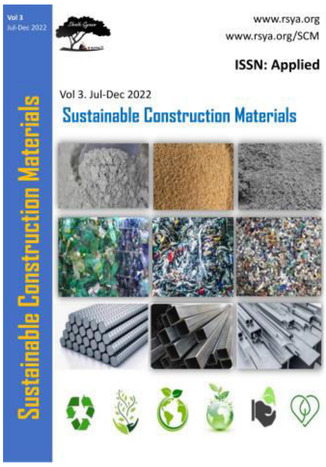

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Manufacturing and Evaluation of Physical Properties Biochar - Clay Bricks

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Abstract. Biodegradable solid waste in the form of waste dumps or as a waste effluent in rivers is a major source of pollution in India creating severe environmental problems. This biodegradable solid waste can be a breeding ground for pests and diseases in waste dumps, could create a large amount of greenhouse gas emission upon burning and may even lead to blockage of the drainage system if discharged along with sewage. One of the solutions to this problem is to use this waste in the form of biochar. The use of biochar as a building material helps in carbon fixing this waste in buildings and can pose as a viable solution for the infrastructure sector, which could be instrumental for protecting the environment to a greater extent and positively influence human life. In the past years, a great deal of research has been done on eco- friendly and green building materials using recycled raw by-products and wastes. This study examined the possibility of making clay bricks from biochar, which was formed using the putrescible waste produced at homes, with partial replacement of clay. Sample of the waste used for the formation of biochar mainly consisted of food wastes or garden wastes and the biochar formed was crushed into powdered form and sieved through a 75 micron sieve. Biochar having considerable plasticity index was used directly without any additives. The bricks were made in increments of 5% biochar concentration up to a total of 20%. The bricks formed using more than 20% biochar concentration were rejected as cracking was observed in the brick samples. The bricks were termed as biochar - clay bricks. 25 biochar - clay bricks for each increment were formed. The biochar - clay bricks were sundried and then fired in a kiln at different temperatures. The quality of bricks was analyzed for compressive strength and dimensional tolerance. The biochar - clay bricks were cured and their corresponding characteristic compressive strength was determined. The bricks with 5% by weight biochar - clay composition and 15 day curing were found to be most suitable.

INTRODUCTION

The sudden burst of population in India has led to a considerable increase in MSW (Municipal Solid Waste) production. According to the World Population Prospects, the population of India has ballooned from 1028 million in 2001 to 1352 million in 2019 [1]. Nearly 62 million tonnes of municipal solid waste are generated in India which is expected to grow to 165 million by 2030. Out of this 62 million tonnes, nearly 46.83 million is biodegradable waste [2]. Organic-natural building materials are a solution for the construction industry that can help to improve environmental protection while also having a good impact on human life [3]. Some studies have explored the use of waste ash as building materials but it has been found to reduce the strength of the matrix. Moreover, combustion of such wastes has been associated with generation of toxic particulates and gas which may cause cytotoxicity and inflammation [4]. This study aims to use inert carbonaceous particles produced by biodegradable waste (food waste, garden trimmings) as carbon sequestering additive to clay bricks. Depending on the type of method used for the formation, biochar has been found to reduce GHG greenhouse gas emissions by 62 - 66 % [5]. Carbon sequestration using MSW biochar, formed in the absence of oxygen, can be an effective alternative to hold stable carbon in form of structures for hundreds of years thereby reducing the total annual emission from MSW. This would in turn reduce the overall open dumping and landfilling requirements of the MSW and add value to the waste generation in general.

AN OVERVIEW OF THE CURRENT STATE OF THE ART IN THE USE OF BIOCHAR IN CLAY BRICKS

There has been a surge in interest in using biochar as a construction material. Zeidabadi et al. [6] investigated the synthesis, characterization, and assessment of biochar made from agricultural waste biomass for application in construction materials and discovered that incorporating agricultural waste biochar into concrete improved the compressive and tensile strengths. When compared to other concrete mixes, the addition of 5% rice husk biochar and 5% bagasse biochar resulted in maximum compressive strength indicating that biochar may be an acceptable choice for the creation of green concrete. Gupta et al. [7] studied the physical properties and economic viability of Biochar – mortar composite and noted that compressive strength is improved by the addition of 1-2% biochar. Compressive strength decreases upon increase of biochar up to 5%. Gupta and Kua [8] investigated the effect of adding pre-soaked biochar to cement mortar and discovered that pre-soaked biochar had roughly 40% and 30% higher strength than mixes containing no biochar and dry biochar respectively. Biochar derived from food and wood waste was used as a green additive in cement mortar by Gupta et al. [9] The study found that adding biochar made from food and wood waste boosted the compressive strength of cement mortar substantially. Biochar, on the other hand, had no effect on the flexural strength.

