

Study of Papercrete As A Sustainable Building Material

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Abstract- Papercrete is kind of fibrous cement, made by shredding paper (old newspapers, prints, cardboards etc.) into pulp in water and adding Portland cement to it and in some cases sandy soil to be used as an additive. It gains its inherent strength due to presence of hydrogen bonds in microstructure of paper. This thick mix can then be poured into molds and cast like concrete, to make it into any desired shape and size. Papercrete is a sustainable building material due to reduced amount of cement usage and recycled paper being put to good use. It has numerous advantages in construction industry, namely low carbon footprint, recycled material usage, low embodied energy, high strength to weight ratio, high thermal insulation, high sound absorption, aesthetic and cost effective. Much research is being carried out globally on the material but it is yet to be acknowledged by Indian standard practices and codes and recognized by major building material organizations in India.

It has numerous advantages in construction industry, namely low carbon footprint, recycled material usage, low embodied energy, high strength to weight ratio, high thermal insulation, high sound absorption, aesthetic and cost effective. There are many varieties of Papercrete possible when the constituents mixed in different proportions. It gains its inherent strength due to presence of hydrogen bonds in microstructure of paper. This paper reviews about the environment impact caused by the paper pollution. Further it discusses about the numerous advantages and disadvantages of papercrete in the construction industries.

Properties like absorption, crushing strength, hardness, presence of soluble salts, etc. are studied. Certain measures to overcome the limitations in the properties are also mentioned. Much research is being carried out globally on the material but it is yet to be acknowledged by Indian standard practices and codes and recognized by major building material organizations in India

Keywords- Paper Crete, Sustainable construction Building blocks, Environmental friendly, Recycled

I. INTRODUCTION

Papercrete is a recently explored construction material that consists of re-pulped paper fiber with cement or clay. It is an experimental material that replaces a certain proportion of cement with paper in the normal concrete mix. It is perceived as an environment friendly material due to the vital recycled content. By doing so, the total weight, cost and the carbon emissions during production are reduced. Its use remains limited, because of the lack of official data about its structural properties, mechanical properties and durability. In order to establish papercrete as a standard material, further experimentation is needed.

As nominal mix has not been defined yet and guidelines for mix design of papercrete are not yet available, making the efforts towards achieving an optimum mix is difficult. Each ingredient has a significant role in the mix. Newspaper is most commonly used because it produces consistent results. When paper is mixed with cement, it creates a very good bond and the final product is both lightweight and strong.

The environment impact of paper is significant, which has led to changes in industry. With the use of modern technology, harvesting wood, disposable paper has become a cheap commodity which has led to a high level of consumption and waste. The production and use of paper has a number of adverse effects on the environment which are known as paper pollution. Discarded paper is a major component of it. Taking this issue into account, construction material know



PAPERCRETE

Objectives of the Study

The various objectives of the study of Papercrete are asunder:

- 1) To study the properties of Papercrete to determine its potential as a sustainable building material.
- 2) To determine the Ideal Papercrete Mix.
- 3) To do comparative analysis of Concrete, wood & Papercrete.

Aim of the Study

The scope of this study can be summed up as below:

- To prepare the samples of the locally available materials.
- To determine the compressive strength of different Papercrete mixes.
- To evaluate the pros & cons of Papercrete for use in construction.
- To determine the areas of further research and future scope of Papercrete

II. MATERIALS

- 1) **CEMENT:** Cement is a binding substance used as a construction material that sets, hardens and can bind other materials together. In today's construction world, cement is the most important building material.
- 2) **GROUND GRANULATED BLAST FURNACE SLAG (GGBS):** It is a by product which is obtained during the manufacturing process of pig iron in blast furnace. Its chemical composition indicates the presence of silica glass which contains calcium, magnesium and aluminium. It also has a cementitious character which enhances lower heat of hydration, higher durability and higher resistance to chemical attack.
- 3) **QUARRY DUST:** They are the remains obtained after the process of quarrying. The dust should have uniform size for proper utilisation. It should be devoid of impurities but often contains organic impurities and salts. The dust from the quarry sites has become a major source of pollution but if they are used in the construction industry as an alternative material for sand, pollution may be reduced to some extent. Using quarry dust in replacement of sand also reduces the cost of construction and construction material would be saved.

