Structural Properties of Papercrete Interlocking Wall Panels

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***Abstract*—The construction sector has access to various building blocks, but a new study aims to utilize wastepaper as an alternative material for building blocks. The study focuses on creating lightweight composite blocks and utilizing wastepaper for low-cost production. The aim is to determine the properties of papercrete wall panels, including weight, compressive strength, water absorption, heat resistance, and hardness, by incorporating wastepaper. Papercrete provides an effective way to recycle paper waste into inexpensive papercrete wall panel walls that are strong, offer high sound absorption, insulation, and aesthetic appeal. The study involved adding 10%, 20%, and 30% paper pulp to concrete and casting the papercrete wall panels in different trial mixes, then comparing the results to conventional papercrete wall panel and concrete. The use of paper pulp in concrete was found to be cost-effective, lightweight, eco-friendly, and can contribute to solving solid waste management problems, leading to low-cost housing.**

Keywords—Low-Cost Material, Waste Material, Papercrete, Compressive Strength, Papercrete wall panel Masonry.

I. INTRODUCTION

Papercrete, a material that was first developed 100 years ago, has recently been rediscovered. With the demand for paper expected to reach 500 million tons per annul by the end of 2025, civil engineers have been challenged to transform commercial waste into beneficial construction materials. One such recycling possibility is the use of wastepaper as a construction material. The construction industry uses a large quantity of non-renewable resources, and the potential characteristics of wastepaper for producing low-cost and lightweight composite wall panels can not only provide a way to recycle wastepaper, but also reduce the demand on global resources. Papercrete is a new composite material that partially replaces Portland cement with wastepaper, thereby reducing the amount of cement used and making it an environmentally friendly building material. The fibers from wastepaper add strength to the cement, making it a lightweight and strong alternative building material. The process of making papercrete involves soaking wastepaper in water overnight to soften the fibres, mixing the paper pulp with Portland cement, sand, and water, pouring the mixture into forms, and allowing it to dry. Papercrete promotes the recycling of waste Papercrete, a material that was first developed 100 years ago, has recently been rediscovered. With the demand for paper expected to reach 500 million tons per annul by the end of 2025, civil engineers have been challenged to transform commercial waste into beneficial construction materials. One such recycling possibility is the use of wastepaper as a construction material. The construction industry uses a large quantity of non-renewable resources, and the potential characteristics of wastepaper for producing low-cost and lightweight composite wall panels can not only provide a way to recycle wastepaper, but also reduce the demand for global resources. Papercrete is a new composite material that partially replaces Portland cement with wastepaper, thereby reducing the amount of cement used and making it an environmentally friendly building material. The fibers from wastepaper add strength to the cement, making it a lightweight and strong alternative building material. The process of making papercrete involves soaking wastepaper in water overnight to soften the fibers, mixing the paper pulp with Portland cement, sand, and water, pouring the mixture into forms, and allowing it to dry. Papercrete promotes the recycling of wastepaper, saves landfill space, and reduces the use of trees and other construction resources. paper, saves landfill

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II. OBJECTIVES

1. To utilize the waste materials like paper, silica etc., in the process of manufacturing new types of eco-friendly wall panels.
2. To produce and research the strength and durability of papercrete wall panels to employ them successfully in commercially for construction purposes.
3. To extend the investigation further to study the structural behavior of the papercrete wall panel masonry experimental.

III. SCOPE OF STUDY

1. The review of the literature indicates that the papercrete building papercrete wall panel enhances its various mechanical properties, dimensional stability, and structural integrity.
2. An attempt has been made in the present investigation to conduct an experimental program to study the strength, durability, energy absorption capacity and ductility of silica-fume-based papercrete wall panels.

IV. GAPS TO BE FOUND

1. The effect of other supplementary cementation materials like meta kaolin, blast furnace slag, ground granulated blast furnace slag, etc. similarly, working on the strength and durability of lightweight papercrete can be rewarding.
2. The strength and durability of other papercrete building elements like wall panels, floor slabs, etc.
3.The strength and behaviour of reinforced papercrete structural members like beams, slabs, etc.

