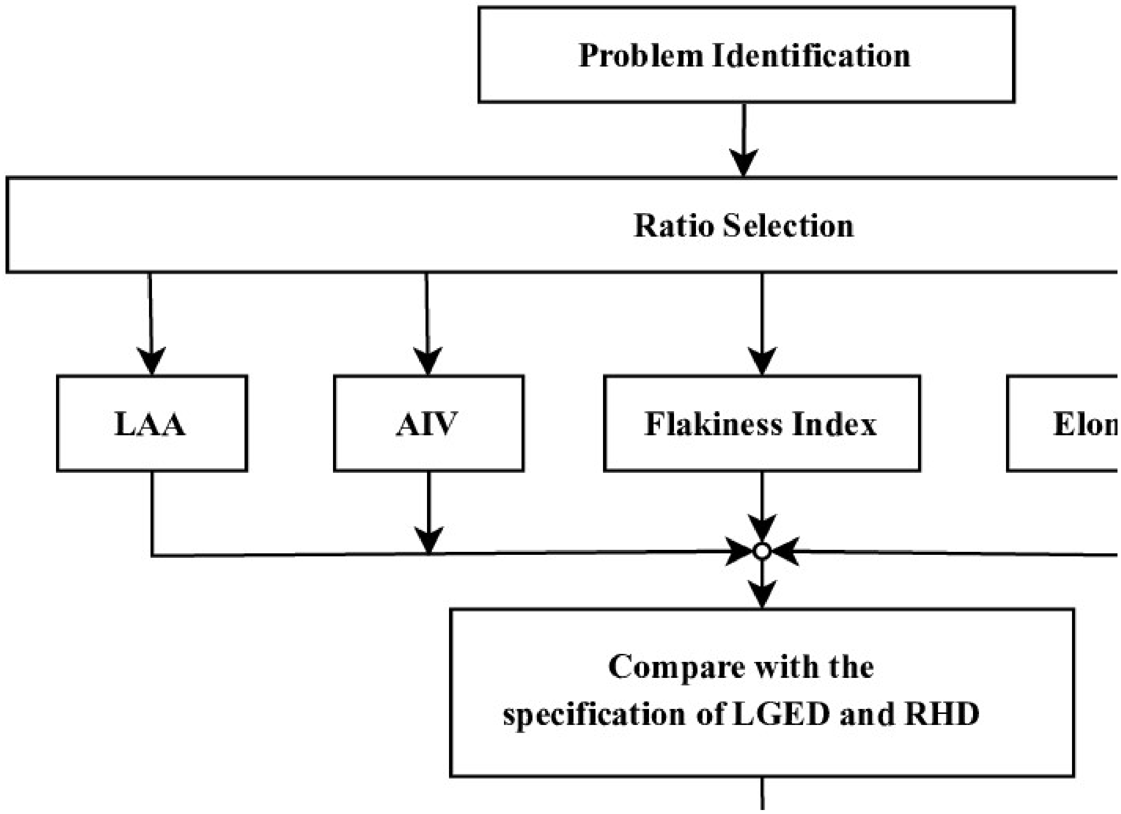

Figure 3: Flow Chart of Experimental Program

3. RESULT AND DISCUSSION

3.1 Physical Properties of Materials (Cement, Sand and Tiles)

The cement fineness test was performed according to ASTM C595. The exam resulted in a score of 92.4. For the initial and final setup times, the ASTM C191 technique was used. Both the initial setting time of 115 minutes and the ultimate setting time of 279 minutes passed ASTM specifications.

The ASTM C136 technique was used to estimate the fineness modulus of sand. The test yielded a score of 1.21. The ASTM C128 technique was used to assess the specific gravity and water absorption of sand. The specific gravity was 2.569 and the water absorption was 3.26. The ASTM D1557 technique was used to estimate maximum dry density. The highest Dry Density value discovered was 1.554. The ASTM C29 technique was used to calculate the bulk unit weight of sand. The bulk unit weight was 1.2 gm/cc.

