PERFORMANCE OF CERAMIC TILES WASTE AS A PARTIAL REPLACEMENT OF BRICK AGGREGATE ON MECHANICAL AND DURABILITY PROPERTIES OF CONCRETE

Sumit Basak[1], Md. Abul Kalam Azad[2], Md. Rashedul Haque[*3] and Md. Montasir Rahman[4]

[1] *Undergraduate Student, Hajee Mohammad Danesh Science and Technology University, Dinajpur, e-mail:* sumit.1707349@std.hstu.ac.bd

[2] *Undergraduate Student, Hajee Mohammad Danesh Science and Technology University, Dinajpur, e-mail:* azadaslam27621@gmail.com

[3] *Assistant Professor, Hajee Mohammad Danesh Science and Technology University, Dinajpur, e-mail:* rashed.civil@hstu.ac.bd

[4] *Undergraduate Student, Hajee Mohammad Danesh Science and Technology University, Dinajpur, e-mail:* montasirshourav@gmail.com

***Corresponding Author**

ABSTRACT

Concrete has acquired significant recognition as a prominent construction material due to its low cost, efficiency, and simplicity of usage. However, the availability of natural aggregates such as stone chips is a particularly challenging issue nowadays. Thus, using these wastes in the manufacturing of concrete might be an effective way of protecting the environment and enhancing the quality of concrete. Examining the mechanical strength properties of ceramic tile waste (CTW) concrete, including its compressive strength and splitting tensile strength, and utilizing a water absorption test to assess its durability and performance were the specific objectives of this study. To measure and compare the strength development and durability characteristics of the three concrete mixtures prepared in this study, which replace 25%, 50%, and 75% of coarse aggregate (brick chips) with CTW, one concrete mixture with regular brick chips was served as the control specimen (CC). This research used a mixed proportion of 1:1.5:3 with a water-cement ratio of 0.45. The workability of all the mixes was evaluated through a slump test. To attain early-age strength, a water-reducing superplasticizer was used to minimize the water-cement ratio. For the mechanical and durability tests, a total of sixty (60) concrete cylinders of 100 mm × 200 mm were cast, cured, and tested at 7, and 28 days. Mechanical strength results revealed a significant increase in CTW concrete mixtures up to a certain incorporation of CTW at the place of brick chips, and the water absorption performance improved with the incorporation of CTW in concrete mixes. Significant environmental advantages may also result from using ceramic waste instead of brick chips in concrete.

Keywords: *Ceramic tiles waste, brick chips, superplasticizer, mechanical strength properties, durability strength properties.*

1. INTRODUCTION

Concrete has been broadly accepted as a prominent construction material, mainly because of its availability, affordability, performance, and comfort of working [1]. Concrete is a universally used construction material in all forms of structures. It is estimated that approximately 25 billion tons of concrete are produced each year. This equates to around 3.8 tons per person worldwide every year [2]. Concrete is a combination of cement, fine aggregate, coarse aggregate, and water. Aggregates are considered one of the main constituents of concrete. A huge amount of natural aggregates, sand, and water are being consumed in concrete production. For that reason, the natural resources of aggregates are depleting worldwide in the present day. Hence, it's possible that using substitute materials in place of natural aggregates will be necessary [3]. One of the most serious problems in the world has been removing waste and reusing it. In several studies, researchers employed different waste materials as a replacement for natural aggregates in varying amounts and examined the mechanical and durability aspects of concrete [1]. Therefore, there is a growing concern for protecting the environment and a need to preserve natural resources, such as aggregate, by using alternative materials that are discarded as waste. Construction and demolition (C&D) wastes represent nearly 75% of all waste produced globally [4]. Additionally, around 54% of the waste from construction and demolition is made up of waste from ceramic products [4]. Ceramic items (tiles, electrical insulators, sanitary fittings, etc.) are increasingly being used in building and structural construction, due to the fragile properties of ceramic, which often break during production, shipping, and installation [1].

