Highly compressed flyash based papercrete brick

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Abstract – *In this work experimental approach is carried out to analyze the feasibility of papercrete brick in practical field. In past research we found that researchers conclude that water absorption for papercrete brick is nearly about 35% which is not accepted. Basically the work is contribute to make papercrete brick as a practical brick work. Different parameters such as strength, durability, density and water absorption is determined to check the feasibility.*

Key Words: Papercrete brick, flyash brick, Test on brick, Earthquake brick, low cost brick,

1. INTRODUCTION

The present era of construction industry requires new innovative material due to it's rapid growth and new challenges. Paperecrete is originally developed 90 years ago but recently rediscovered. It's main contain is fibrous cement compound with waste paper and Portland cement. These components are blended with water to form pulp and then poured into mould and allow it to dry and can be utilized as building material. It should be noted that papercrete is rediscovered innovative concept with limited scope.

1.1 Relevance of work

- To utilize the waste materials like paper, flyash etc. in the process of manufacturing new type of eco-friendly bricks, namely papercrete bricks.
- To manufacture and study the strength and durability of the papercrete bricks in order to effectively use these papercrete bricks commercially for construction purposes.
- To extend the investigation further to study the structural behaviour of the papercrete brick masonry experimentally and theoretically.

1.2 Relevance of work

- In this work, it is proposed to evaluate the strength, durability and structural properties of flyash based papercrete building bricks. Then the results will compare with those of conventional bricks.
- The strength and durability of cement composites containing waste paper, flyash, and sand will have studied in detail and the optimum mix proportions will have obtained.
- It is proposed to know the performance of the papercrete bricks. The papercrete brick will have tested for their compressive strength, water absorption, and acid resistance then the performance of the papercrete brick will compare with the conventional clay bricks.

2. LITERATURE REVIEW

Manuel (2002) studied that physical characteristics of papercrete are mainly depending upon the relative amount of sand and Portland cement used.

Dunster (2007) said addition of 20% calcined paper sludge with cement paste accelerate setting time by 60 minutes. Workability also reduced.

H. Yun et al (2010) gives that density of papercrete was decreased when the replacement of waste paper increased. When paper replacement ratio was 5%, density was measured 1.88g/cm^3, and it was reduced to 15% and 22%, respectively by increasing paper ratio 10% and 15%. The shrinkage of papercrete was increased according to increase of paper-cement replacement ratio.

Ms.S.Suganya (2012) bricks are relatively light weight, good sound absorbent and more flexible but it has high percentage of water absorption than conventional bricks. It can be easily cut in to desirable shape. And also it does not expand or contract due to surround environment.

J.N Akhtar et al (2011) In this study, six different mix proportions were computed by utilizing the Paper pulp and industrial by products like Fly ash, Rice husk ash. And also, due to the addition of paper pulp the bricks have low thermal conductivity, and it reduces the energy requirement for temperature control. While using paper pulp to make bricks, it will reduce approximately 50% of weight of the brick. Therefore these bricks will reduce the dead weight of the structure to considerable amount. So it changes our design and building as economical one.

Akinwumi (2014) The water absorption and fire resistance of papercrete were found to be high and increased with increasing waste paper content while the bulk density and compressive strength of papercrete were low and decreased with increasing waste paper content. Papercrete was recommended to be an effective and sustainable material for the production of lightweight and fire-resistant hollow or solid blocks to be used to make partition walls of especially high-rise buildings. Mix proportions were recommended for production of hollow and solid blocks using papercrete

3. SPECIMEN MAKING

Paper is the major constituent of the mix proportions. From literature support, papers with cement, fly-ash, sand, paper pulp are used as ingredients of the mix with various proportions. From these materials, 9 mix proportions were used and studied in terms of compressive strength and percentage of water absorption.

Table 1 shows the details of mix proportions used in the study.