The fineness modulus of sand (Tiles) was determined using the ASTM C136 procedure. The result of the test was 1.96. The specific gravity and water absorption of sand were determined using the ASTM C128 procedure. Water absorption was 1.13 and specific gravity was 2.825. Maximum Dry Density was determined using the ASTM D1557 procedure. The maximum Dry Density value discovered was 1.667. The bulk unit weight of sand was determined using the ASTM C29 procedure. The bulk unit weight per cubic centimetre was 1.416 gm/cc.

3.2 Flakiness Index

The Flakiness Index is a physical and material technology metric that quantifies the degree of flatness and elongation of elements in an aggregate material. It is reported as a proportion and is calculated by comparing particle characteristics to specific thickness and length requirements (Salih & Sravana, 2013). The Flakiness Index is an important statistic in substance testing, particularly when evaluating aggregate form and particle geometry and it is an important metric of the proportion of flaky or elongated particles in an aggregate sample (Prowell & Weingart, 1999). The Flakiness Index is significant because of its influence on the workability, strength, and durability of concrete (Ponnada, 2014). A higher Flakiness Index shows an increased number of elongated and flat particles, which can have a negative impact on the qualities of concrete, resulting in decreased workability and poorer strength. This dimension is especially relevant in the development of roads because aggregate type has a considerable impact on the mechanical properties of asphalt mixes.

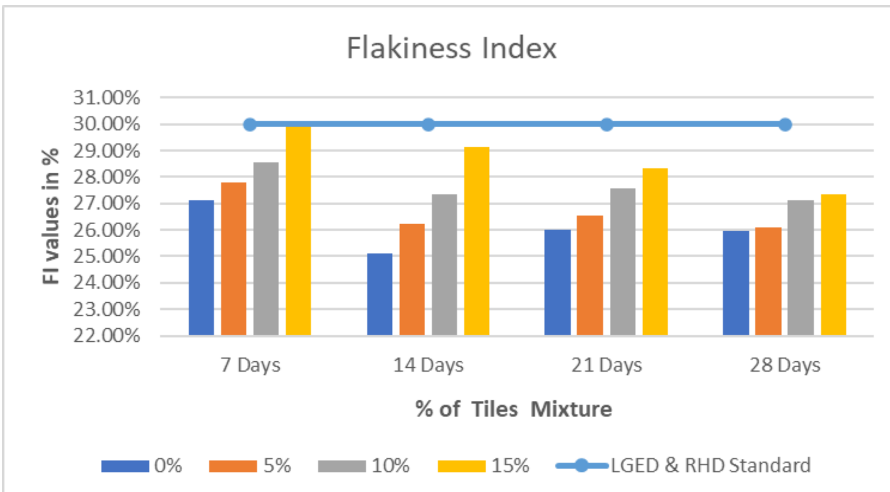

Figure 4: Flakiness Index

It is undesirable to utilize flaky particles in road building, particularly in the surface course, this is because when a load acts along the flaky flat particles' thin axis (the axis of least moment of inertia), they are readily fractured down. To avoid this scenario, the particles must be examined for flakiness index values to determine their acceptability for road building. This is why the test was performed. At 28 curing days, the FI were 25.94% (for 0% tiles mixture), 26.11% (for 5% tiles mixture), 27.12% (for 10% tiles mixture) and 27.36% (for 15% tiles mixture). Because all experiment data was less than 30% (as LGED and RHD requirement), it is preferable to employ flaky particles in road building, particularly in surface courses.

3.3 Elongation Index

In materials science and technology, "elongation" typically describes a change in the length of a material before it breaks bones or breaks under tension, and it is frequently defined as a percentage of the initial length; Moreover, elongation at break is an important property when assessing the ductility of materials, such as heavy metals or polymer compounds, and is a measure of how much a material can deform before failing (Das, 2006). Materials with greater elongation percentages are often more ductile and less prone to unexpected failure under load (Arasan, Hasiloglu, & Akbulut, 2010).