Ceramic waste, such as wall tiles, floor tiles, sanitary ware, and household ceramics, is probably cost-efficient to use as a replacement for natural aggregates [5]. Based on the global production data, China is the largest ceramic tile producer, producing 46.6% of the overall production, while India comes in third with 6.2% of the worldwide production [4]. In Bangladesh, most of the construction works such as buildings, bridges, and highways are being constructed using a significant amount of local brick aggregates. The utilization of ceramic waste will reduce the use of brick chips in concrete production and will help in the control of hazardous gases such as CO_2, CO, SO_2, NO_2, and others that are emitted from brickfields. Using waste ceramic tiles as a replacement for brick aggregate in concrete production can have several potential implications, including environmental sustainability and cost-effectiveness. The objective of this research is to determine the safe proportion of Ceramic Waste Aggregate (CWA) usage to improve the concrete without compromising its properties and to compare the mechanical properties such as compressive strength and splitting tensile strength between conventional brick aggregate concrete and CWA concrete. Besides these durability properties such as water absorption capacity will also be investigated in this research. Therefore, employing these wastes in concrete manufacturing might be an efficient way to protect the environment while also increasing the quality of concrete.

2. METHODOLOGY

2.1 Materials

2.1.1 Cement

For this research purpose, Ordinary Portland Cement was used. It conforms to the Bangladesh Standard BDS EN 197-1:2003 CEM-I 42.5 N and 52.5 N.

2.1.2 Aggregates

Sand: River sand is used as fine aggregate in concrete. The origin of this sand is the Panchagarh district, and the sand was collected from Dosmile in Dinajpur district.

Brick chips: It’s a coarse aggregate composed of broken bricks. Brick gravel, brick khoa, and brick ballast are various names for it. For this work, generally, 19mm downgrade brick chips are used as coarse aggregate.

Ceramic waste aggregate: In this work, ceramic floor porcelain tiles are used as a Partial replacement for brick chips. Ceramic tiles waste (CTW) has been collected from Parbatipur, Dinajpur. The collected tiles were broken manually into standard aggregate sizes.

2.1.3 Admixture

The main purpose of using admixture is to produce high-workability concrete without loss of strength and high-quality concrete with improved durability. Conplast SP337 was used as a superplasticizer for the better workability of cement, and a reduced water/cement ratio increased density [6].

a. Cement

b. Brick chips

c. Sand

d. Ceramic tile waste

Figure 1: Research Materials and their collection point

Concreting ingredients. Other concreting ingredients such as aggregate, cement, admixture, and water were collected or managed locally. Table 1 shows the properties of aggregates used in this study.

Table 1: Properties of Aggregates

Property	Fine Aggregate (Sand)	Coarse Aggregate (Brick chips)	Ceramic Tile Aggregate
Fineness Modulus	3.16	6.16	6.96
Maximum Aggregate Size (mm)	-	19	19
Unit Weight (kg/m^3)	1704	1130	1399
(%) Voids	35.43	55.12	41.21
Specific Gravity	2.65	1.80	2.39
Water Absorption (%)	1.01	16.04	1.26

2.2 Mix proportions

A total of four mixes were prepared including the control mix. For conducting this work, a mix proportion of 1:1.5:3 (cement, fine aggregate, and coarse aggregate) was adopted. To calculate the exact amount of cement, fine aggregate, coarse aggregate, and water, using the calculation given below with a fixed W/C ratio of 0.45 for all mixes including the control mix. A super-plasticizer admixture of 1% (weight of cement) was used in all mixes to produce high-workability concrete without loss of strength. The mixing proportions of concrete are summarized in Table 2.

Table 2: Mixing proportions of concrete [1:1.5:3]

Mix Name	Percentage of broken ceramic tiles replacement(%)	W/C Ratio	Cement (kg/m^3)	Water (kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (Brick Chips) (kg/m^3)	Ceramic Tiles Aggregate (kg/m^3)
CC	0%	0.45	403	181.35	715.68	949.2	0
CWA-25	25%					711.9	237.3
CWA-50	50%					474.6	474.6
CWA-75	75%					237.3	711.9

2.3 Workability test

This test was frequently used on construction sites across the world as an indirect measure of concrete performance. At the end of each concrete mix, workability was examined according to standard ASTM C143 [7].

2.4 Preparation of Concrete Specimen and Testing

Standard cylindrical concrete specimens (100 mm × 200 mm) were prepared and tested for mechanical properties such as compressive strength by ASTM C39 [8], split tensile strength by ASTM C496 [9], and durability properties.

3. RESULTS AND DISCUSSION

3.1 Workability

The slump value of conventional brick aggregate concrete was found to be 85 mm. After that, when the replacement was started, the slump value increased. Because ceramic tile waste has a smooth surface, that's why particles reduce friction and flow more easily. By replacing brick chips at a rate of 25%, 50%, and 75% with ceramic waste tiles, the slump value increased. Slump value of different mixes is shown in Figure 2.

