

RESEARCH ARTICLE



ISSN: 2321-7758

STUDY AND BEHAVIOR OF SOME PROPERTIES OF PAPERCRETE BRICK WITH MODULAR BRICK

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Article Received:07/05/2015

Article Revised on:15/05/2015

Article Accepted on:19/05/2015

ABSTRACT



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The construction industry consumes a large amount of non-renewable resources. Our project aimed to utilize the waste paper to use as a construction material constitutes a step towards sustainable development. For this effort two different mix proportions [1:1:1], [1:1.25:1.5] are used to make bricks. The bricks are made of normal mix and aggregate based mix in above two proportions. For normal mix Portland cement, sand, sludge is used. In case of aggregate based mix, paper sludge is replaced by coarse aggregate by 5%,10% and 15% respectively to investigate some properties like strength, water absorption, fire resistance, hardness, soundness etc by conducting the different tests on prepared bricks. While using paper pulp to make bricks, it reduces approximately 50% weight of the brick. Therefore these bricks will reduce the dead weight of the structure to considerable amount. So it changes our design and building cost as in economical point of view.

KEY WORDS: Papercrete brick, compression test, Effloracence test

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INTRODUCTION

Papercrete is a new composite material using waste paper as a partial replacement of Portland cement. This increase in the popularity of using environmental friendly, low-cost and light weight construction materials in building industry has brought about the need to investigate how this can be achieved by benefiting the environment as well as maintaining the material requirements affirmed in the standards. As natural sources of aggregates are becoming exhausted, it turns out urgent to develop. The majority of abandoned paper waste is accumulated from the countries all over the world causes certain serious environmental problems. Papercrete is a recently developed construction

material which consists of re-pulped paper fiber with Portland cement. Papercrete is a construction material which consists of cement and fine aggregate. It is perceived as an environmental friendly material due to the significant recycled content, by the presence of cement. It is an important building material that is light weight, insulate and low cost concrete. It is cost-effective, relies on locally available materials, but it is insect free, fire resistant, durable and great potential as a low carbon building material. Papercrete, known by alternative names such as fibrous concrete, padobe and fidobe, low carbon construction material, 45% of discarded papers is recycled annually; 55% thrown away or goes in to the land fill. Therefore efforts

have been made to utilize the waste paper in to concrete and form a Papercrete. It is a construction material which consists of paper slurry, white lime and Portland cement. Papercrete is mould resistant and has the ability to absorb energy and can be used in many applications requiring sound-proofing material. Also, Papercrete blocks won't deteriorate if left out in the rain, since the paper fibers bind the blocks together. The strength of Papercrete as engineering materials appears to lie in their ability to absorb energy and can be used in many applications requiring sound absorption and fire resistance.

2. LITERATURE REVIEW

I. M.S.SUGANY¹ "Light weight bricks-Made up of waste papers" International Journal of Computer & Organization Trends, Volume-2, Special Issue-2, Number-2, April 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 absorbent so, these bricks can be used in auditoriums. Since, the waste materials are used; it will reduce the landfills and pollution.

II. M. Rame Gowda¹, K. Prasanna² "Development and study of some properties of Papercrete concrete", ICJ Special Issue, Volume- 88, October 2014. Carried an experimental work on Papercrete concrete cubes made with cement, sand, paper and fly ash in different mix proportions for determine the some properties. They had reported as Papercrete can easily be moulded into any desired shape, light in weight compared to conventional blocks and very good surface finish can be achieved.