V. MATERIALS FOR PAPERCRETE

A. Paper

Cellulose is a natural polymer that is composed of wood cellulose, which is the most abundant organic compound on the planet. It is made up of monomer glucose units that are linked together in a polysaccharide chain. Despite containing several hydroxyl groups, cellulose is insoluble in water due to the stiffness of the chains and the hydrogen bonding that occurs between adjacent chains. This bonding creates hard, crystalline regions that provide strength and stability to the cellulose. The strength of papercrete is also based on this hydrogen bonding, which is broken when a force is applied to the paper. By coating the cellulose fibres with Portland cement, a cement matrix is created that encases the fibres, providing extra strength to the mix. The polar -OH groups on the cellulose chain form numerous hydrogen bonds with adjacent chains, bundling them together.

B. Cement

Portland cement, is a fine Grey powder that serves as a binding material and is commonly used in construction. Portland cement is a mixture of chalk or limestone and clay that sets, hardens, and adheres to other materials to bind them together. It is typically used in combination with sand and gravel (aggregate) to create concrete, or with fine aggregate to produce mortar for masonry. In India, OPC is manufactured in three grades: 33 grades, 43 grade, and 53 grade. After 28 days, the compressive strength the of cement is determined according to standard testing procedures. The study in question utilized 53-grade OPC.

C. Sand

Sand particles are composed of small grains of silica (SiO2) that are the result of the decomposition of sandstone caused by weather requires conditions. There are different types of sand based on the natural resource from which they are obtained, such as Pit sand, River sand, and Sea sand, and they can be classified according to the grain size as fine, coarse, or gravel. The properties of sand are tested based on the standards set by the Bureau of Indian Standards (BIS). However, one drawback of using fine-aggregate concrete is that it is more binder, resulting in increased shrinkage and creep. In this study, M sand, which is available locally and passes through a 4.75mm IS sieve, was used.

D. Water

Water plays a crucial role in the chemical reaction between cement and paper fibres in the production of papercrete. Therefore, it is a significant ingredient in the mixture. The water used in making papercrete should not contain any organic matter and its pH value should range between 6 and 7.

E. Fly-ash

Fly ash, also known as coal ash, is a residue produced during combustion that consists of fine particles carried by flue gases. Using ash as a substitute for sand has the potential to provide significant benefits in terms of reducing environmental impact. The study examines the use of ash as a replacement material for cement to enhance the properties of papercrete. For this purpose, Class F fly ash is employed.

F. Silica Fume

Silica fume particles have a diameter between 0.1 to 0.2 microns and a surface area of approximately 30,000 m^2/kg. Their density ranges from 150 to 700 kg/m^3, with an optimal density of around 550 kg/m^3 for use as a concrete additive.

VI.PREPARATION OF PANELS

A) Pulp Generation

Before using wastepaper to make papercrete, it needs to be processed. The paper is shredded to remove any pins, threads, or other materials present. The shredded paper is then soaked in water for 3 to 5 days to form a paste. After this, the paper is ground in a mixer to obtain paper sludge, and the excess water is squeezed out. The resulting pulp is then placed on a non-absorbent plate.

Fig 1. wastepaper

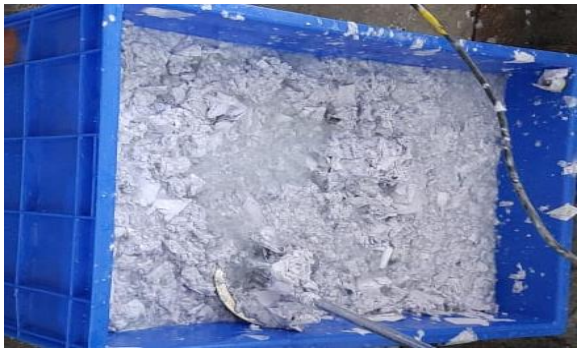

Fig 2. paper plub

B) Preparation of Paper Particles

The excess water from the paper is expelled from the method of squeezing the paper pulp in a gunny bag, which is used for packing materials for construction. The squeezed pulp is let dry for a day or two before usage of pulp for casting papercrete wall panels.