- 4) **PAPER:** Paper is principally wood cellulose. Cellulose is natural polymer. The cellulose chain bristles with polar –OH groups. These groups form hydrogen bonds with –OH group on adjacent chains, bundling, and the chain together. In order to form a hard and a stable crystalline region, the chains are packed regularly so that the bundled chains gain more stability and strength.
- 5) **WATER:** Water is an important ingredient of papercrete as it actively reacts with cement in the chemical reaction and the pH value should be between 6 and 7.

III. SPECIMEN MAKING FOR PAPERCRETE BRICKS

Paper is the major constituent of the mix proportions. They used 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.

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.

Formation of Pulp for Papercrete Bricks

- a. As the collected papers cannot be used directly so first papers were converted into slurry form, known as pulp then is mixed with other ingredients.
- b. Pins, threads and other materials attached to the collected paper were removed.
- c. Then papers were torn into small pieces and all the torn pieces of papers were immersed in water.
- d. The papers were kept in water for 3 to 4 days, and they soon degraded into a paste like foam.
- e. 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.
- f. 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.

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

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



Fig. Casting the papercrete brick.

Casting of Specimen for Papercrete Bricks

The paper pulp is mixed uniformly with flyash, cement and sand. The specimen was casted in form of cuboids of dimension 235mm x 105mm x 90mm, as shown in figure 1.

IV. PROPERTIES OF PAPERCRETE BRICKS

a. Presence of Soluble Salts:

The soluble salts, if present in bricks will cause efflorescence on the surface of bricks. In order to find out the presence of soluble salts in a brick, this test was carried out which includes immersion of the papercrete bricks in water for 24 hours. Then the bricks were taken out and were made to dry in shade. Grey or white deposits were not found on the bricks surface which concludes that the bricks are free from soluble salts.

b. Soundness Test:

In this test, two bricks which are of the same proportion were taken and they were struck with each other. The bricks did not break and a clear ringing sound was produced which means that the bricks are good.

c. Structure Test

In this test, a brick is broken and the structure of the broken brick was closely observed. If there are any defects like holes, lumps, etc., then the bricks are not of good quality.

d. Hardness test:

In this test, a scratch was made on brick surfaces. This test was carried out for all the three proportions of brick. While the scratch was made with the help of finger nail on the bricks, very light impression was found on the surface of the fibrous concrete brick. So this test results that fibrous concrete bricks are sufficiently hard.

e. Nailing:

When compared to conventional bricks, fibrous concrete bricks are less hard. So, in order to find out whether the brick can hold the nail or not, this test was carried out. Two specimens of bricks were taken. Out of the two bricks, a nail was hammered on the surface of one brick and a screw is also screwed on the other brick. The fibrous concrete brick could not hold nails but screws worked well and hold a considerable weight. So, the screws are the anchors of choice for fibrous concrete bricks.

f. Cutting and Glue:

The labours could not able to cut the bricks exactly what they need. But, fibrous concrete bricks can be cut into exactly two pieces by using conventional saw blades. So, we can get any shape and size of fibrous concrete brick. Many cut bricks are wasted in now a day. But if we apply a sufficient amount of glue on the bottom piece, the two fibrous concrete can be hold together and hence will not come apart.

Installing plumbing lines requires cutting holes and channels in papercrete. Using a circular or chain saw, the electrical runs were cut. To make holes for outlets, horizontal and vertical slits was cut with a circular saw. Then unwanted pieces were removed with the help of a screwdriver. Home fires start, where the wiring enters the outlet boxes. So, non-flammable mortar should be put behind the outlet boxes for safety. Once the electrical wiring and outlets are installed and then tested, the channels for the electrical runs are for filled with papercrete.

