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Investigation on the Potential use of Waste Paper to Produce Papercrete Bricks

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Abstract. A significant demand has been placed on the building material industry, especially in the last decade due to the increasing population, which causes a chronic shortage of building materials. The current study aims at utilizing waste paper to produce papercrete bricks and study their engineering properties, a step towards sustainable development. Papercrete is rapidly gaining popularity in the building construction industry worldwide because of its environmental friendliness, low-cost and lightweight. The study considered literature and related ideas up to conceptualization and design of the trial ratio used in testing. Trial mixes of paper sludge, sand, and cement at different proportions made papercrete bricks of dimensions 220×110×102 mm. The tests conducted included compressive strength and water absorption. The mixes of paper sludge, sand, and cement in the ratio of 50, 35, and 15%, respectively, gave the best results. The compressive strength increased with the increase in the curing period. The rate at which the papercrete bricks absorbed water reduced as the curing period increased for all the papercrete trial mixes. It was concluded that percentages of paper sludge less than 50% are recommended for non-load bearing walls such as parapet walls and partition walls.

INTRODUCTION

Vast quantities of paper (around 450 million tons) are produced globally per year, and its demand keeps increasing [1, 2]. Some of these waste papers are later discarded, thus posing a threat to the environment [3]. About 28,000 tons of waste materials in Kampala, Uganda, are collected and delivered to landfills every month. The records from Kampala Capital City Authority show that out of the solid wastes generated, 5.3% is paper, 73% organic waste; 1.7% sawdust; 1.6% plastics; 3.1% metals; 0.9% glass; 8% tree cuttings and 5.5% street debris which have become one of the most pressing and challenging environmental problems in most of the urban areas of Uganda. The environmental problems associated with poor management of solid wastes include global warming, soil and groundwater contamination, and many others. The wastes end up in landfills or dumpsites. However, landfill and disposal sites are becoming overcrowded and expensive for waste disposal.

Efforts are being made to minimize the quantities of waste materials delivered to landfills and open environments. Instead of taking the waste papers to the landfills, they could be recycled and be used as building materials in the form of papercrete bricks. Papercrete is a new construction material made out of waste paper, sand and Portland cement [4]. According to Sudarsan et al. [5], papercrete could also be made of waste paper, fly ash, quarry dust, cement, and water. Papercrete was discovered 80 years ago as a construction material and is currently being emphasized. Papercrete

consists of waste paper which is fibrous, and Portland cement. Both the constituents are mixed thoroughly and well blended to create a paper cement pulp, which can shape using a mould and dried to get a proper papercrete brick which can be used as a durable building material [6]. It is rapidly gaining popularity in the building construction industry worldwide because of its environmental friendliness, low-cost and lightweight. This has caused the need to investigate how this new composite material can be better utilized while maintaining the material requirements affirmed in the standards while still benefiting the environment. As natural sources of aggregates are becoming exhausted, it is urgent to develop a new sustainable material (papercrete bricks).

Different studies have been conducted on the reuse of waste papers in some countries like India, and Nigeria and the outcomes were promising. For example, the study by Sudarsan et al. [5] showed that bricks made out of waste paper satisfied the properties of conventional bricks after conducting various laboratory tests. The study by Akinwumi et al. [1] concluded that papercrete has low bulk density and could thus be used as hollow or solid blocks in constructing walls. However, limited studies have been conducted in Uganda regarding the use of waste paper for making bricks. This study attempts to use some percentages of waste paper blended with sand and cement to produce papercrete bricks. The properties of the papercrete bricks were determined by conducting laboratory tests, like compressive strength and water absorption tests on the made bricks.

MATERIALS AND METHODS

Materials

The materials used in this study were ordinary Portland cement, sand, and waste paper.

Ordinary Portland cement

Ordinary Portland cement of Grade 32 was used in the making of papercrete bricks. It was secured from a local hardware.

Waste paper

The waste paper considered in this study included newspapers, record sheets, and magazines. They were collected from Ndejje University halls of residence and near-by schools in Luweero district.

Fine aggregates

Fine aggregates used in this study was sand obtained from the nearest quarry.

Methods

This study was experimental. The samples were prepared, and different laboratory tests were conducted. The tests include specific gravity for the materials, sieve analysis for sand, consistency and setting time for ordinary Portland cement, and water absorption and compressive strength for papercrete bricks after a curing period of 7 and 28 days. The papercrete bricks that were made and tested are shown in Figure 1.



FIGURE 1. Papercrete bricks that were made.

Sample preparation

In an investigation on the effect of waste paper on cement mortar, four proportions as shown in Table 1 were chosen as the primary investigation target to achieve the standard physical properties according to ASTM C 140 – 07a procedures [7].

TABLE 1. Trial mix proportions.

Specimen ID	Specimen	Proportions (%)
A	Sand: Cement (Control)	50:50
B	Paper: Sand: Cement	50: 35: 15
C	Paper: Sand: Cement	60: 30: 10
D	Paper: Sand: Cement	70: 25: 10

Sieve analysis

This test was conducted following ASTM D 6913-04 procedures [8]. A representative specimen was taken from the air-dried sample and oven dried at temperatures between 105° and 110°C for 24 hours

Consistency and setting time for ordinary Portland cement

This test was conducted in accordance to BS EN 196-3 procedures [9].