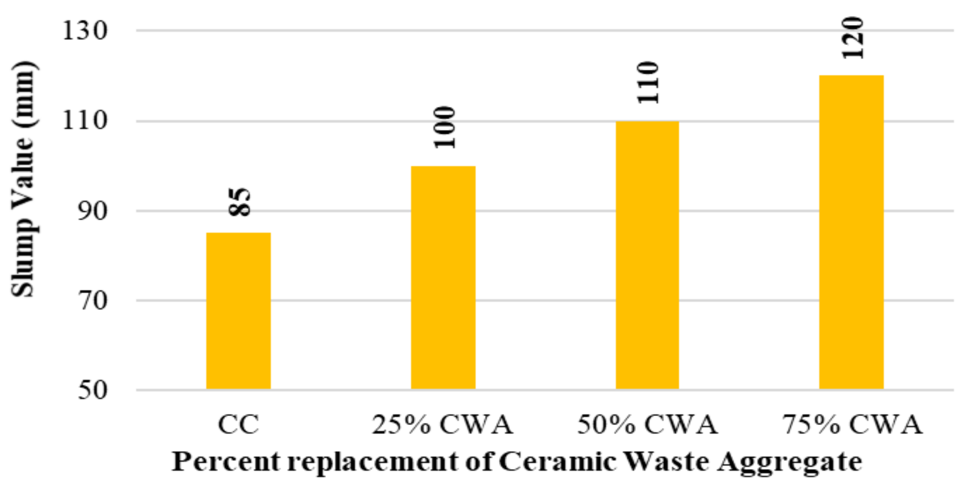

Figure 2: Comparison of slump value of different mixes

3.2 Unit weight of cylindrical concrete specimens

The unit weight of a cylindrical concrete specimen is the weight of the specimen per unit volume. In this work, different types of mix proportions with the calculation of unit weight in different curing periods. Figure 3 shows that after the percent replacement of ceramic waste aggregate is increased the unit weight might be increased because of higher specific gravity and lower presence of voids in ceramic waste aggregate.

