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Papercrete as a Sustainable Building Material- An Experimental Study

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Abstract -*The high demand of concrete creates a situation to think about creating a sustainable and economic concrete. One such solution was the evolution of papercrete which is sustainable, environment friendly and moreover cost effective. Papercrete is thus the mixture of cement, fine aggregates, paper-pulp and water. Papercrete has good fire resistance, thermal insulation and sound absorption properties. Many researches are being carried out globally on this concrete but it is yet to be acknowledged by Indian codes and practices.*

The present work is a modification for Papercrete to reduce water content and thereby improving the properties. The experimental results for compressive strength, water absorption and heating tests are included in this paper. Thus, an experimental study was carried out to investigate the potential use of papercrete as a low cost and environment friendly building material.

***Key Words*: Papercrete, Water absorption, Compressive strength**

1. INTRODUCTION

With increase in population due to industrialization and urbanization, an increasing demand is being placed on the construction industry to create a greater number of structures. This in turn increases the demand for a large number of materials for making concrete. Hence, these resources are being depleted at an alarming rate. As a result, there a need for alternate materials that can be used as a substitute for making of concrete. One such material that can be used as replacement is waste paper. A large amount of paper is being generated and discarded. Tons of waste paper ends up in dump yards and landfills each day. Making use of such waste paper to make concrete is a positive approach made in construction practices. It constitutes a step towards sustainable development.

By using waste paper to make concrete, a new material called Papercrete is formed. Papercrete is similar to conventional concrete and is more eco-friendly. It is a composite material made up of paper, cement and water. Using these materials leads to cost reduction that would otherwise be present for conventional concrete with aggregates. Making use of waste paper to make concrete would lead to reduction of waste generation thus reducing the waste that ends up in landfills. Papercrete has good sound absorption and thermal insulation properties. Paper generally has a high-water absorption. Hence, to curb this problem water proofing compounds can be added. This significantly reduces the problem of water absorption. Papercrete bricks are of low density and so these can be used for light weight construction purposes. By using papercrete, the paper is added in partial replacement to cement. This reduces the amount of cement used in the mix. It holds shape well and is remarkably strong. As around 80% of the material is recycled it is a sustainable material which reduces the overall carbon footprint as well.

Papercrete is a recently developed material and is slowly gaining recognition for its numerous properties and usage. Any kind of waste paper can be used for the making of papercrete such as newspapers, magazines, cardboards etc. Papercrete has three main derivatives which are:

- Fibrous Concrete

It is a mixture of paper, Portland cement and water. It is an eco-friendly material as there are no harmful effects produced and no by-products to the making of this concrete. Cement is only being used in a small proportion to the paper.

- Padobe

It is a mixture of paper, water and earth with clay. Hence there is no cement being used in Padobe. Clay is used as the binding material here.

- Fidobe

This is just like Padobe. The difference is that it may contain other fibrous materials as well.

Fig-1: Papercrete Blocks

2. PAST STUDIES

- A REVIEW ON PAPERCRETE

The authors **Khonica et al. (2017)** discuss about using papercrete as a substitute material as to the conventional concrete. It reduces the negative impact on the environment and puts waste paper to good use. The various characteristics of papercrete such as crushing strength, shape, size, absorption etc. are discussed in detail. From this it could be understood that papercrete has almost similar properties as that of the conventional concrete and that it was used as a suitable replacement to the conventional concrete. Various advantages and disadvantages are discussed as well. These bricks are more efficient when used as non-load bearing walls as in one-storied building. As the papercrete brick are lightweight, they can be used in earthquake prone areas. Also, by using papercrete carbon footprint can be considerably reduced.

- PROPERTIES OF PAPERCRETE

The authors **Iqbal et al. (2017)** mentions of the various properties of papercrete. Papercrete has good thermal insulation, sound absorption and fire resistance properties. The amount of paper used in various percentages by weight of cement was tried out to find which percentage yielded the best properties of compressive strength, split tensile strength, flexural strength, density etc. The materials required for making papercrete are cement, fine aggregate, coarse aggregate, waste paper, water proofing compounds or superplasticizers. Tests were conducted on fresh concrete and hardened concrete. The water absorption is shown to be decreased due to the addition of the superplasticizer. It could be seen that papercrete has a low bulk density which shows that it can be used to produce lightweight concrete structures. The mixture with 5% paper pulp yielded the best results.

