Investigation on Performance of Recycled Aggregate Concrete Brick: A Review

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Abstract - *Waste management is a vital issue the world is experiencing. Glass waste and e-waste are non-degradable and harmful to the earth at disposal as landfills. Concrete brick is a masonry unit used for various construction purposes. Production of these units involves the emission of CO2 on the extraction of natural resources, which affects the environment. Alternate materials substitute for natural aggregates to maintain a greener environment. This review paper presents the manufacturing process of concrete bricks with the complete replacement of fine aggregate with glass waste and partial replacement of coarse aggregate with e-waste and tests carried out. The main aim is to produce concrete bricks without compromising the strength, durability and comfort, and elegance of materials. Performance study includes the strength characteristics, water absorption, and durability parameters to obtain a cost-effective product.*

***Key Words*: Concrete brick, greener environment, e-waste, durability parameters, masonry unit, glass waste.**

1. INTRODUCTION

Technologies are changing with time as the world is progressing. Development in technologies is enabling businesses to process in various dimensions. India is a rapidly developing country. The development of infrastructure is in danger. As technology advances, so do the forms and techniques of development. IS: 2185 (Part 1): 2005 gives the information about hollow concrete blocks. Having a closed or open cavity these hollow concrete blocks can be used to build load-bearing and non-load-bearing walls. Environmental concerns and health dangers associated with the construction industry have been brought to the attention of both the government and environmental groups. Aggregates, sand, clinker, and fuel in the form of resources are all utilized by the cement and concrete industry. The large portion of waste generated from industries and agricultural works is a result of fuel combustion, slag, bagasse, fly ash, and large-scale manufacture of a range of products. These wastes, which are produced in large quantities, can cause contamination and dispersion of substances such as manganese, mercury, etc, if not disposed of properly, particularly when deposited in dumps, mines, and bodies of water. Their use in concrete production is a prime illustration of parallel recycling and reusing. Growth in the human population and the challenges of globalization cause the scarcity of raw materials needed in the construction industry. The task of converting industrial waste into useful construction material is a challenge to engineers of this generation. A structured recycling program helps people to obtain recycled construction materials [7].

E-waste is the waste generated by abandoned electronic gadgets. It is a growing problem that is producing major environmental issues because it is difficult to dispose of e-waste correctly without harming the environment. The traditional technique for disposing of e-waste is to dump it into a landfill, but this method has numerous drawbacks, including the requirement for a large amount of land, which is scarce in our country, and the presence of numerous dangerous compounds such as lead, cadmium, and beryllium. When these chemicals come into contact with soil, they pollute it, and when they come into contact with groundwater, they contaminate it, making it extremely dangerous to drink. If someone drinks this water, they will experience major health problems, and in some cases, cancer. We generate roughly 15 million metric tons of e-waste in India, and this amount is expected to rise to 30 million metric tons by 2018, with just 3% of the e-waste effectively decomposed and the remainder decomposed by tiny peddlers who are unconcerned about the detrimental impacts of the e-waste. The waste generated by discarded electronic equipment poses a significant disposal challenge. In the concrete industry, efforts have been undertaken to partially substitute coarse aggregates with non-biodegradable components of E-waste. The fineness modulus of coarse aggregate containing varied levels of E-waste ranges from 1.86 to 2.78. The E-plastic waste particles can be used as a partial coarse aggregate replacement while maintaining the same mix ratio. The particle size of the split particles is estimated to be between 1.18mm and 2.36mm [5].

1.1 Literature Review

For the specimens, the researchers just used Portland Pozzolanic Cement (Type IP), which is widely used in the field today. They were manually crushed and sieved after cleaning to achieve particle size consistency. The researchers used a Class-A mix (1:2:4 ratio) of cement, sand, and gravel. Recycled bottles were crushed and used to replace some percent of sand (25%, 50%, 75%, and 100%), and a control combination was also available. On the 7th, 14th, 21st, and 28th days of curing, three specimens were selected from each mixture 6"x12" cylindrical moulds and examined for compressive strength using UTM. Crushed samples were sieved according to ASTM standards to ensure that the cullet size was less than 2.0mm but more than 0.0625mm. The study is more concerned with the impact of using recycled bottles as fine aggregates than with the characteristics of the aggregate [1].