METHODOLOGY

Production of Biochar

Biochar was formed using a locally available mix of wood, sticks, leaves and household biodegradable wastes. Before being subjected to pyrolysis, the waste material was sun-dried to remove any moisture. The waste material gathered was pyrolyzed at 500°C. A decentralized system was used for the formation which consists of a kiln with a gas burner and an airtight container with a small opening to release the gases produced during the process and prevent the container from bursting. After the pyrolysis process was completed, the biochar was cooled and kept in airtight containers. By mass, the production of biochar was roughly 25% by mass. The biochar was ground into smaller sizes in an industrial grinder before adding to the clay bricks. [7-9]

Clay Used for Clay Bricks

Locally available topsoil was taken for the formation of clay bricks. The surface was cleaned and dug up to 5 ft and the clay deposit free from rocks and organic impurities was selected.

Brick Formation

The bricks were formed with an increment of 5% biochar concentration by weight. Bricks with more than 20% biochar were rejected due to the formation of cracks in the drying stage. To make a clay brick, the basic materials, which are the biochar and the soil, are crushed and processed first. Then the ingredients are then extruded to make the final product. The powdered elements are combined with water, compacted, and extruded from a shape-specific die. After the bricks have been made, they are dried to remove any excess moisture that could lead to cracking. The bricks are then piled onto carts and transported to enormous furnaces known as kilns. The bricks are burnt at a high temperature of roughly 800-1000 °C in a high-temperature kiln and then cooled. The brick hardens and strengthens as a result of the firing process. They are allowed to cool after firing [10]. The brick formation for this experiment was carried out by Ghanshyam Brick Field in a kiln with a capacity of 10,00,000 bricks per loading.

Tests Conducted

The dimensions of the bricks are measured to the nearest 1 mm. Number of specimens to be tested = 5 for each sample [11].

Compressive Strength Test

Grinding is done to remove the unevenness in the bed faces, resulting in two smooth and parallel faces. After that, the sample is immersed in room temperature water for 24 hours. At room temperature, the specimens are removed and drained of any excess moisture. The frog as well as any cavities in the bed face are filled with cement mortar (1 cement, 3 sand) and stored for 24 hours before being immersed in clean water for three days. Moisture traces are eliminated and wiped out. The specimen is carefully centred between the compression testing machine's plates with the flat face horizontal and the mortar-filled face facing upwards. The maximum load at failure is determined by applying axial force at a consistent rate until failure occurs. The load at failure is the maximum load at which the specimen fails to increase the testing machine's indicator reading any further [12].

Dimensional Tolerances

From the sample, twenty individual bricks are chosen at random. All blisters, loose particles of clay and minor projections were scraped away. The bricks were then put in a straight line along their length, width and height on a flat surface in touch with each other. The overall length of the assembled bricks was measured with a tape long enough to span over the entire row. When tested, the dimensions of bricks must fall between the following range per 20 bricks: [13].

1. Length – 4520-4680 mm (4600 ± 80 mm)
2. Width – 2240-2160 mm (2200 ± 40 mm)
3. Height – 1440-1360 mm (1400 ± 40 mm)

RESULTS AND DISCUSSION

Compressive Strength Test

The tests were completed in compliance with the guidelines provided in IS 3495 Part 1: 2002 'Methods of Tests on Burnt Clay Building Bricks.