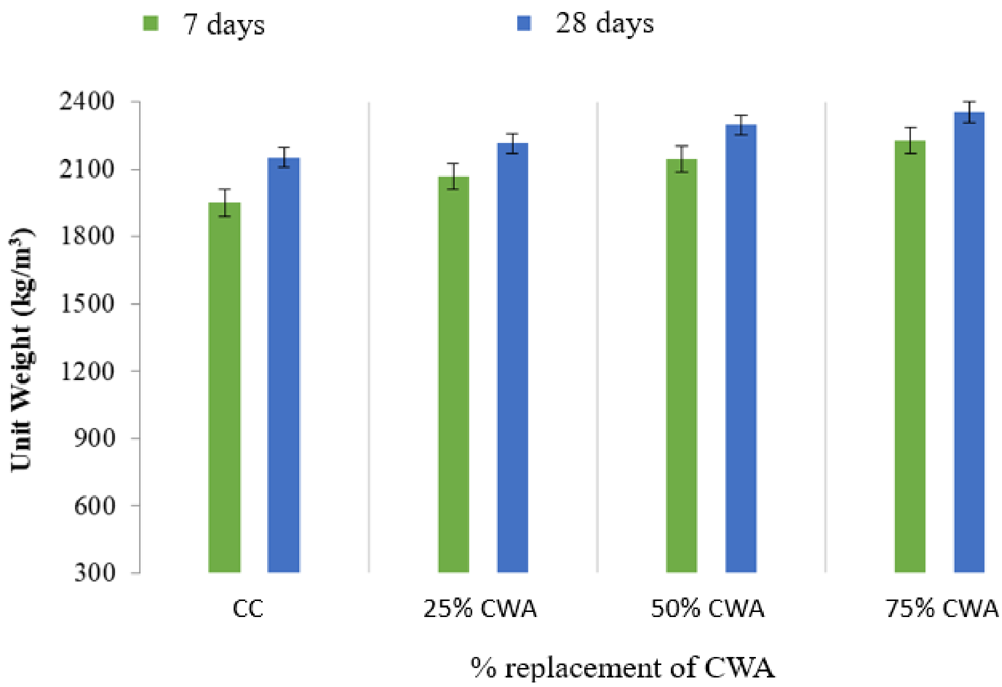

Figure 3: Comparison of Unit weight in both OD and SSD condition

3.3 Mechanical Properties of Cylindrical Concrete Specimens

3.3.1 Compressive strength

The compressive strength of concrete is significant because it influences the load-bearing capacity and longevity of concrete structures. Concrete constructions with higher compressive strengths may withstand greater loads and are less prone to cracking and other types of damage. The compressive strength of the specimen improves with curing age in both conventional brick aggregate concretes and ceramic waste aggregate concretes, as expected. After 7 days of curing, the optimum compressive strength of CWA concrete at 50% replacement is 28.95 MPa, which is 15.62% higher than conventional brick aggregate concrete. After 28 days of curing, the optimum compressive strength of CWA concrete at 50% replacement is 31.78 MPa, which is 16.71% higher than conventional concrete. There is a reason that the CWA has a more uniform composition and better interlocking and bonding in concrete composition which leads to higher compressive strength value. A different pattern of gaining strength of conventional brick aggregate concrete and CWA concrete can be observed in Figure 4.

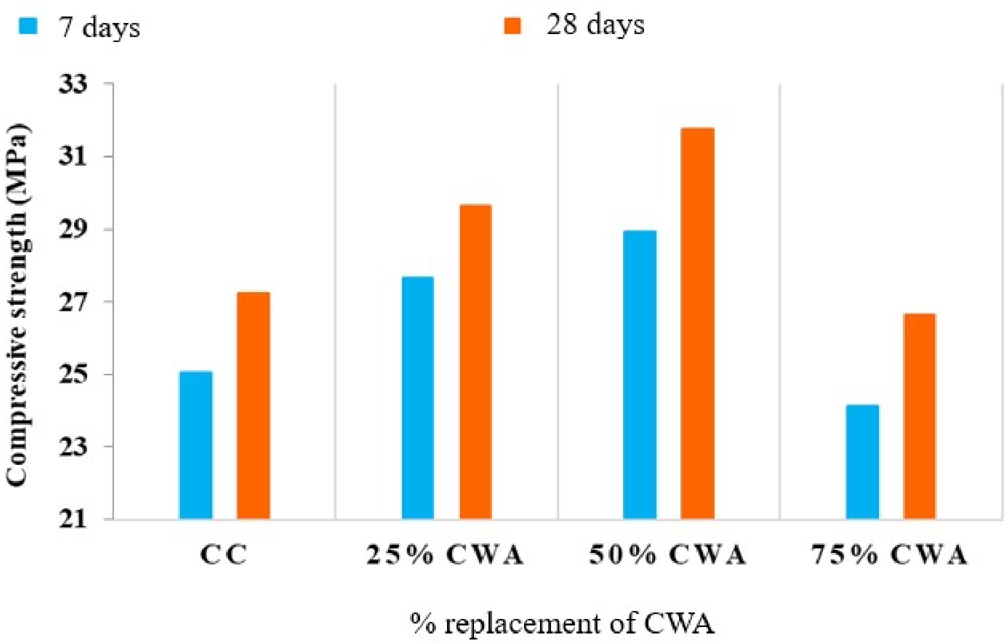

Figure 4: Comparison of 7-day & 28-day compressive strength of CC to CWA concrete

3.3.2 Modulus of Elasticity

The modulus of elasticity of cylindrical concrete specimens, commonly known as Young's modulus, measures the stiffness or resistance to deformation of the concrete. The modulus of elasticity improved a significant amount by using ceramic waste aggregate in concrete. The optimum modulus of elasticity is obtained at 50% replacement which is 8.07% higher than conventional brick aggregate concrete after 28 days of curing. Figure 5 shows the variation of elasticity.