Table-1: Details of Mix Proportions

Sr. No.	Mix Designation	Cement: Flyash: Sand: Paper
1	A1	1: 3: 4: 6
2	A2	1: 3: 3: 6
3	A3	1: 3: 2.5: 6
4	B1	1: 2: 3: 4
5	B2	1: 2: 4: 4
6	B3	1: 2: 2.5: 4
7	C1	1: 1.5: 2.5: 2
8	C2	1: 1.5: 4: 2
9	C3	1: 1.5: 3: 2

All the proportions were taken on a weight basis. Papers were taken in wet condition, i.e. slurry form. Flyash was taken from Shrinivasan Enterprises. In this project, Koromandal king 53 grade Pozzolona Portland cement has been used in all times.

3.1 Formation of Pulp for Papercrete Bricks

The papers which were collected could not be used directly. Before mixing with other ingredients, papers were converted into slurry form, known as pulp. First the pins, threads and other materials were removed. Then the papers were torn into small pieces and all the torn pieces of papers were immersed in water. The papers were kept in water for 3 to 4 days, and they soon degraded into a paste like foam. After that period, the papers were taken out from water tank and shredded into little pieces by manually on large wire mesh. The shredded papers were converted into pulp. The various stages of pulp generation are shown in following images. The paper pulp had residual water in itself, and it was not good enough for mixing the ingredients. So the required amount of water was added at the time of mixing.

Figure-1: Paper immersed in water

3.2 Casting of Specimen for Papercrete Bricks

After paper pulp was generated, first dry ingredients were taken out on the weight basis and all the dry mixes were mixed uniformly. Then, these dry mixes were sprinkled over the required amount on watertight pan and paper pulp was spread over that mix, and mixed uniformly manually and then. After mixing, the mixes were placed in the mould for 30 minutes. From this process, 3 moulds were used at a time to make the process very fast. In this study, the bricks were moulded manually by hand i.e. hand moulding. And these bricks were ground moulded bricks. Before mixing, the steel mould was ready for casting the brick specimen. Machine oil was applied to the inner surfaces of mould for easy removing of mould and without causing any damage to the specimen. The size of the specimen was 235mm x 105mm x 90mm. The specimen was kept on the vibrating table. Papercrete fibrous mix was poured into the mould by three layers and fully compacted mechanically. Casting was completed and then the specimen was laid on the laying table. After 15 minutes, the mould was removed carefully from the specimen. After 28 days of air drying, i.e. on hearing the metallic sound when striking out the brick surface, the specimen was ready for testing.

Figure-2: Casting the papercrete brick

4. TESTS ON PAPERCRETE BRICK

The testing of the materials was an important study for the fitness of material at desirable location in the structural system. All the tests were carried out with BIS specifications. As per IS: 3495 (Part 1 to 4)-1992 recommendation, compressive strength and percentage of water absorption were examined.

4.1 Compressive Strength

Brick is one of the building elements used in the construction of a wall and the wall is a compression member. So the use of good brick indicates how much amount of compressive strength it has. This test is carried out as per the guidelines given in IS 3495-1992. Compression test is the main and important test for bricks. This test was carried out by a Compression Testing Machine (CTM). This test was carried

out on the 28th day from the date of casting of brick. Figure 5.1 shows the compression test being done. The bricks were then tested under a uni-axial compressive force using 200 tonne compressive testing machine. Since the longitudinal deformation rises more and more, the plunger of the CTM comes out of the cylinder in a fast manner. When the brick failed at the higher load, the brick did not fully collapse. While testing the brick, great care must be taken, because papercrete bricks never failed catastrophically, it just compressed like squeezing rubber. Even though the brick failed at the higher load, the structure did not collapse. Only the outer faces cracked and peeled out. So the papercrete bricks showed elastic behaviour and less brittleness.

Figure-3: Compression test on papercrete bricks

4.2 Water Absorption

The two specimen of each proportion taken for water absorption test. Initial weight taken as w1. Then the dried specimen was immersed completely in clean water at a temperature of 27 ± 2°C for 24 hours then the specimen was removed and wiped out to remove any traces of water with a damp cloth. Later, the specimen was weighed after it had been removed from water as W2. The percentage of water absorption by mass, after 24 hours immersion in water was noted and the average of the result of each proportion was noted.

