Paper Crete: A Sustainable Building Material

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Abstract: Paper Crete 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.

This paper is based on the findings done in a study which was undertaken as a part summer school course work done in this area at CEPT University and illustrates the methods adopted for manufacturing building blocks, studying mechanical properties and construction technology associated with papercrete building blocks. It also looks into the applications, limitations and possible modifications by way of admixtures to overcome some of these limitations.

Keywords: Paper Crete, sustainable construction, building blocks, recycled material

1. 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. Fibers 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. [1] 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.

2. MATERIALS, PROPORTIONING AND MIX PREPARATION

A small scale work related to the material was carried out at CEPT University as part of the summer school program. The following paragraphs illustrate the aspects of production, testing and construction based on this work.

The main materials used for papercrete mix preparation were waste paper (newspaper), Portland cement OPC-53 grade, Sand, Potable water and Soil.

Four types of mixes were prepared for the experiment. Mix proportions by volume in percentages are indicated below:

1) 50% wet paper pulp/ 30% damp earth/ 10% dry sand/ 10% Portland cement

2) 60% wet paper pulp/ 20% damp earth/ 15% dry sand/ 15% Portland cement

3) 65% wet paper pulp/ 25% damp earth/ 10% Portland cement

4) 70% wet paper pulp/ 15% damp earth/ 15% Portland cement

Typically, earth may be sandy dirt, clay or clay-sand mix. It is desirable to have earth with high clay content. The "wet paper pulp" was drained on a screen (can also be done by cloth) and further water was added if required to adjust the workability. The first mix results in a hard and dense material and the following mixes result in comparatively lighter and softer finished material.

The major steps for preparation of blocks and related equipment used are described below:

1. IS sieve 4.75mm was used to remove all coarse aggregate from the sand and soil by temping.

2. Shredded newspaper was wetted in water in the curing tank and a motor run machine called the pulp beater machine was used to obtain wet paper pulp.

3. Next, the soil, sand, pulp and cement were mixed into a more uniform and consistent mass with help of a cement mixer. The mixer machine was allowed to work for around 3 to 4 minutes to obtain papercrete.

4. Wooden moulds were prepared in the experiment but acrylic or plastic sheets can also be used for mould. The moulds were then greased with burnt oil or taping was done on the moulds which may help in releasing the blocks quickly and easily.

5. The papercrete mix was then poured into moulds and compacted on a vibrating to remove voids and achieve more density, resulting in stronger and more durable product. Temping bar was also used for the same purpose.

6. The mix was then leveled to achieve satisfactory dimensions and finish.

7. After 40 hours, papercrete seemed to attain sufficient amount of strength after which the moulds were released and casted blocks were allowed to sundry for further strength gain and development of load carrying capacity.

Small structures in compression such as compound wall and arch were constructed as part of the experiment. The masonry unit was bonded using mortar for the compound wall and fitted without mortar using a key and hole mechanism inbuilt in the form of the block. Three types of mortar were prepared for bonding: (a) Cement, sand and water (C:S-1:4) (b) Cement, sand, water and paper pulp (C:S:P- 1:4:6) and (c) Cement, paper pulp and water (C:P:W-2:4:1). The last one was found to be most appropriate and it was used for providing proper strength and bonding in the papercrete masonry.

3. PROPERTIES OF PAPERCRETE

The above lab scale manufactured papercrete blocks were tested for key properties and following values were obtained.

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/mm^2 after 3 days of cube preparation. Other research also suggests similar results. [1, 5]. For more strength, higher grade of cement can be used.

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.

Shrinkage

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

Water absorption

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

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.

4. APPLICATIONS

Figure 1 :papercrete interlocking arch made by jil,dhruv,shivam,aakansha and devisha as a group.

As part of the summer school work, a group of 30 students conceived and designed various structures like interlocking arch (180 cm radius) which did not need any binder for joinery (Refer fig). Other structures constructed on campus included seating, a funicular shed and a compound wall. Apart from this, papercrete can be used for plastering and can be given any form, be it panels or curved elements. Literature illustrates its uses for partition walls, and façade material where benefit of dead load reduction of the structure is obtained. It can be used in interiors as it provides aesthetics and opportunity for diverse designs. High rise buildings in seismic zone can use papercrete as it is less catastrophic then other materials like concrete but due to limitations in some other properties such as behavior towards fire, durability concerns, biodegradability etc. it requires a significant amount of research for justifying its applications.Houses of paper may be trend of future.[4]

5. ADVANTAGES AND DISADVANTAGES OF PAPERCRETE

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 the recycling of waste paper, especially in communities with no recycling services. Papercrete is viable option for low cost housing and temporary shelters and offices. Crises of building materials lead to high demand and need for recycling industrial waste or finding alternative source. Wastepaper helps in low- cost, eco friendly and therefore, sustainable design. In India's context only a fraction of paper is recycled annually. This means that the rest is still disposed off, mostly ending up in landfills for slow degradation and capacity consumption of dumpsites. Conservatively speaking, it takes about 15 trees to make 1 ton of paper.[2] As it is recycled material, there is a benefit in embodied energy due to reutilization. It has good thermal and sound insulation properties.

The material has certain limitations in its application.[3] Apart from the fact that the material is still to be recognized and researched, there are also major obvious shortfalls in the materials mechanical and chemical properties. Lack of literature, official data or guidelines on its preparation, structural behavior or long term viability is one of the constraints for commercial usage of the material. Papercrete is a brittle material. It expands and contracts frequently leading to cracks, bulging and buckling and it has very low tensile strength. It is difficult to exercise quality control of the mix batches and obtain smooth surface. There is also a major issues of dimensional stability. Also, it is not waterproof and flameproof and this is not desirable for building applications. The production of papercrete units uses a large quantum of water. Durability is another major issue owing to the tendency of paper to degrage due to thermal, biological and chemical action.

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 fiber (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.

6. CONCLUSION

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.

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