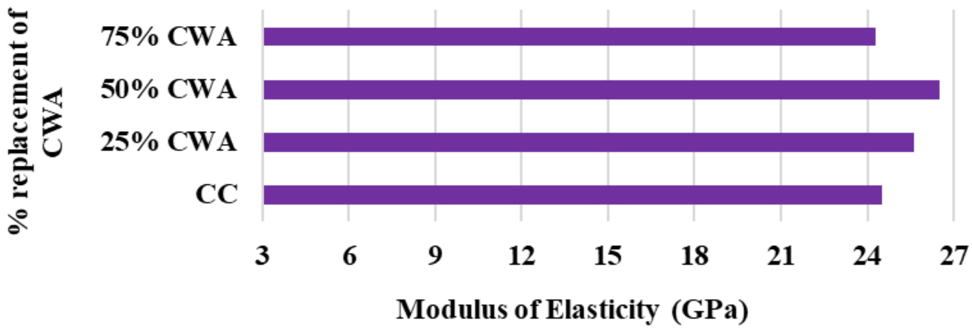

Figure 5: Modulus of elasticity of CC to CWA concrete after 28 days of curing

3.3.3 Split tensile strength

Split tensile strength is a tensile strength measurement of a material, commonly concrete. A compressive load is applied to a cylindrical specimen, causing the cylinder to split along its vertical diameter. In this work using CWA can significantly improve split tensile strength. At 25% replacement, the optimum split tensile strength of CWA concrete is 4.16 MPa, which is 21.28% higher than conventional concrete, and similarly, 4.89 MPa, which is 25.38% higher than conventional concrete, respectively, after 7 and 28 days of curing because of better interlocking and bonding in concrete composition. Figure 6 shows the variation of splitting tensile strength after different curing ages.

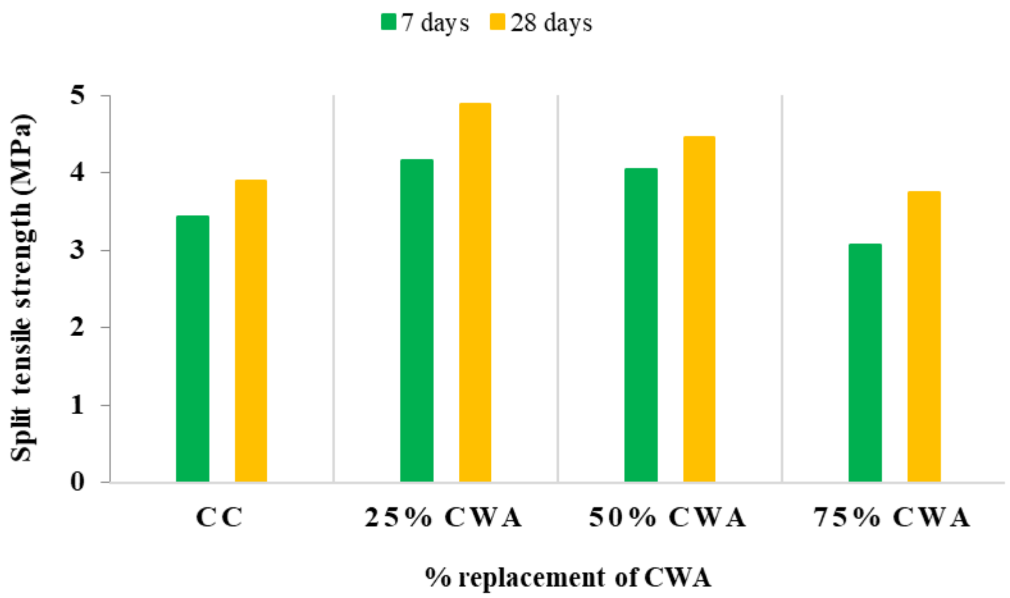

Figure 6: Comparison of split tensile strength of 7-day & 28 days of CC to CWA concrete

3.4 Durability Properties of Cylindrical Concrete Specimens

3.4.1 Water absorption test

The cylindrical concrete specimen water absorption test assesses how much water a concrete sample can absorb. In conventional concrete specimens, the average absorption is 10.70%. But, after the replacement is started, the average absorption decreases by 7.12%, 6.8%, and 6.02%, respectively. Because brick chips have higher water absorption than ceramic tiles waste. Water absorption decreases when increases the CWA, which indicates that the concrete is less porous and denser. The rate of water absorption capacity of cylindrical concrete specimens is shown in Figure 7.

