



A Review on Papercrete as a Building Material

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Abstract : *The major problem faced in Construction industry is the environmental pollution . Similarly, Papers were used and reused several times and ends in a form of solid waste. Papercrete is a sustainable building material due to reduced amount of cement usage and recycled paper being put to good use. Papercrete is a one type of fibrous cement, made by shredding paper such as old newspapers, prints, cardboards etc. as pulp in water, Portland cement and sandy soil. 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 thick mix can then be poured into moulds and cast like concrete, to make it into any desired shape and size. Moreover papercrete bricks can also be manufactured. Papercrete bricks are relatively light and more flexible so, they are potentially ideal material for earthquake prone areas. Different parameters such as strength, durability, density and water absorption is determined to check the feasibility. This paper reviews about the environment impact caused by the paper pollution.*

Key Words: *Paper Crete, Sustainable construction, Building blocks, Environmental friendly, Recycled material.*

I. INTRODUCTION

A large amount of non-renewable resources is consumed by the construction industry throughout the world. Everyday tons of waste papers are discarded as landfill or dump sites than those recycled. It is learnt that it takes about fifteen trees to make a ton of paper which means that 720 million trees are used once and then buried as landfills each year. In order to address these issues it has become imperative to push the boundaries of research in the field of innovative sustainable construction materials. Papercrete is also known as fibob, fibrecrete, padobe etc. Papercrete is an innovative composite material developed to build an environmental friendly house made up of paper, cement and water. It has been reported to be a cheap alternatively building construction material, to have a good absorption and thermal insulation, to be a light weight and fire resistant material. When paper is mixed with cement, it creates a very good bond and the final product is both lightweight and strong. Fibres contribute to sound insulation properties and help in crack control. Portland cement is an integral component of the mix and acts as a binder. Cement reduces the drying time and the effect of pulp shrinkage and increases the strength and dimensional stability. However it adds weight to the mix and makes it more brittle. Adding coir, sand, dirt or pumice increases the volume and the mineral content. Sand adds thermal mass and makes the mix stronger and impervious to water but results in heavier structure. 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 known as papercrete is invented.



Figure 1: Papercrete brick

There are three derivatives of papercrete namely fibrous concrete, padobe and fidobe.

- i) Fibrous concrete – mixing of paper, Portland cement and water.
- ii) Padobe – mixture of paper, water and earth with clay.
- iii) Fidobe- It is like padobe, but it may contain other fibrous material

II. LITERATURE REVIEW

*K.Anandaraju et al. (2015) studied and they defined the term „Papercrete“ as a mix of concrete and waste paper. Their exists different types of Papercrete with varying percentage of waste paper. They had not given any thumb rule to inculcate the percentage of waste paper. They used trial mix proportions and determine a standard proportion of Papercrete which provides required physical properties. In their study, they carried out test for many physical properties to determine the best mix, some of these are density, mechanical properties, flame retarded and thermal properties.

*Shivangni Khandelwal et al. (2015) studied the trend of density with varying Papercrete proportions. The conclusion reported that with increase in percentage of waste paper, the density of resulting mix will decrease. In their research, they tested Papercrete for compressive strength and shear strength. The compressive strength ranged between 140-160 lb/square inch and the R-value of Papercrete was in between 2-3 per inch in the test of Papercrete block for shear strength. They also stressed over the inflammability of Papercret as it was not burnt in an open flame.

* Issac I. Akinwumi et al. (2014) worked over two categories of Papercrete former was prepared by waste newspaper whereas waste office paper were used in the later. The specimen thus formed has the respective ratios of cement: sand : waste paper as 1:1:0.2, 1:1:0.4, 1:1:0.6 and 1:1:0 and were tested for density, compressive strength, water absorption and fire resistance. The conclusion drawn revealed that the specimen with waste paper had improved test result than the specimen without waste paper.

*M. Rame Gowdal, K. Prasanna (2014) Studied the Some Properties of Papercrete Concrete and they carried various experimentations on the cubes made with different proportions of cement, sand, paper and fly ash for determination of some engineering and physical properties. They concluded from the results of these experiments that the conventional blocks prepared without paper were bulky and not properly moulded and finished to desired shape whereas the blocks with modified mix had light weight, could be easily moulded to any shape and the finished surface was also very good.

* M.S.SUGANY (2012) Investigated on Papercrete bricks has reported as Papercrete bricks are relatively light weight, and more flexible, these bricks are potentially an ideal material for earthquake prone areas. Papercrete bricks are good sound absorb.