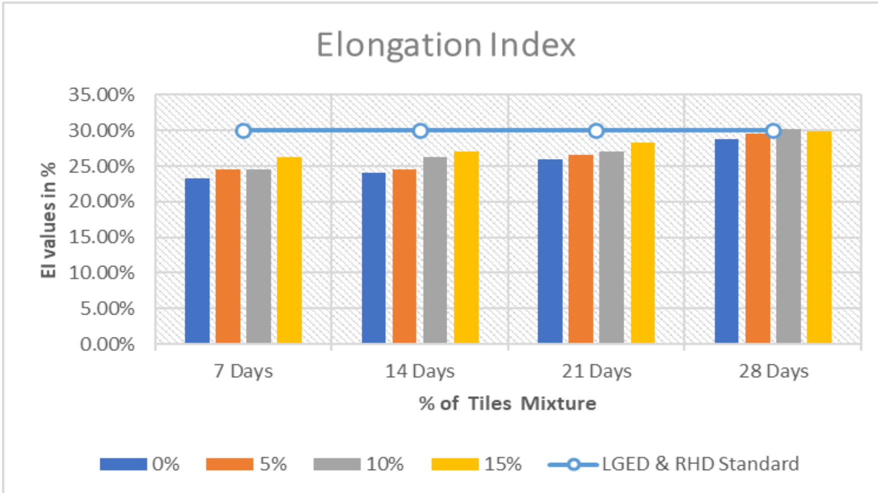

Figure 5: Elongation Index

To eliminate the possibility of these aggregates breaking owing to strong loads applied by vehicular traffic or during compaction, the particles must be examined for their elongation index values to determine their acceptability for use in road projects. Here every experiment data was less than 30% (as LGED and RHD requirement) except 28 days 10% tiles mixture and the value of EI was 30.12%. Rest of 28 days EI values were 28.74%, 29.54% and 29.93% for 0%, 5% and 15% respectively. It is worthy to use elongated particles in construction of roads especially in surface course without 28 days (10% tiles mixture).

3.4 LAA (Los Angeles Abrasion)

The Los Angeles Abrasion (LAA) examination is an established technique to evaluate the abrasion resistance of aggregates, which are commonly used in construction materials such as concrete and the test is internationally accepted and is often referred to as the LAA test or L.A. Abrasion test, and it supports in evaluating the strength and durability of aggregates, which are key factors in pavement formulations (Umar, Egbu, & Saidani, 2020). The LAA test evaluates the durability of aggregates for asphalt and concrete, consequently assisting engineers in selecting impervious materials to ensure the long-term durability and strength of building operations (Ozcelik, 2011).

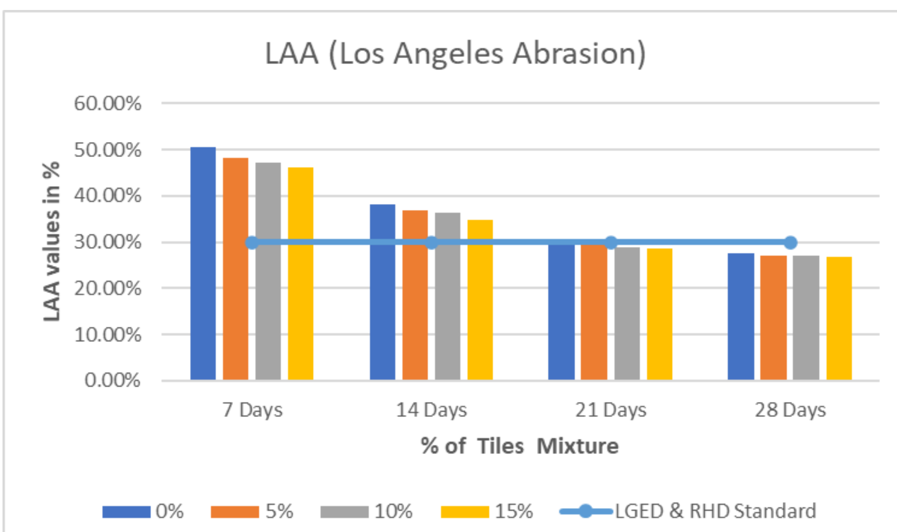

Figure 6: LAA (Los Angeles Abrasion)

For the LAA, it is clearly seen that there was dramatic fall in the findings with the curing days duration. On the 21 and 28 days fulfilled the LGED and RHD requirement (maximum acceptable value 30%). On the flip side, the LAA values for 7 and 14 days was higher than 30%. On 28 days for the 0%, 5%, 10% and 15% tiles mixtures the LAA values were 27.60%, 27.13%, 27% and 26.86% in that order and outcomes were perfectly acceptable.