Table shows the physical characteristics based on the study.

Sr. No.	Mix Designation	Cement: Fly-ash: Sand: Paper	Water Absorption (%)	Weight (kg)	Compressive Strength (N/mm ²)
1	A1	1:3:4:6	39.54	2.2	1.86
2	A2	1:3:3:6	41.94	2.085	1.66
3	A3	1:3:2.5:6	48.11	1.99	1.37
4	B1	1:2:3:4	34.46	2.355	2.43
5	B2	1:2:4:4	31.81	2.45	2.51
6	B3	1:2:2.5:4	37.47	2.26	2.35
7	C1	1:1.5:2.5:2	23.26	2.80	2.91
8	C2	1:1.5:4:2	18.95	3.07	3.24
9	C3	1:1.5:3:2	33.3	2.52	3.03

g) Fire:

A brick which is used for construction should not flammable in open flame, so this test was carried out for the bricks. This test was carried out only for fibrous concrete bricks but not for padobe bricks for padobe bricks were already heated in kiln at high temperature so, it won't burn. The following are the steps involved in this test:

- First, the brick was wiped with cloth to remove and all the foreign matters.
- Then some of the flammable sticks were fired. After that, the bricks were held on the flame for five minutes.
- After five minutes fixing was stopped and the bricks were observed.

From the test conducted above, it was observed that the fibrous concrete bricks did not burn with an open flame. They smouldered like charcoal. But after burning for several hours, these brick would be reduced to ash. If the interior plaster and exterior stucco is provided on th

V. PROPERTIES OF PAPERCRETE BLOCKS

We tested the above lab scale manufactured papercrete blocks for key properties and following values were obtained:

1) Compressive Strength

Compressive strength tests on 15 cm x 15 cm x 15 cm papercrete cubes revealed an average compressive strength of 0.57 N/mm² after 3 days of cube preparation. Other research also suggests similar results. [1, 5]. For more strength, higher grade of cement can be used.

2) Weight and Density

Density of the material increased with increase in the percentage of cement in the mixture and reduced with increase in the amount of the paper in the mixture. Average weight of 8 cubes casted was observed to be 3.624 kg, thus block density was about 1.07 gm /cc. This is therefore lightweight in comparison to standard concrete or brick masonry units.

3) Shrinkage

Shrinkage measured was between 8-9% in each block.

4) Water absorption

Water absorption of the blocks was about 30% in all cases.

5) Drying time

40 hours at least are needed for drying of papercrete before it can be demolded. After this it should be sundried for 4 days before usage for better strength. Or it can be placed in oven at nearly 70 °C for 40 hours after casting. Putting it at higher temperature than this can result into segregation of material.

Tests for other properties such as 7 day and 28 day compressive strength, thermal resistance, sound insulation, behavior under fire etc. are under progress.

VI. ADVANTAGES OF PAPERCRETE

1. They are light weighted but strong:

Unlike concrete or adobe, papercrete blocks are lightweight, less than a third of the weight of a comparably-sized adobe brick. It is strong enough to hold up the load of roof on "low height" buildings.

2. Easy to use:

It is quick, easy to make and durable as well as fairly inexpensive and while most municipalities would not recognize it as an acceptable building material.

3. Low-cost:

Papercrete is suitable for making low cost homes with limited longevity and durability. They are remarkably

inexpensive, since all the ingredients except for the cement are available for free or nearly free.

4. They can be easily made by everyone:

As the basic constituents of papercrete are only paper, cement and water, it can be easily made by following the steps.

5. They are environmentally friendly:

By the term environmentally friendly, it simply means having a lifestyle that are better for the environment. By using paper in buildings we can significantly decrease amount of paper landing in the landfills. Using the concept of recycling of waste materials, papercrete is not only reducing the amount of cement using but also making it environmentally friendly.