Figure-4: Dry Specimen & Wet Specimen

4.3 Acid resistance test

The immersion container was a plastic bucket or other suitable container of a sufficient size to contain immersion fluid and to accommodate the test bricks for immersion. The immersion container shall have a cover which is not impaired by the immersion fluid.

The immersion temperature was 25 ±5°C. The immersion period was 7 days. Each of the test specimens was immersed completely in the solution. Care must be taken to ensure that the water in the solution does not evaporate and that carbon dioxide in the air is not absorbed during immersion.

The test specimens shall be visually inspected before and after immersion and compared in terms of color, surface condition and change in shape.

After acid immersion, the test specimens shall be rinsed with water.

Figure-5 Acid Resistance Test

4.4 Fire Test

The following are the steps involved in this test:

1) First, the brick was wiped with cloths and all the foreign matters were removed. Bricks were weighed in a well-conditioned electronic weighing machine.

2) Then the flammable sticks and charcoal were fired. After that, the bricks were held on the flame for 20 minutes.

3) After 20 minutes fixing was stopped and the bricks were observed.

4) After this brick were cooled to room temperature.

5) Then weight of brick was taken and compressive strength test is carried out.

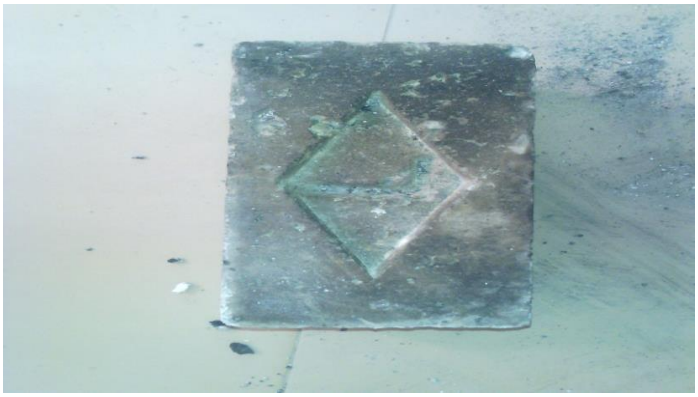

Figure-6: Specimens after fire test

Fibrous concrete bricks did not burn with an open flame. They smoldered like charcoal. But these brick would be reduced to ashes after burning several hours. If the interior plaster and exterior stucco is provided on the fibrous concrete bricks, the bricks won't burn.

5. RESULTS

5.1 Result of weight of papercrete brick

Lightweight bricks are also the important objective of this project. So, all the bricks were tested whether they are having less weight or not. All the bricks were weighed in a well-conditioned electronic weighing machine. The following are the weight of the bricks:

Table-2: Weight of brick

Mix Designation	Proportion	Weight (kg)
A1	1:3:4:6	2.2
A2	1:3:3:6	2.085
A3	1:3:2.5:6	1.99
B1	1:2:3:4	2.355
B2	1:2:4:4	2.45
B3	1:2:2.5:4	2.26
C1	1:1.5:2.5:2	2.80
C2	1:1.5:4:2	3.07
C3	1:1.5:3:2	2.52

Following graph shows weight of papercrete brick:

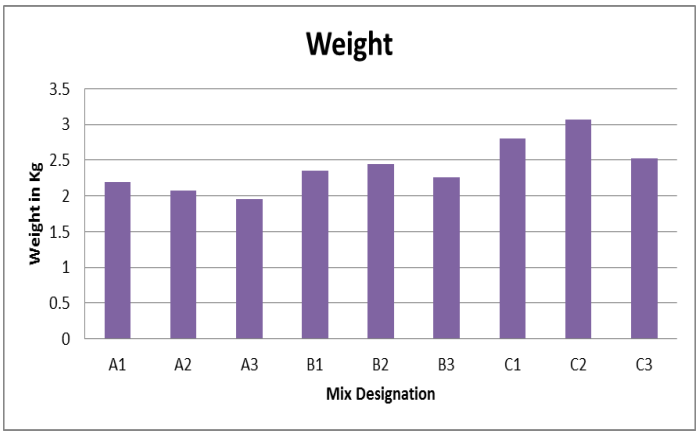

Chart-1: Weight of different types of papercrete bricks

5.2 Result of compressive strength

From the tests on compressive strength, it was observed that sand mixed proportions attained high compressive strength compared to other mixes. The compressive strength was decreased while increasing the paper percentage into papercrete mix. In the mix, sand acted as a filling material. So the voids in between the cement grains were filled. The sand present in the mix became densified and resisted the more compressive strength. When the paper content became high in the mix, the brick did not appear brittle in nature. It compressed like squeezing rubber.

Following table shows compressive strength of papercrete brick:

Table-3: compressive strength result

Mix Designation	Proportion	Compressive strength(N/mm^2)
A1	1:3:4:6	1.86
A2	1:3:3:6	1.66
A3	1:3:2.5:6	1.37
B1	1:2:3:4	2.43
B2	1:2:4:4	2.51
B3	1:2:2.5:4	2.35
C1	1:1.5:2.5:2	2.91
C2	1:1.5:4:2	3.24
C3	1:1.5:3:2	3.03

Following graph shows variation of compressive strength of papercrete brick:

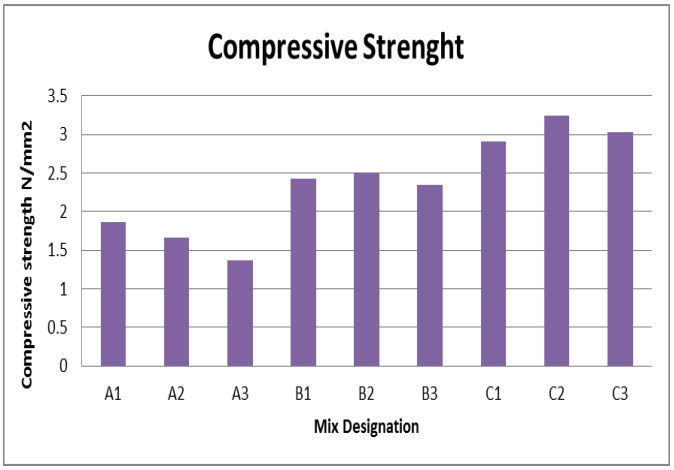

Chart -2: Compressive strength of different types of papercrete bricks

5.3 Result of water absorption

From the test on percentage water absorption, it is seen that more sand mixed proportions were absorbed less amount of water compared to the other mix proportions. The proportion of paper was increased in the mix and the percentage of water absorption was also increased.

The sand present in the mix prevented the percentage of water absorption compared to other mixes. Also, more paper absorbed more water and retained in a particular period. It may be observed that flyash based papercrete bricks had high strength. Following table shows result of water absorption:

Table -4: Water absorption result

Mix Designation	Proportion	Water Absorption (%)
A1	1:3:4:6	39.54
A2	1:3:3:6	41.94
A3	1:3:2.5:6	48.11
B1	1:2:3:4	34.46
B2	1:2:4:4	31.81
B3	1:2:2.5:4	37.47
C1	1:1.5:2.5:2	23.26
C2	1:1.5:4:2	18.95
C3	1:1.5:3:2	33.30

Following graph shows variation in water absorption of papercrete brick:

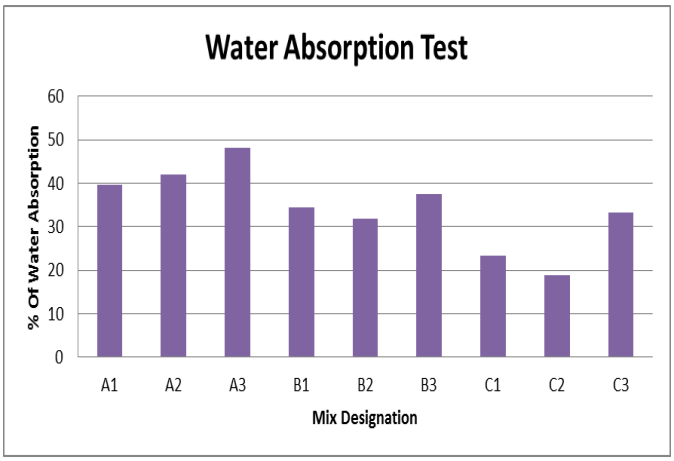

Chart-3: Water absorption of different types of papercrete bricks

5.4 Result of Acid Resistance

5.4.1 Weight Reduction:

The reduction in Weight for the Compressive strength specimens was calculated using Eq. (1) and rounded off to two significant digits. However, all of test specimen was dried and their mass measured.

$$\text{Reduction in weight} = \frac{w0 - w1}{w0} \times 100 \quad \text{..... (1)}$$

$$= \frac{3.07 - 2.92}{3.07} \times 100$$

$$= 4.88 \approx 5\ \%$$

Where,

Change in weight (%)
w0: Mass before immersion (kg)
w1: Mass after immersion (kg)

5.4.2 Reduction in strength:

The Compressive strength reduction shall be calculated using Eq. (2) respectively, and rounded off to two significant digits.

$$\text{Reduction in strength} = \frac{fc0 - fc1}{fc0} \times 100 \quad \text{..... (2)}$$

$$= \frac{3.24 - 2.90}{3.24} \times 100$$

$$= 9.87 \approx 10\ \%$$

Where,

Tensile strength retention (%)
fc0 : Average value for compressive strength before immersion (N/mm²)

fc1: Average value for compressive strength after immersion (N/mm²)

5.5 Result of Fire Resistance

5.5.1 Reduction in weight:

The reduction in Weight of brick was calculated using Eq. (1) and rounded off to two significant digits. However, all of test specimen was cooled and their mass measured.

$$\text{Reduction in weight} = \frac{w0-w1}{w0} \times 100 \quad \ldots\ldots\ldots\ldots (1)$$

$$= \frac{3.07-2.81}{3.07} \times 100$$

$$= 8.46 \approx 9\ \%$$

Where,

Change in weight (%)
w0: Mass before burning (kg)
w1: Mass after burning (kg)

5.5.2 Reduction in strength:

The Compressive strength reduction shall be calculated using Eq. (2) respectively, and rounded off to two significant digits.

$$\text{Reduction in strength} = \frac{fc0-fc1}{fc0} \times 100 \quad \ldots\ldots\ldots\ldots (2)$$

$$= \frac{3.24-2.72}{3.24} \times 100$$

$$= 11.40 \approx 12\ \%$$

Where,

Tensile strength retention (%)

fc0: Average value for compressive strength before burning (N/mm²)

fc1: Average value for compressive strength after burning (N/mm²)

6. PTIMIZATION OF MIX

From the compression test results it is observed that the more sand mixed proportion had 6% to 12% higher compression value compared to other two mix proportions. More paper in proportions (A Group) has a little lower compressive strength than the other mix. From the water absorption test results on A2 mix and A3 mix, the paper percentage was higher. It meant (A2 mix and A3 mix) that the percentage of water absorption was high. But the more sand mixed proportion (C1 mix and C2) had 75% to 44% lower percentage of water absorption than the other mixes.