- EXPERIMENTAL INVESTIGATION OF PAPERCRETE CONCRETE

The work done by **T. Subramani et al. (2015)** was reviewed. The increasing population demands a large number of structures to be constructed which in turn uses a large amount of concrete. Due to this the material sources are being exhausted at an alarming rate. As a result, there is a need for substitute materials for construction. Papercrete is made out of the waste paper that is being accumulated all around the world. This usage of waste paper reduces the amount of waste produced and in turn reduces the global impact on the environment. Various materials that are used for making the papercrete are discussed and the manufacturing process is carried out to make the papercrete bricks. Water proofing compounds are added to the mixture in order to reduce the water absorption of papercrete. Tests were performed to check the strength parameters. By using papercrete, the overall cost can be reduced significantly.

3. METHODOLOGY

Trial mixes were prepared by replacement of various percentages of cement by fly ash (normal papercrete, 30% fly ash papercrete and 50% fly ash papercrete). Trial mix for M15 (1:2:4) (cement: paper: quarry dust) concrete was done. Water proofing compounds were also added.

Manufacturing Process

3.1 Collection of Material

The constituents used in preparing the papercrete mixture and their properties, to attain these goals, minerals were collected from various sources. In any project Material collection is the basic and important step. Yet, the materials that is used in a project should not cause any damage to environment.
The various materials include:
1) Ordinary Portland cement
2) Fly ash
3) Fine aggregate
4) Coarse aggregate
5) Paper pulp
6) Water proofing admixtures

- Ordinary Portland Cement

Among the various kinds cement it is the most commonly used binding material. It is a mixture of chalk or limestone together with clay.
Cement can be defined as a substance used in construction that sets, hardens and adheres to other materials. Cement is used with sand and gravel aggregate to produce concrete.

- Fly ash

Also known as fuel-ash, is one of the residues generated in combustion and comprises the fine particles that rise with the flue gases.
Fly ashes often replaces up to 30% by mass of Portland cement, but can be used in higher dosages in certain applications. It is practically revealed that designed strengths achieved with 40 to 50% replacement of cement.

- Fine Aggregate

Sand particles consists of small grains of silica, which is formed due to various effects of weather.

- Paper

Natural polymer consists of wood cellulose, which is the most abundant organic compound. Hydrogen bonds between water and the cellulose molecule is broken, by applying a force on the paper. coating cellulose fibres with Portland cement creates a cement matrix, which encases extra strength to the mix.

- Water Proofing Compounds

Paper is the major ingredient in papercrete mix and it is a full water absorbable material.
To minimize water absorption, water proofing admixtures were used as one of the additive admixtures in papercrete.

3.2 Weighing and Batching

For every concrete work batching of concrete is an essential task Batching can be defined as a process, in which the quantity or proportion of materials like cement, aggregates, paper pulp etc are measured on the basis of weight or volume to prepare the mix. The batching helps to improve the workability of concrete, to achieve a smooth surface of the concrete, increases the speed of the construction, reduces the wastage of concrete ingredients.

3.3 Mixing

The paper which was collected could not be used directly, before mixing with other ingredients, papers were converted in to slurry form, known as pulp. First the pins, threads and other materials were removed then the paper is torn in to small pieces and all the torn pieces of paper were immersed in water for 3 to 5 days, and they soon degraded in to paste like form.

After that period, the papers were taken out from water tank and shredded in to little pieces. Using the mixing machine, the small papers were converted in to pulp. The paper pulp has residual waste in itself, and is good enough for mixing the ingredients. And all the dry mixes were added according to the proportions and were mixed thoroughly.

Fig-2: Mixing of Paper

3.4 Placing

After mixing, the mixes were placed in mould of dimension 15cm x 15cm x 15cm. Before mixing the mould was ready for casting the specimen. Machine oil was applied to the inner surface of mould for easy removing of mould and without causing any damage to the specimen. The specimen was kept on a vibrating table. The Papercrete mix was filled in the mould in three layers and was fully compacted. Casting was completed and then the specimen was laid on the laying table.

3.5 Compacting

Compaction is a process done in freshly placed concrete where the entrapped air is expelled and the aggregate particles are packed together so as to increase the density of concrete. Compaction is mostly carried out using vibrators.

Fig-3: Compacting of Papercrete

Fig-4: Compacted Papercrete

3.6 Curing

Curing is the process of maintaining moisture levels inside cast concrete so that hydration can continue. It maintains a favorable temperature for hydration to occur for a definite period and prevents or replenishes the loss of moisture from the concrete. Papercrete requires a period of 28 days for curing.

3.7 Testing

Tests Done on Papercrete:

1. Soundness test
2. Structure of Papercrete Blocks
3. Efflorescence test
4. Water absorption test
5. Compressive strength test
6. Heat Test

- SOUNDNESS TEST

Soundness test is usually done on bricks. But here we have done this test on papercrete blocks so as to analyze its properties.