In our research, we found e-waste was partially to replace coarse aggregate. Concrete cubes with varying percent of e-waste (5%, 7.5%, and 12.5%) are cast. The compressive strengths of these cubes are compared to standard grade (M25) concrete cubes. The compressive strength of the cubes increased initially when e-waste is used but decreased subsequently. Concrete's compressive strength dropped to 33.12N/mm2 when 7.5% of e-waste is used, and it begins to deteriorate. The compressive strength is 28.8N/mm2 when 12.5% aggregate is replaced with e-waste. According to the study, replacing coarse aggregate with 7.5% e-waste increases compressive strength by 35% [6]. As a result, using e-waste as a raw material will eliminate the problem of e-waste disposal. Hence less traditional aggregate will be required, the strength of concrete will increase. E-waste is composed of Printed Circuit Boards (PCBs). Electronic waste is procured from local retailers. The aggregate size ranges from 1.18mm to 2.36mm. The metals that were connected to the PCB had to be physically removed [3].

1.2 Classification of Concrete Brick

The hollow concrete blocks are classified into grades:

Grade A – Load-bearing bricks having a block density greater than 1500kg/m^3.

Grade B - Load-bearing bricks with block densities ranging from 1100 to 1500 kg/m^3 [15].

2. MATERIALS AND METHOD

The methodologies used in this study are described in this section. The study includes basic materials such as cement, fine aggregate, coarse aggregate, water.

Material preparation for replacement of glass waste as fine aggregate and e-waste as a coarse aggregate:

Cement: During the mix design process, Portland Pozzolana Cement (53grade) is used. Before use, it was kept in an airtight container [1].

Table - 1: Required values for specified Characteristics

Sl. No	Characteristics	Required Value
1	Fineness	Not less than 300 m^2/kg
2	Setting time	
	a)Initial setting time in minutes	Not less than 30
	b)Final setting time in minutes	Not less than 60
3	Compressive Strength	
	a)3 days	Not less than 16Mpa
	b) 7 days	Not less than 22Mpa
	c) 28 days	Not less than 33Mpa
4	Dry shrinkage %	Not more than 0.15

Fine aggregates: We are using Class A mix, which contains a 1:1:2 ratios of cement, sand, and gravel. Crushed recycled bottles with a 4.57mm nominal size filter were used as fine aggregates in place of sand. According to BS EN 933-1, a sieve analysis test was performed [1].

Coarse aggregate: As coarse aggregate, crushed gravel with a nominal maximum size of 20 mm was employed. The water absorption of the coarse aggregate used in this study was assessed under the SSD (saturated surface dry) condition by immersing them in water for 24 hours and then wiping away excess surface water with a wet cloth after they were removed from the water. The aggregates were deemed to be in the SSD condition when there was no free water on the surface [3].

Water: In the laboratory, tap water that was relatively free of contamination was utilized to hydrate the cement in the combinations[2].

E-waste: Printed Circuit Boards (PCB) are used as e-waste. E-waste is collected from local electronic stores. The aggregate size has been reduced by 20mm. All of the metals attached to the PCB were manually removed [3].

Fly ash: Fine fly ash (pond ash) should be used, which is accessible in thermal power plants. (It is also accessible for free in some sectors.) This item is exempt from any and all taxes. Only the entrepreneur is responsible for transportation costs. This raw material is completely (100%) acceptable for the construction of CLC bricks [15].

2.1 Method of manufacturing a Concrete Brick

Portland cement, sand, and other aggregates are mixed with a moderate quantity of water and blowing mixture into moulds to make concrete blocks. The blocks are taken from the moulds, allowed to set for an initial setting time, and cured in a kiln or autoclave. Usually, the full curing procedure requires less than 24 hours [15].