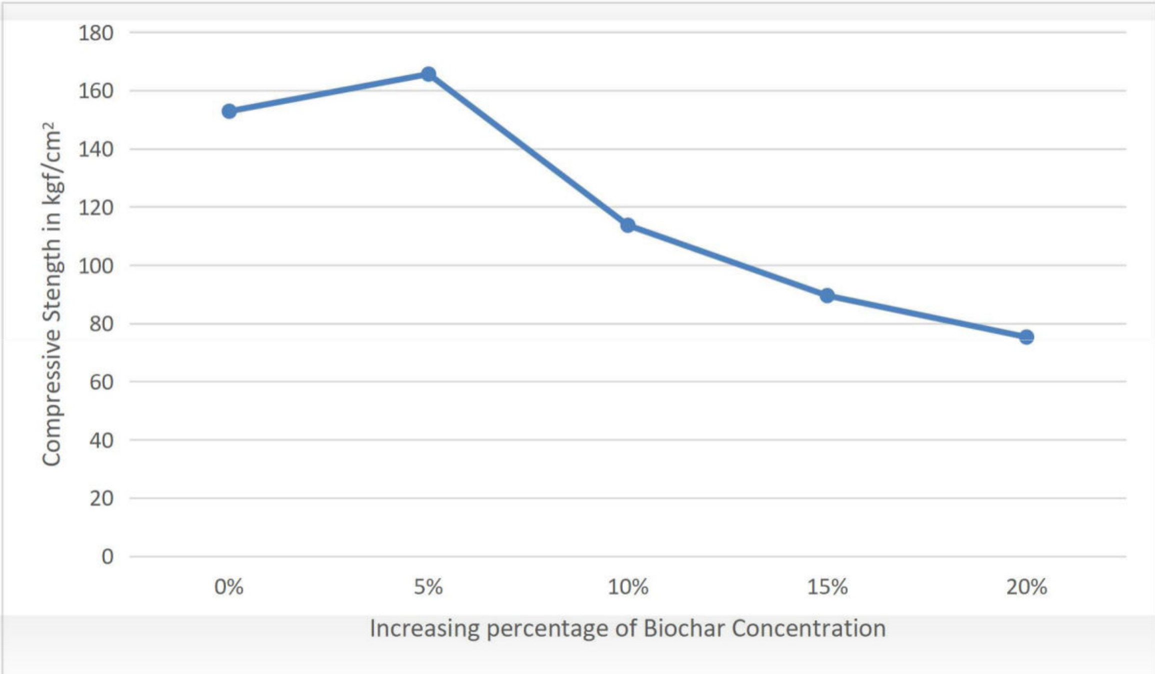

FIGURE 1. Variation of Compressive Stength with increasing Biochar concentration

Dimensional Tolerances

The tests were completed in compliance with the guidelines provided in IS 1077: 2002 'Common Burnt Clay Building Bricks

TABLE 1. Compressive strength for each sample of brick

Biochar content	0 % (kgf / cm2)	5 % (kgf / cm2)	10 % (kgf /	15 % (kgf /	20 % (kgf /
Brick 1	156.34	162.55	117.08	77.75	85.17
Brick 2	150.09	149.52	98	87.1	77.47
Brick 3	155.38	150.44	132.21	79.82	83.22
Brick 4	146.57	186.37	121.83	92.38	60.86
Brick 5	155.85	179.18	102.34	110.62	69.7
Average	152.85	165.61	113.69	89.53	75.28
Std. Dev.		9.023	27.690	44.774	54.850

TABLE 2. Dimensional Tolerances observed for each sample group

Percent Biochar	Length (mm)	Width (mm)	Depth (mm)
0	4628	2227	1438
5	4589	2237	1423

10	4558	2229	1431
15	4634	2235	1439
20	4611	2230	1435

1. Bricks with no biochar content have a compressive strength of 152.85 kgf/cm^2 and hence fall in the AA Class of bricks.
2. Bricks with 5% biochar content have a compressive strength of 165.61 kgf/cm^2 and also fall in the AA Class of bricks but are comparatively much stronger than bricks with no biochar content.
3. Bricks with 10% biochar content have a compressive strength of 113.69 kgf/cm^2 and fall into the First- Class bricks category.
4. Bricks with 15% biochar content have a compressive strength of 89.53 kgf/cm^2 and fall into the Second- Class bricks category.
5. Bricks with 20% biochar content have a compressive strength of 75.28 kgf/cm^2 and fall into the Second- Class bricks category.
6. The length, breadth and height of the clay bricks formed were well within the limits specified by IS code and no large scale expansion or contraction was observed.

CONCLUSION

The application of biochar generated from MSW at 500°C as an addition to clay bricks was investigated in this work. The following results were drawn after observing the influence of gradual biochar addition on major physical parameters of clay bricks : The compressive strength of the bricks was found to considerably increase up to 5% biochar concentration and then reduce significantly as the biochar content was further increased. The bricks formed with high biochar content had low compressive strength, but they could still be used for construction work where the load is not too high like houses, boundary walls etc. For bricks with 5% biochar, 140 gm biochar was used in each brick. For every gram of biochar used, more or less one gram of CO_2 is prevented from re-entering the atmosphere. That means for every biochar–clay brick that has higher compressive strength, we also prevent 140 gm of CO2 from entering the atmosphere. This could lead up to a large amount of carbon sequestration in form of biochar–clay bricks. No uneven expansion or shrinkage was observed in the biochar – clay bricks after burning. Biochar–clay bricks had better defined edges as compared to burnt clay bricks.

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