Soundness test shows the nature of these blocks against sudden impact. The blocks are chosen randomly and struck with one another. Then sound produced should be clear bell ringing sound and blocks should not break. Then it's said to be a good block.

- STRUCTURE OF PAPERCRETE BLOCKS

To know the structure of blocks, pick one block randomly from the group and break it. Observe the inner portion of the block clearly. It should be free from lumps and homogeneous.

- EFFLORESCENCE TEST

A good quality block should not contain any soluble salts in it. If soluble salts are there, then it will cause efflorescence on the block surface. To know the presence of soluble salts in a block, place it in a water bath for 24 hours and dry it in shade. After drying, observe the block surface thoroughly. The presence of white or grey color deposits indicates that it contains soluble salts and is not useful for construction.

- WATER ABSORPTION TEST

Water absorption test is conducted on blocks to find out the amount of moisture content absorbed by blocks under extreme conditions. In this test, sample dry blocks are taken and weighed. Bricks are placed in water with full immersing for a period of 24 hours after weighing. Then the wet bricks are weighed and values are noted. The difference between dry and wet weights will give the amount of water absorption. For a good quality block, the amount the amount of water absorption should not exceed 20% of weight of dry brick.

- COMPRESSIVE STRENGTH TEST

Crushing strength of blocks are determined by placing blocks in compression testing machine. After placing the block in compression testing machine, apply load on it until block breaks. Note down the value of failure load and find out the compressive strength.

Fig-5: Compression of Papercrete

4. RESULTS

- SOUNDNESS TEST

Two blocks were randomly chosen and struck against each other. When struck, it produced a distinct ringing sound. It did not break when struck. Hence, we can say that it is a good block.

- STRUCTURE OF PAPERCRETE BLOCKS

A papercrete block was selected randomly and was broken. The inner surface of the block was inspected. There were little to no lumps inside.

- EFFLORESCENCE TEST

A block was selected in random and placed in a water bath for 24 hours. Then it was taken out and dried in a shade. After that the surface of the block was checked. The surface was free from any visible colour changes. Hence, there are no soluble salts present in the block and can be used for construction purposes.

- WATER ABSORPTION TEST

The results for water absorption tests for different proportions of fly ash in papercrete are presented in table 1. From the table it can be understand that the papercrete with 30% fly ash has the least water absorption. Normal papercrete with 50% fly ash has similar values of water absorption. Hence the effective value of fly as can be selected is 30% fly ash papercrete.

Table-1: Results obtained for water absorption test

Particulars	Normal Papercrete	30% Fly Ash Papercrete	50% Fly Ash Papercrete
Dry weight (Kg)	7.570	7.572	7.125
Wet weight (kg)	7.636	7.565	7.178
Water absorption (%)	2.5	2	2.4

- COMPRESSIVE STRENGTH TEST

The papercrete cubes were tested for compressive strength after 28 days of curing. The values are presented in Table 2. From the table we understand that the papercrete with 30% fly ash proportion has the most compressive strength when compared to other two blocks.

Table-2: Compressive strength test results

Particulars	Normal Papercrete	30% Fly Ash Papercrete	50% Fly Ash Papercrete
Compressive Strength (N/mm^2)	18.32	21.1	17.268

- HEATING TEST

Table-3: Weight Comparison between Normal block and Papercrete block before Heat Test

Normal concrete cube (Kg)	Papercrete Cube (30%)	Papercrete Cube (50%)
8.132	7.86	7.65

Table-4: Weight Comparison after Heat Test

Normal concrete cube (Kg)	Papercrete cube (30%)	Papercrete Cube (50%)
8.06	7.8	7.52

- COMPRESSIVE STRENGTH AFTER FIRE TEST

Table-5: Results for strength after fire test

Normal cube (N/mm^2)	Papercrete (30%)	Papercrete (50%)
21.11	20.84	19.9

From the results it was clear that there were no considerable changes in papercrete blocks after heating. Weight and compressive strength were same.

6. CONCLUSIONS

The study was conducted with an aim to improve the properties or papercrete and the following conclusions were drawn:

1. The low bulk density of papercrete shows that this could be an important alternative environment friendly and sustainable resource to produce lightweight concrete

2. Addition of fly ash and water proofing compounds has resulted in reduction of water absorption

3. 30% replacement of cement by fly ash reduces the water absorption of papercrete than 50% replacement of cement by fly ash.

4. 30% replacement of cement by fly ash increases the compressive strength of papercrete than the normal papercrete blocks

5. Usage of papercrete leads to reduction in construction cost to about 10 to 20%

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