Specific gravity

The value for the specific gravity of sand was determined in accordance to ASTM D 854-02 procedures [10].

Water absorption

. Three specimens were prepared to test for absorption as complying with ASTM C 140– 07a (2007).

Compressive strength of papercrete bricks

This test was conducted following ASTM C 140 – 07a procedures [7]. The compressive strength of papercrete bricks needs to be determined for structural analysis purposes, and the compressive strength was used to judge the overall strength of papercrete brick.

RESULTS AND DISCUSSIONS

This section demonstrates analysis and interpretation of the results obtained from the study—the relationship between the curing time and compressive strength, water absorption and curing time.

Specific gravity

From the test, the apparent specific gravity obtained was 2.6493, bulk specific gravity (oven-dry) obtained was 2.5178, bulk specific gravity obtained was 2.5674, which falls within the recommended range of 2.5- 2.9 and for water absorption obtained was 1.972%.

Grading of sand (fine aggregates)

The sand was tested and found to be within the standard envelope, as shown in Figure 2. For the coefficient of uniformity (CU), the standards give a range of 4 to 6 as a well-graded aggregate with which the values obtained from this study (5.8) lie within the range. Thus the aggregate is well-graded and suitable for construction works. For the coefficient of curvature (Cc), the standards give a range of 1 to 3, for well-graded in which our sample with Cc = 1 lies within the range thus deemed suitable for construction works.

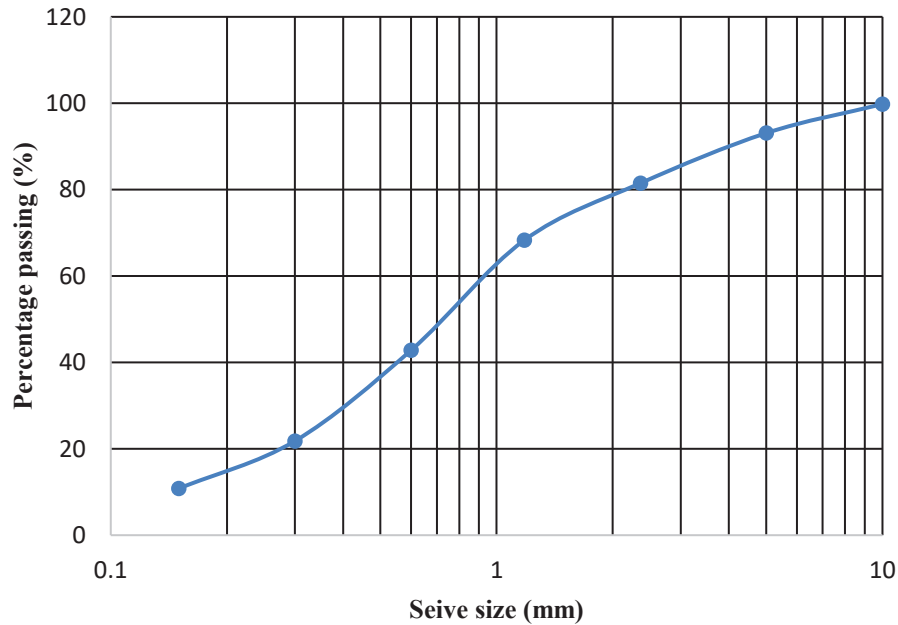


FIGURE 2. Particle size distribution of sand.

Consistency and setting time (initial and final setting of OPC)

From the test, the consistency obtained was 25%, and the initial and final setting time obtained was 173 and 353 minutes as seen in Table 2.

TABLE 2. Consistency and setting time of OPC-32.

Properties	Results obtained	Requirements of EN 196-3
Initial setting Time	173 minutes	≥ 30 minutes
Final setting time	353 minutes	≤ 600 minutes
Consistency	25%	22-30(%)

Compressive Strength

Samples were tested after 7 and 28 days of preparing papercrete bricks, and the results are shown in Figure 3. The compressive strength increases with the curing period, giving the papercrete brick the desired strength, thus attaining its durability properties. These results of increasing strength with increased curing period was also attained by different researchers upon using different materials, for example, Tiboti et al. [11] when they used quarry dust to make cement laterite blocks. Niyomukiza et al. [12] also found an increased strength after an increased curing period in a study of determining the effect of curing time on expansive soil stabilized with lime and *Keruing* sawdust. In addition, the compressive strength also reduces with an increase of paper-pulp quantity as evidenced by trial mix of sample ID D (70:25:5), whose compressive strength is meagre, which may be due to paper-pulp quantity present in the mix is higher than the amount required. The higher quantities of waste paper replace the cementitious material but do not contribute to the strength of the brick. The previous studies by other scholars also show a reducing trend of compressive strength with an increased percentage of waste paper [1].