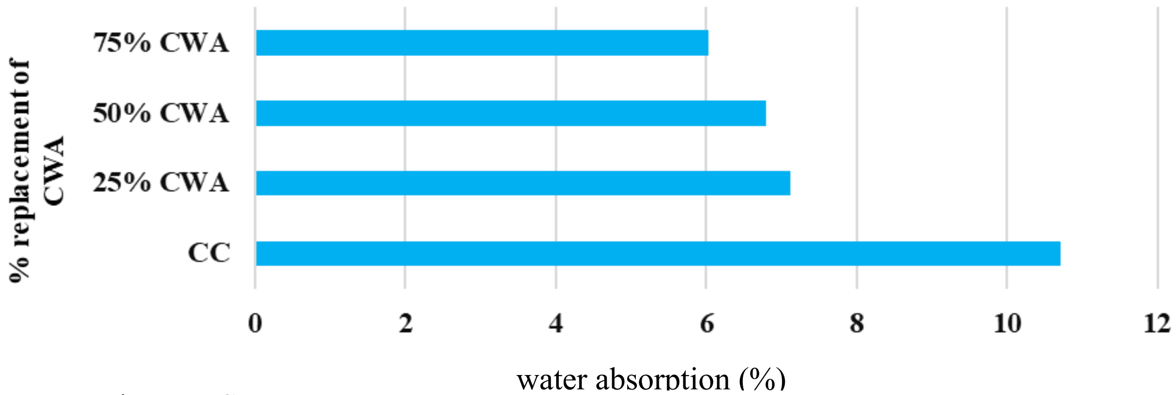

Figure 7: Comparison average (%) of water absorption of brick and CWA concrete

4. CONCLUSIONS

In this study, various percentages of ceramic tile waste (25%, 50%, and 75%) were utilized to make concrete. A destructive test was performed to determine the strength variation. The following outcomes were observed from this study. The slump value varies between conventional brick aggregate concrete and CWA concrete and ranges from 85 to 120 mm. If the amount of ceramic tile waste is increased, the concrete will be more workable. The unit weight of ceramic waste aggregate concrete was high as compared to conventional brick aggregate concrete specimens due to its higher specific gravity and lower presence of voids. After 7 days of curing the optimum compressive strength of CWA concrete is obtained at 50% replacement. The value is 28.95 MPa which is 15.62% higher than conventional brick aggregate concrete and after 28 days of curing the optimum compressive strength of CWA concrete is obtained at 50% replacement. The value is 31.78 MPa which is 16.71% higher than conventional concrete. The optimum modulus of elasticity is obtained at 50% replacement which is 8.07% higher than conventional brick aggregate concrete after 28 days of curing. At 25% replacement, the optimum split tensile strength of CWA concrete is 4.16 MPa, which is 21.28% higher than conventional concrete, and similarly, 4.89 MPa, which is 25.38% higher than conventional concrete, respectively, after 7 and 28 days of curing. The water absorption capacity is decreased if the replacement is increased. It indicates that the CWA concrete is less porous and denser. Above all test findings, 50% ceramic waste aggregate substitution in place of brick chips is recommended to increase concrete strength.

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REFERENCES

[1] Goyal, R. K., Agarwal, V., Gupta, R., Rathore, K., & Somani, P. (2022). Optimum utilization of ceramic tile waste for enhancing concrete properties. *Materials Today: Proceedings*, *49*, 1769-1775.

[2] T.C.S.I.R.C World Business Council for Sustainable Development, "Recycling Concrete" 2009. Accessed: Oct. 14, 2022 [Online] Available: https://www.wbcsd.org/Sector-Projects/Cement-Sustainability-Initiative/Resources/Recycling-Concrete.

[3] Bommisetty, J., Keertan, T. S., Ravitheja, A., & Mahendra, K. (2019). Effect of waste ceramic tiles as a partial replacement of aggregates in concrete. *Materials Today: Proceedings*, *19*, 875-877.

[4] Daniyal, M., & Ahmad, S. (2015). Application of waste ceramic tile aggregates in concrete. International Journal of Innovative Research in Science, Engineering and Technology, 4(12), 12808-12815.

[5] Halicka, A., Ogrodnik, P., & Zegardlo, B. (2013). Using ceramic sanitary ware waste as concrete aggregate. Construction and Building Materials, 48, 295-305.

[6] Prasanna, K. S. A. S. R. K., Anandh, K. S., & Ravishankar, S. (2017). An experimental study on strengthening of concrete mixed with ground granulated blast furnace slag (GGBS). *ARPN J. Eng. Appl. Sci.*, *12*(8), 2439-2444.

[7] ASTM C143/C143M-15, "Standard Test Method for Slump of Hydraulic-Cement Concrete". https://cdn.standards.iteh.ai/samples/91998/d1e4e334a64d483aac76e28aec54d67a/ASTM-C143-C143M-15.pdf

[8] ASTM C39/C39M-18, "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens". https://www.astm.org/c0039_c0039m-18.html

[9] ASTM C496/C496M-17, "Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens". https://www.astm.org/c0496_c0496m-17.html