2.3 Process of manufacturing of Concrete brick

1. The dimensions of the blocks that are commonly used for load-bearing masonry building are (150mm×200mm×400mm).

2. The mix proportion considered for manufacturing this process by specified volume.
3. All the above-mentioned materials (i.e., cement, sand, coarse aggregate and water) are batched by volume and mixed in a concrete mix.
4. In a casting machine, a lean concrete is made and utilized for casting (mould-vibrator assembly).
5. The concrete squeezed in the machinery takes the shape of the mould, which is a block, and it is stacked for one day of sun drying.
6. The blocks are pilled and cured after 24 hours.

Drying and Curing of Concrete Brick

7. The blocks are sundried for 24 hours and cured for 7, 14 and 28 days [15].

3. TESTS TO BE CONDUCTED

1. Compression strength
2. Permeability
3. Chemical test
4. Shrinkage and Creep
5. Carbonation depth

3.1 Compression Strength Test

Bricks are made even by grinding. Then they are immersed in water for 2 hours at 23 degrees C. Mortar is prepared by mixing the cement and sand at the ratio of 1:1. The frog is filled with mortar paste and allowed to set the bricks in jute bags for 24 hours. Flush mortar to voids present on the brick surface. Bricks are taken out from the bag and again immersed in water for 7 days to complete the hardening of mortar on the brick. Bricks should be allowed to dry. The specimen is tested under a compressive testing machine, with a mortar-filled face-up. Bricks are held in position using plywood sheets. The brick is loaded axially at a rate of 14 N/mm² (140 kg/cm²) per minute until it fails.[8]

Compressive Strength =

$$\frac{\textit{Maximum load (N) at which the specimen begins to fail}}{\text{Surface area (mm2)}}$$

3.2 Permeability

A self-made permeable device is used to test the permeability of the concrete. The permeation coefficient of the experiment and along with the factors influencing the permeability of the concrete was obtained and contrasted and examined. Darcy's experiment resulted in the formulation of classic law which mentioned that 'Velocity of flow a water flux q in one dimensional is directly proportional to the hydraulic gradient responsible for flow'.

$Q = qt$ ... (1)

$q = Aki$ ... (2)

$i = \frac{h}{L}$ (3)

Finally, equation (4) is obtained by the above equation: $k = \frac{QL}{hAt}$ (4)

Here, the proportionality constant K = hydraulic conductivity of the porous medium or soil and is recognized as a composite property of both the porous medium (soil) and the flowing liquid (water), A = constant bulk cross-sectional area of the soil column, and

Q = volumetric time (t) rate of water flow perpendicular to A.

h = hydraulic heads and

L = height of the test block.

A = Constant bulk cross-sectional area of the soil column,

h = Hydraulic heads and,

L = Height of test block.

Specimen preparation: With the help of crystal clear water, clean the aggregate 4.75mm-9.5mm (A), 9.5mm-16mm (B), and 16mm-19.5mm (C) then in proportion cementing material has to be added and stirred with a concrete mixer. Three layers of compaction mold i.e., 100mm×100mm×100mm is formed and divided. After molding the sample is shown in figure 1. Test pieces are placed in curing box constant temperature has to be maintained with humidity. The permeability test is performed using the device shown in figure 2. The results are found when hydraulic heads are constant [4].

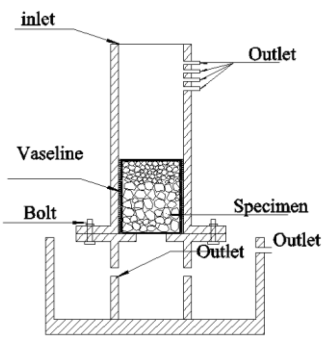

Fig. 1 Permeable Device

3.3 Chemical Test

Concrete is tested for chloride penetrability using a method known as pressure penetration similarly determining the water permeability using a pressure cell.