* Dunster Andrew et al. (2007) concluded from their research work that the addition of 20% calcined paper sludge with cement paste modified initial setting-time by accelerating the process in 60 minutes. The incorporation of 10% and 20% thermally activated paper-sludge leads to an increase in the drying shrinkage of mortar 2 and 2.5 times more than that shown by the ordinary Portland cement used as control.

III. MATERIAL DETAILS & EXPERIMENTAL PROCEDURE

1. Materials Used To attain these goals, materials were collected from various sources.

a) 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 53 grade OPC conforming to IS: 8112-1982 gives the properties of cement used.

b) SAND: It is used as a filler material to fit the gap between the aggregates i.e. porosity of concrete is reduced. It also has high tensile strength that results from its fine-grained structure.

The main properties of Sand we used are:

- Specific gravity 2.5
- Water absorption 0.6%
- Fineness modulus 2.

c) 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. Paper is a natural Polymer which consists of wood cellulose, which is the most abundant organic compound on the planet. Cellulose is made of units of monomer glucose (polysaccharide). Wood fragments are thermometrically or mechanically treated to dissolve the lignin binder and to free the cellulose fibers. The Cellulose chains provide more stability and strength. Paper-pulp we used contained 85% of water. Lowest quality of paper was used, i.e. newspaper. Paper was soaked in water for 3 days for preparation of pulp and after that using putty mixer paper pulp was produced.

d) 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.

2. EXPERIMENTAL PROCEDURE

There is no specific procedure for casting the bricks and the procedure followed in this investigation was as per our conveniences. The mix proportion adopted was 1:1.25:2 [Cement: Paper sludge: River Sand & M-Sand]. River sand was used as M-sand has the tendency to absorb more water. The bricks were cast in this ratio and the tests on the bricks were then conducted after 14 and 21 days.

- *Preparation of Paper Sludge :*

The papers used were from a variety of sources. Newspapers, record sheets, magazines, etc., These papers were torn into small pieces and soaked in water for 3 – 4 days until they started degrading to paste like form. Then the papers were removed from water and ground in a mixer to obtain the paper sludge. The pulp is later taken on non-absorbent plate after having the extra water squeezed out. This pulp generating procedure consumed a lot of time and was tedious. But for mass production, mechanically operated tow mixers can be recommended to reduce the cost [4].



Fig.2 Soaked papers and Paper sludge

- *Mixing of dry ingredients:*

The other constituents of papercrete – cement, river sand and M-sand, were dry mixed until a uniform colour was formed. In this work, mixing was manually done and the paper sludge thus obtained was then mixed with it to get the desired papercrete mix. No additional water was added unless it was essential.



Fig 3 Mixing of dry ingredients

- *Mould Specifications:*

Brick mould made of ply wood sheets was used. The sheet is extended to outside for holding the mould while preparation of brick. The dimensions of the mould were that of the modular bricks i.e., 190 mm x 90 mm x 90mm.



Fig.4 Papercrete mould and brick

- *Casting of bricks :*

The mix should be poured in the mould within 30 minutes of mixing on a table and the material was compacted using a tamping rod manually. The extra mix was removed by a metal strike. Two moulds were used at a time to cast the bricks at a faster rate. A few bricks were then sundried for 21 days and a few others were sun-dried for 7 days and later cured in water for the next 14 days.

IV. Tests and Results

Various tests were conducted to analyse the properties of the papercrete bricks and compared with that of the conventional bricks.

➤ *Weight*

The results are to be taken on weight of the papercrete bricks and the conventional bricks which can compare easily. Sun-dried as well as water-cured bricks can be taken for test.

➤ *Compressive Strength Test :*

The test was carried out by a Compression Testing Machine. This test was carried out on the 7th, 14th and 21st day from the date of casting. It was observed while testing the specimens that the bricks did not crush or completely collapse, it just compressed like squeezing a rubber. So the load was applied to half compression. Compressive Strength of Papercrete Bricks With test results, the compressive strength of Papercrete bricks can compare sun-dried and water-cured brick. It can also give elastic behaviour and brittle.