3.5 AIV (Aggregates Impact Value)

The Aggregates Impact Value (AIV) test includes impacting a sample of coarse aggregate in a cylindrical steel drum in order to emulate the circumstances it may encounter in service, and the percentage of fines generated during the test is calculated; a lower AIV demonstrates better impact resistance (Al-Waked, Bai, Kinuthia, & Davies, 2022). The Aggregates Impact Value (AIV) test is vital to assessing aggregates' appropriateness in road construction, allowing engineers to choose materials that can sustain heavy traffic while also assuring the longevity and safety of road surfaces by anticipating real-world performance over time (Jayawardena, 2008).

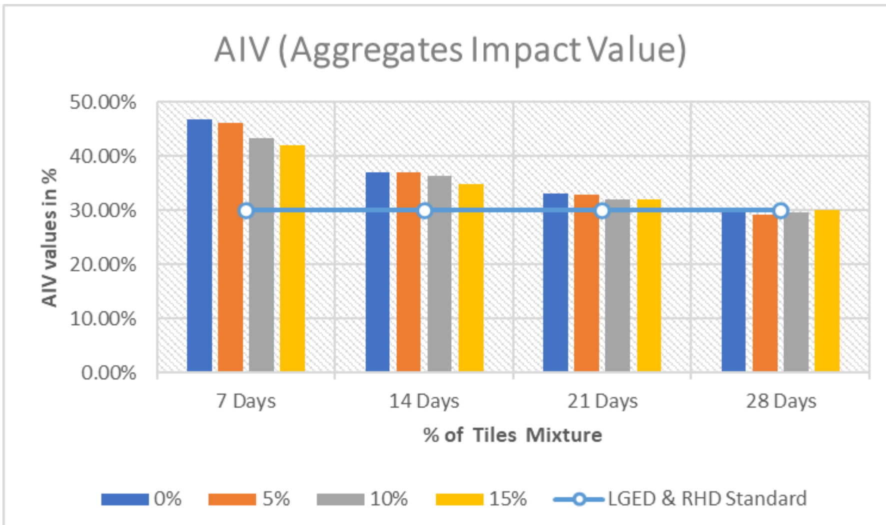

Figure 7: AIV (Aggregates Impact Value)

Although, the values of 7, 14 and 21 days were above from recommended level, but experiment value of 28 days values were satisfied for road surfacing as LGED and RHD requirement. However, the AIV values for all tiles waste mixture steadily decreased with the curing days. Finally, on 28 days samples satisfied requirement level by performing acceptable values. There were 29.70%, 29.30%, 29.60% and 30% AIV values for 0%, 5%, 10% and 15% tiles mixtures in turn.

4. CONCLUSIONS

- The flakiness index for all mixtures perfectly satisfied the rhd and lged specification.
- Artificial stone made from concrete cylinder at 7, 14, 21 and 28 days (curing) shown a better elongation index result, which met the specification for RHD and LGED, exception was only for 10% tiles waste mixture on 28 days curing.
- The AIV value of crushed aggregate from cylinder decreased as the percentage of tiles increased. At 28 days, crushed aggregate made from concrete cylinder was performed better in terms of AIV and also used to fulfill RHD and LGED specifications.
- As the percentage of tiles increased the LAA value of crushed aggregate from cylinder decreased, crushed aggregate created from concrete cylinder and cube performed better in terms of LAA at 28 and 21 days and was also utilized to met RHD and LGED requirements.
- Replacing natural stone with artificial stone could save rock hills from destruction during stone collection as well as stone containing rivers from abrupt digging during stone collection.
- Tiles waste used for artificial stone manufacture (15%), at the same time this methodology has provided sustainable waste management approach and reduced sand amount for construction that could be positive for environment.

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