To avoid leakage care must be taken to ensure an adequate seal around the sides of the cell. Pressure must be applied when a chlorine-containing solution is introduced to one face of the concrete until the concrete sample is removed from the cell and tested for chloride the pressure must be maintained for a while. At a specific time, the depth of the penetration of a known concentration of chloride must be determined under identical conditions this depth can be used to rate different concrete which is tested. A colorimetric technique, which includes spraying of silver nitrate to determine the depth to a known concentration. Using the equation of Valenta, the calculated value is used to measure the water permeability.

$$k = \frac{(n*l*Xd)}{(t*h)}$$

Where, k = hydraulic conductivity,

n = porosity,

l = length of the specimen,

X_d = depth of chloride penetration,

t = time over which pressure was applied and,

h = applied head [11].

3.4 Shrinkage and Creep Test

The term shrinkage refers to a decrease in the volume of concrete caused by the loss of water. The shrinkage coefficient changes with time. The shortening coefficient is:

At 28 days, the probability is 0.00025.

0.00035 - after three months,

0.0005 - after a year.

$$Shrinkage = Length \ x \ Shrinkage \ coefficient$$

Because half of the overall shrinkage occurs within the first 28 days, excessive shrinkage can be avoided by properly curing during this time.

Table – 2: Compressive Strength and Specific Creep

Compressive Strength	Specific Creep
(MPa)	10" per MPa
20	145
30	116
40	80
55	58

Creep is the gradual distortion of a material under continual tension or pressure over a long period. At any given stress, creep deformations for a specific concrete are nearly proportional to the magnitude of the applied stress; high-stress concrete shows less creep than lower strength concrete.

Creep shortenings are computed as follows:

Consider a 3m column that is continuously loaded for a number of years:

f_c' = 30 MPa, Compressive strength

Load-induced sustained stress = 10 MPa

Specific creep for a pressure of 28 MPa

f_c' = 116 x 10^{-6} / MPa

Creep = 10 × 116 x 10^{-6}

= 116 x 10^{-5}

Shortening = 3000 x 116 x 10^{-5} = 3.48 m [15].

3.5 Carbonation Depth

Carbonation profundity test: It is performed to decide the level of carbonation to assess the rate of erosion of steel in the concrete structure.

Procedure:

1. IR Range Examination for Concrete Carbonation: IR range strategy measures the concentration of CO2 retained by the concrete example. This method of testing is not much appealing for the chemical testing of concrete. The IR range strategy set up comprises of a closed circle in which a mixture of discussing and carbon dioxide can be presented at certain relative stickiness. The pump circulates the blend of discussing and CO2. The concentration of CO2 is diminished in the gas blend due to the carbonation response. The concentration of Co2 in gas is measured by utilizing an IR retention gadget. The relative stickiness and temperature are additionally recorded.

2. pH Marker Investigation for Concrete Carbonation:

To locate the region affected by carbonation, a 0.2 percent solution of phenolphthalein chemical is sprayed on the concrete surface. The presence of phenolphthalein in the concrete indicates a change in pH. If the grey colour of the concrete turns pink, it indicates that it is in good condition. When the colour of concrete does not change, the surface has been affected by carbonation.

The carbonation test is carried out by removing in-situ concrete cores. To conduct the carbonation test, drill a hole in the concrete surface to various depths up to the concrete cover. The dust is brushed and blown away to clean the hole. Spray a 0.2 percent phenolphthalein solution over such newly drilled concrete using a physician injection syringe or needle and watch the colour change. At 4 to 8 locations, measure the depth of the uncolored layer (carbonated layer) in millimeters from the external surface. Calculate the average of the values.

The change in colour profile is used to estimate the concrete carbonation depth. The level of carbonation is directly proportional to the square of time, thus after one year if the depth of carbonation is 1 mm, after 9 years it will be 3mm, after 25 years it will be 5mm, and after 100 years the depth of carbonation will go up to 10 mm. pH can be also estimated by examining a sample of core powder acquired by drilling from the site. It is measured by dissolving the powder sample in distilled water and then performing a laboratory titration. The main drawback is the minimal damage to the concrete surface caused by drilling a core [16].

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