Fig. 5 Compression test on papercrete bricks

➤ *Water Absorption Test :*

The procedure for water absorption test for bricks was conducted as per IS: 3495 – Part 2. A brick is taken and weighed dry. It was then immersed in water for a period of 24 hours. It was weighed again and the difference in weight indicates the amount of water absorbed by the brick. It should not, in any case, exceed 20% of weight of dry brick. Water absorption value of bricks largely influences the bond between brick and mortar. If water absorption in bricks is more and bricks are not soaked before the masonry work, the water from freshly laid mortar is likely to be absorbed by bricks. This results into poor mortar strength as the sufficient quantity of water will not be available for hydration process.

➤ *Efflorescence Test:*

This test was conducted to know the presence of any alkaline matter in papercrete bricks. The brick samples were taken and placed along their ends in a dish. The depth of immersion in water was 2.5 cm. The whole arrangement is placed in a warm, well-ventilated room until the water evaporates in the dish. When the water is completely absorbed and the brick appears to be dry, the same procedure is repeated. The bricks are later examined for efflorescence after second evaporation. If the white deposit covers about 10% surface, the efflorescence is said to be slight and it is considered as moderate, when the white deposit cover about 50% surface. If grey or white deposits are found on more than 50% of surface, the efflorescence becomes heavy and it is treated as serious. Here it can confirm that the bricks are free from soluble salts or any alkaline matter.



Fig.6 Specimen after Efflorescence Test

➤ *Fire Resistance Test :*

A brick which is used for construction should not be flammable in open flame, so this test was carried out for these bricks. The following are the steps involved in this test,

- ♣ First, the brick was wiped with cloths and all the foreign matters were removed.
- ♣ Then the flammable sticks were fired. After that, the bricks were held on the flame for 30 minutes.
- ♣ The bricks were then observed. From the above test, it was observed that the papercrete bricks just smoldered like charcoal. But if these bricks are exposed to fire for several hours, they will become ashes. Interior plaster and exterior stucco should be provided on these bricks, to prevent them from getting burnt.



Fig.7 Fire Resistance Test

➤ *Structure:*

In this test, the bricks were broken and the structures of that bricks were examined, whether they were free from any defects such as holes, lumps, etc., The fibrous concrete brick were cut into equal parts and observed. The structure of the papercrete brick was homogenous, compact, and free from defects and this brick pieces look like a sponge.



Fig 8 Structure of Papercrete

➤ *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 $25 \pm 5^\circ\text{C}$. 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.



Fig 9 Acid resistance test

V. ADVANTAGES AND DISADVANTAGES

➤ **ADVANTAGES OF PAPERCRETE:**

1. They are lightweighted but strong
2. It is quick, easy to make and durable as well as fairly inexpensive and while most municipalities would not recognise it as an acceptable building material.
3. Papercrete is suitable for making low cost homes with limited longevity and durability.
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 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. 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.
7. Papercrete is viable option for low cost housing and temporary shelters and offices.

➤ **DISADVANTAGES:**

1. Papercrete is not structural product. 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.
3. 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. Therefore, they tend to break before their stated limit and the point where such type of failure occurs depends on the size of flaw which again depends on how material was processed or handled.
5. Unavailability of suitable equipments. Machinery designed for use with traditional concrete are built for use with very heavy materials, therefore the machines are heavy and costly.

➤ **APPLICATIONS:**

1. They are largely used in the building of houses.
2. They can be mould into any different shapes to decorate houses, flowerpots, etc.
3. Can be used as sound proofing material.
4. It is less catastrophic than materials like concrete so they can be used in high rise buildings in seismic zones.
5. They can be also used in simple furniture in interiors as it provides aesthetic and opportunity for diverse designs.

VI. CONCLUSION

The study recognized papercrete as a sustainable building material and emphasized on more research towards its performance parameters. 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) Eco friendly iii) Thermal insulation iv) Less weight v) Less water absorption.

From this investigation, the following conclusions can be derived on the basis of the tests:

- A Papercrete brick consists of recycled material and therefore cost is low compared to conventional bricks.
- Papercrete can be easily moulded into any shape, bricks are much easier for someone to lift to any desired height and very good surface finish can be achieved.
- These bricks are not suitable for water logging and external walls. It can be used in inner partition walls. This research is just an initiation to papercrete study.

However, further studies are required on following issues:

- Modification of mix proportions to achieve optimum properties.
- Addition of materials like coconut fibres or fly ash to improve compressive strength of papercrete.
- Colour and texture for better aesthetics and design versatility.
- Addition of silicon, concrete sealer or epoxy compound to help in waterproofing of papercrete
- Admixtures can also be added to improve setting and bonding properties.
- Studies on various other sustainable aspects.

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