6. They provide good insulation:

According to Jeododibroto (1983), raw material of paper contains a lot of fiber cellulose. The content and coating of paper contain aluminium fiber influence to the heat resistance to building material, so that it can save heat energy to cool the room. Unlike those of concrete where heat from the sun heats the wall up and the concrete allow that heat to pass all the way through and radiate into the interior of the house.

7. Papercrete can be produced by harnessing solar energy.

The only power needed is for the purpose of mixing. Papercrete is far lighter in weight and has remarkable insulating qualities, unlike concrete which is relatively heavy. It can be easily shaped when cured and dried. The most important benefit of papercrete is the reduction of cement in the mix.

Carbon footprint during production, the total cost and weight are reduced, resulting in an eco-friendly and lightweight material. Paper fibers result in excellent heat and sound insulating properties. Papercrete incentivizes there cycling of waste paper, especially in communities

VII. DISADVANTAGES

1. Papercrete is not structural:

It means that they cannot be used over doors and windows without some additional support i.e. either by wood or concrete.

2. It is water absorbent:

Another disadvantage to papercrete is that it absorbs water. One must be careful to put a good protective coating on all exterior surfaces that are meant to expose to rain. It is also not actually to be used on the ground as it will absorb water from the surrounding earth.

3. They have low durability:

Durability is another major issue owing to the tendency of paper to degrade due to thermal, biological and chemical actions like fire, micro- organisms and sulphate and chloride attacks respectively.

4. Papercrete is a brittle material:

In brittle materials, fracture happen mainly due to the presence of flaws on the surface or inside the material where flaws act as crack initiation site. They also stretch elastically when loaded to a certain point but they tend to shatter very quickly if loaded beyond this point.

5. The cost of raw paper will increase:

As papercrete grows in popularity, it will become harder to find enough paper. Right now, there is an overabundance of excess paper, and one can get as much paper as we want for free. As papercrete grows in popularity, people will realize there is a market for old paper and start selling it – thus the cost of building with papercrete will go up.

Certain limitations in the properties can be overcome by below measures:

1. Modification of mix proportions can help achieve optimum properties.
2. Addition of reinforcement like coconut fibre (5%-10%) or fly ash can be done to improve compressive strength of papercrete.
3. Color and texture can be added to papercrete for better aesthetics and design versatility.
4. Addition of silicon, concrete sealer or epoxy compound can help in waterproofing of papercrete.
5. Admixtures can also be added to improve setting and bonding properties.
6. Higher strength can be obtained by using higher grade of cement.
7. Papercrete made with certain mixes are resistant to fire, fungi, and pests to a larger extent.
8. Papercrete blocks made with a sufficient quantity of Portland cement and sand have improved fire resistance.

VIII. CONCLUSIONS

This study was conducted with an aim to learn the small scale preparation of papercrete blocks, its design and construction skills and also had a focus on the assessment of the properties of this building blocks. The study recognized papercrete as a sustainable building material and emphasized on more research towards its performance parameters. The manufacturing, processing and construction techniques are still not developed enough to facilitate its use and this requires extensive amount of research. Papercrete can be developed as a material which is suitable for low cost housing and temporary shelters and offices and can help reduce carbon footprint. It is thus evident that it can be looked upon as a sustainable building material and has a promising future. The study recognized papercrete as a sustainable building material and emphasized on more research towards its performance parameters. Papercrete bricks are suitable for non-load bearing wallsonlyi.e. buildings made from this could be only of one storey. The weight of this brick is $1/3^{\text{rd}}$ to $2/5^{\text{th}}$ lesser than conventional clay brick. These bricks are not suitable for water logging and external walls. It can be used in inner partition walls as they are water absorbent. Due to less weight of these bricks, the total dead load of the building will be reduced. Since, these bricks are relatively light weight and more flexible, they have now become an ideal building material for earthquake prone areas. Papercrete can be developed as a material which is suitable for low cost housing and temporary shelters and offices and can help reduce carbon footprint. But the papercrete should have the following characteristics.

- i) Affordable price
- ii) Ecofriendly
- iii) Thermal insulation
- iv) Less weight
- v) Less water absorption

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