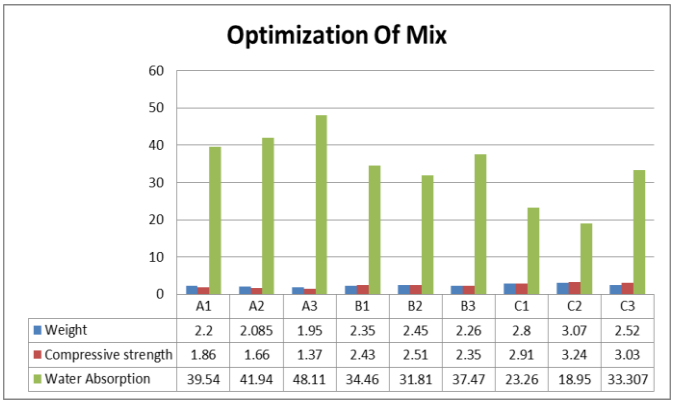

Chart-4: Optimization Of Mix

The results indicate if the percentage of sand is increased the compressive strength also is increased. If the percentage of paper is increased, the percentage of water absorption is also increased. Therefore it is important to reduce water absorption but increase compressive strength without any reduction in its strength. So C2, i.e. 1:2.5:4:2 (Cement: Flyash: Sand: Paper) mix proportion of Trail Mix gave desirable result and this mix was considered as the optimized mix of papercrete.

Finally, optimized mix was arrived based on the trial mix results. Chart 5 shows the percentage of ingredients of flyash based papercrete by weight basis.

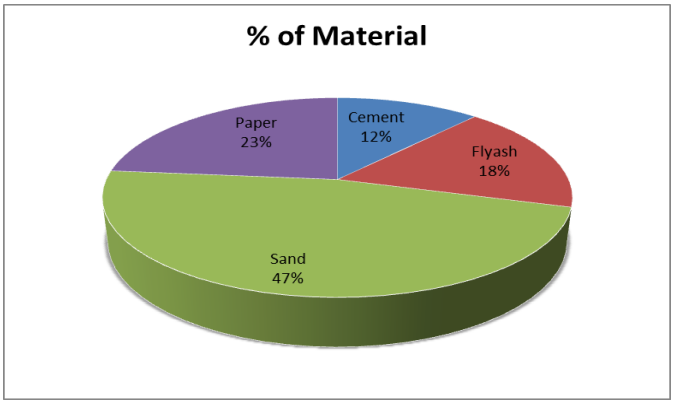

Chart-5: Ingredients in optimum mix

7. CONCLUSIONS

- It is evidently concluded that the flyash based papercrete building bricks can be used for the

construction of external walls, partition walls, infilled walls, compound wall, basement, etc. in non-earthquake prone area.

- In the manufacture of conventional clay bricks, a large amount of fuel is needed in order to burn the bricks. This causes social deforestation and the non-cultivation of land. It may be avoided or minimized by adopting papercrete bricks.
- The adoption of the aforesaid composite material helps to construct a cost effective and green building. The research work also focuses on job opportunities that can arise due to this activity.
- This type of prefabricated building blocks may be used for the speedy construction of projects.
- The weight of papercrete brick is 3.07 Kg which is higher than clay conventional brick. So that it increase dead load of structure.
- The compressive strength of papercrete brick is 3.24 N/mm^2 which is higher than clay conventional brick.
- The water absorption of papercrete brick is 18.95% which is less than clay conventional brick and satisfies the IS code recommendation (IS 3495 Part-2).
- The optimized mix proportion for papercrete brick is 1:1.5:4: 2 (Cement Flyash: Sand: Paper) in comparison of papercrete brick.
- The optimized mix proportion for papercrete brick is 1:1.5:2.5:2 (Cement Flyash: Sand: Paper) in comparison of Conventional clay brick.
- This project has been successful in developing a new composite material viz. Flyash based Papercrete (sand based) building bricks with required proportions of the constituents to obtain high Durability and load carrying capacity.
- The load carrying capacity of the papercrete brick is 20.68 % more than conventional brick. But papercrete brick can withstand the load beyond the ultimate level. So it can be suitable in framed structure.

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BIOGRAPHIES

He is efficient technical person and extremely interested in research work.

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