Fig 3. Dry weight paper pulb

C)MIXING OF SPECIMEN

A) Mix Proportion.

The mixture proportion chosen was 1:1:2, which means that for each part of cement, one part of sand and two parts of the paper were used. Currently, there is no code specifying the mix proportion for papercrete. Various types of papercrete wall panels were produced, with the first type made from a mixture of cement, sand, and paper pulp at different proportions. The other types of papercrete wall panels were made by replacing cement with fly ash and lime, at varying mix proportions, along with sand and paper pulp.

Table 1. mix preparation.

S.No.	Mix Designation	Mix Proportions					
		C	FA	S	P	G	SF
1	P1	1	--	7	12	--	--
2	P2	1	1.0	7	12	--	--
3	P3	1	1.5	6	12	--	500
4	C1	1	--	6	--	6	--

B) Mixing of dry ingredients

The remaining components of the papercrete, which are cement, fly ash, lime, and sand, were combined in a dry state until a consistent colour was achieved. The mixing process was carried out manually, and the paper sludge was subsequently mixed in to obtain the desired papercrete mixture. Extra water was only included if necessary.

Fig 4. mixing the dry ingredient of paperplub

Fig 5. Mixing the sand and cement

Fig 6. Mixing all ingredients

VI.CASTING OF PANELS.

This study examined 10 different types of moulds with a size of 500mm x 550mm x 100mm, with various proportions of cement, sand, fly ash, paper, and lime as variables. The binding material used was OPC 53 cement. The process of making papercrete involved soaking wastepaper in water overnight to soften the fibres and then thoroughly agitating the mix to create a homogeneous pulp. The pulp was then mixed with Portland cement, sand, and water before being poured into moulds to create papercrete wall panels. The forms were removed after 24 hours, and the papercrete wall panels were left to air cure for 28 days before testing.

Fig 7. Casting the specimen

VII. EXPERIMENTAL STUDY

a) Properties of Papercrete

Properties	Values
Weight	47 GSM
Thickness	0.06 mm
Moisture	7.5%
Bursting Strength	168 k. Pa
Tearing resistance	12.6 kg
Tensile Strength	1.13 kg
Porosity	475 ml. s/minute

The term "papercrete" can be misleading since it implies that it is a mixture of paper and concrete. However, papercrete can be produced in various ways, and it usually consists of 50% to 80% wastepaper.

b) Properties of Silica-Fume:

Components	Percentage (%) by Weight
Silica as SiO_2	89.6
Iron as Fe_2O_3	1.6
Alumina as Al_2O_3	0.9
Calcium as CaO	0.6
Magnesium as MgO	1.0
Alkalis as Na_2O	1.3
Loss on ignition	5

c) Properties of Cement

Properties	Values
	Silica Fume
Moisture content (%)	Nil
Blaine Specific Surface Area (cm^2/g)	29,800
Specific gravity	2.45
Strength index compares with control mortars (%) at 28 days	86
Water absorption (by weight)	Up to 10%

d) Properties of Fumed – Silica.

Properties	Results Obtained	Requirements of IS 8112 - 1989
Fineness (by sieve analysis)	4.6%	Less than 10%
Specific Surface Area (cm^2/g)	2,880	Not less than 2250
Specific gravity	3.15	3.15
Initial setting time (Minutes)	32	Not less than 30
Final setting time (Minutes)	490	Not more than 600
Compressive Strength (MPa) At 3 days At 7days At 28 days	 28 41 52	 23 33 43

VIII. RESULTS & DISCUSSION

A) *Compressive Strength:*

Numerous investigations have been conducted by researchers on papercrete, with varying results on its compressive strength. For instance, Kelly Hart's study indicated a compressive strength of 1.7 MPa, while Fuller reported a range of 0.96-1.1 MPa for papercrete. Meanwhile, Kokkinos' research at TU Delft in the Netherlands found that the average compressive strength of a papercrete cube was 1.12 MPa, with the highest compressive strength recorded at 2.36 MPa.