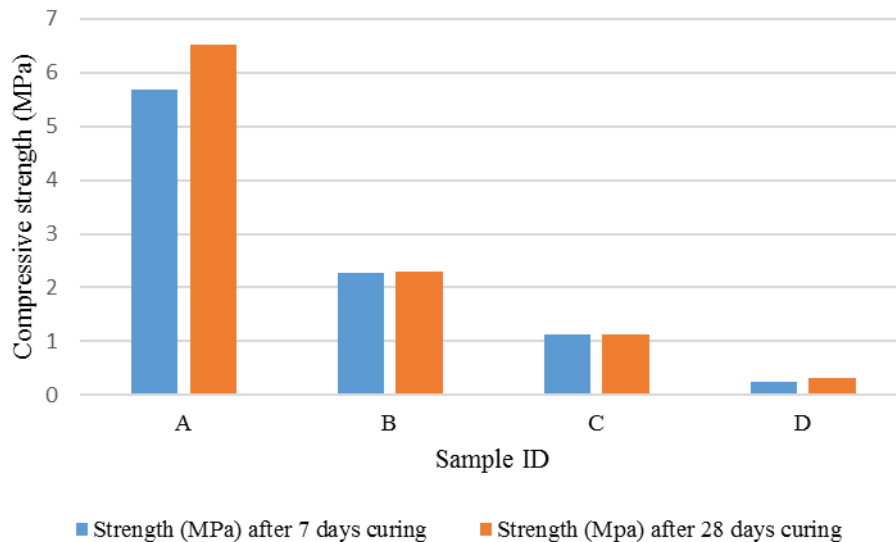


FIGURE 3. Compressive strength of the specimens at 7 and 28 days of curing.

Water Absorption

The results of water absorption are shown in Figure 4. It was noted that higher water absorption was observed as the substitution level increased. For instance, 50% substitution of paper sludge shows a minimal increase in the water absorption compared to the control sample. On the other hand, as the substitution level increases, the rate of water absorption decreases. Overall, 28 days samples show relatively lower water absorption ability as compared to 7 days curing. On the other hand, the substitution level of paper sludge has a high positive correlation on the specimen water absorption ability; this happens due to the hydrophilic properties of paper sludge and the loss in cohesion and poor binding of the C- S-H gel on the cellulosic materials.

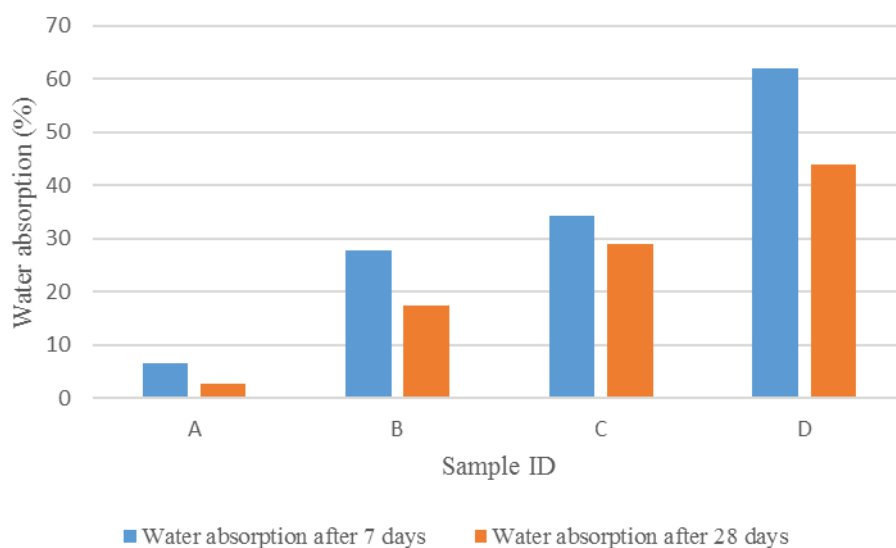


FIGURE 4. Water absorption for 7 days and 28 days curing.

Figure 4 shows that water absorption reduces with an increase in curing time and increases with an increase in paper waste content. As per standards, the bricks should not absorb water more than 20% of their weight. According to the results from the current study (see Figure 4), it is observed that the control sample and the mix that contains 50% paper pulp absorbs water less than 20%. Trial mixes of 60% and 70% paper-pulp bricks absorb more than 20%. Therefore, these bricks are not suitable for water-logged areas and exterior walls. Papercrete bricks could be used for interior partition walls, while bricks with 50% paper pulp could successfully be used for interior and exterior walls.

CONCLUSIONS

This study investigated the possibility of using waste paper to make papercrete bricks. The following conclusions were derived.

The compressive strength dominantly decreased as the waste paper sludge quantity was getting higher. On the other hand, the compressive strength also increased as the curing age increased no matter the percentage of the paper pulp. Hence the longer the brick is cured, the higher the compressive strength attained.

The rate at which the papercrete bricks were absorbing water reduced as the curing period increased for all the papercrete trial mixes, and also it increased as the amount of paper sludge in the mix increased. The trial mix of 50% of paper sludge gave the best results for water absorption, and therefore they are suitable for construction purposes. The papercrete brick prepared from a trial mix of 50% paper, 35% sand, and 15% cement gives the best results and is recommended for non-load bearing walls such as parapet and partition walls.

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