B) *Weight and Density:*

In 2006, Titzman conducted research on the weight density of papercrete, which revealed that the density of the material increased as the percentage of cement in the mixture increased. Conversely, as the amount of paper in the mixture increased, the density decreased. Yung et al. conducted further research, which showed that th`e density of papercrete decreased as the replacement ratio of wastepaper increased. For instance, when the paper replacement ratio was 5%, the density was measured at 1.88 g/cm³ (1800 kg/m3), but it was reduced to 15% and 22%, respectively, by increasing the paper ratio to 10% and 15%.

C) *Tensile strength*

Titzman's investigation into the tensile strength of papercrete revealed that its tensile strength was notably low. Specifically, the papercrete exhibited a maximum tensile strength of 28.3 MPa and a minimum of 0.195 to 0.052 MPa.

D) *Thermal Conductivity and Insulation*

Barry Fuller's research on thermal conductivity demonstrated that papercrete has an R-value between 2.0 and 3.0 per inch (0.078–0.12 per mm) with a wall thickness of 12-16 inches (304.8-406.4 mm) for one or two-story houses. Meanwhile, Titzman's research revealed that papercrete's thermal conductivity was 0.10 W/(m·K), while that of concrete was between 1.25 and 1.75 W/(m·K). As a result, papercrete provides much greater insulation than concrete due to its significantly lower thermal conductivity.

IX. CONCLUSION

The process for creating papercrete involves several steps. First, paper is shredded into small pieces and then soaked in water for several days. Next, the wet paper is mixed with cement, sand, and other additives to create a slurry. This mixture is then poured into melds or applied as a coating onto a frame. Finally, the material is left to dry and harden. Compared to wood or concrete, papercrete is much lighter, has excellent water absorption and insulation properties, experiences less shrinkage, and is environmentally friendly with a high strength-to-weight ratio. Although further research is necessary, papercrete could be used to reduce the dead weight of structural elements in cases without special loads. Furthermore, as 55% of paper waste around the globe is still not recycled, a significant portion of it could be used to manufacture papercrete. Future research could focus on improving its tensile strength, opening possibilities for papercrete as a construction material worldwide.

REFERENCES

1. Gunarto A, Satyarno I, Tjokrodimuljo K. “Newsprint Paper Waste Exploiting for Papercrete

Panel." Institute of Research Center, Gadjah Mada University. 2008.
2.Malthy R, Jegatheeswaran D. "Comparative study on papercrete bricks with conventional bricks." ICI Journal. January–March 2011.
3. Mohammed BS. "Papercrete as infill materials for composite wall system." European Journal of Scientific Research. 2009; 34(4): 455p
4.Titzman LC. "Analysis of low-cost building material for the mix also process." Dissertation. Texas A & MUniversity.2006
5.Fuller B, Fafitis A, "Santamaria Structural properties of a new material made of wastepaper". Building Integrated Solution, ASCE. 2006.
6. Gallardo RS, Adajar MA. "Structural performance of concrete with paper sludge as fine aggregates partial replacement enhanced with admixtures. Symposium on Infrastructure Development and the Environment." 2006.
7.Yun H, Jung H, Choi C. "Mechanical properties of papercrete containing wastepaper. Architectural Institute of Korea. 18 TH International Conference on Composite Materials."2007
8.Sharmala YD, Varma MB. Papercrete: "An efficient use of wastepaper. Recent Trends in Civil Engineering & Technology." 2015; 2(3): 54–59p.