III. Agilan.V¹ has carried out experiments on bricks after 21 days from date of casting of bricks. He has reported as Papercrete bricks are used for non-load bearing walls. He was compared these bricks based on their weights and he has reported as the weight of this brick is 1/3rd to 2/5th lesser than conventional clay brick

IV. H. JUNG¹, H. YUN², "Mechanical properties of Papercrete containing waste paper" has done the investigation on bricks for finding the mechanical properties of waste paper. They reported as the density of Papercrete was decreased when the replacement ratio of waste paper of Papercrete increased and the shrinkage of Papercrete was

increased according to increase of paper-cement replacement

3. PROJECT PHILOSOPHY

In order to accomplish the aforesaid objectives, the research work has been divided into four major parts. They are:

1. Collection Materials and their properties
2. Specimen making
3. Preliminary tests

1. Collection of Materials and their properties: To attain these goals, materials were collected from various sources. Material collection is the basic and important step in any project. Yet, the material that is used in a project should not cause any damage to the environment.

PAPER:

In this study, paper is the main constituent material. Different types of Papers are like newspapers, record sheets, old newspapers, magazines. Paper is principally wood cellulose, which is considered a fibrous material. Cellulose is the second most abundant material on earth after rock. Cellulose is a natural polymer, a long chain of linked sugar molecules made by the linking of smaller molecules. The links in the cellulose chain are a type of sugar, β -D-glucose. The cellulose chain bristles with polar-OH groups. These groups form many hydrogen bonds with OH groups on adjacent chains, bundling the chains together. The hydrogen bonding forms the basis and strength. The typical cellulose structure is Shown in figure.

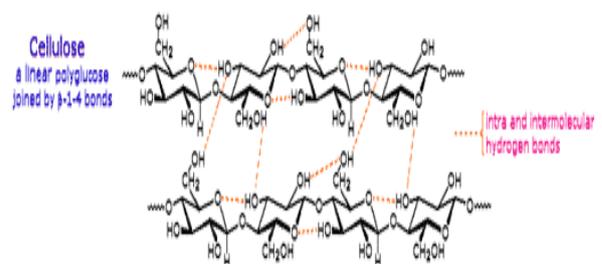


Fig- 1 Chemical structure of paper

CEMENT:

Cement is one of the binding materials in this project. Cement is the important building material in today's construction world 53 grade Ordinary Portland Cement (OPC) conforming to IS: [8112-1989] cement used.

Table 1: Properties of cement

S.NO	Properties	Results Obtained	Requirements of IS [8112 – 1989]
1	Fineness (by sieve analysis)	98.2%	-
2	Specific gravity	3.15	3.15
3	Initial setting time (Minutes)	68minutes	Min. 30minutes
4	Strength in N/m ³	35.50 N/m ³ for 7 days curing	-

SAND:

The sand particle consists of small grains of silica (SiO₂). It is formed by the decomposition of sand stones due to various effects of weather. According to the natural resources from which the sand is obtained, it is termed as Pit sand, River sand and Sea sand. According to the size of grains, the sand is classified as fine, coarse and gravel. The properties were studied as per BIS standard.

Table 2 Properties of sand

S.NO	Properties	Results Obtained
1	Fineness (by sieve analysis)	4.40%
2	Specific gravity	2.64

COARSE AGGREGATE:

The aggregate is used in partial replacement in paper sludge while making of bricks by 5%, 10%, 15% in 1:1:1, 1:1.25:1.5. The aggregate which is passed through 6mm IS sieve and retained on 4.75mm IS sieve is used. Aggregate is collected from local area.

Table 3 Properties of coarse aggregate.

S.NO	Properties	Results Obtained
1	Fineness (by sieve analysis)	5.47%
2	Specific gravity	2.95

2. SPECIMEN MAKING

Preparation of paper sludge: The paper to be used can come from a variety of sources. Newspaper, junk mail, magazines, books, etc obtained from the local dump or from waste bins is all useful. Depending upon the type of mixer used to pulp the mix, the paper may be soaked in water beforehand. A typical home made mixer uses a small electric mounted directly on a shaft with two four-inch square blades attached, resembling milk shake maker. The paper sludge is prepared by soaking waste paper in water for 24hours. It is then ground into a fine paste. Thus the paper sludge paste was obtained. The paper is placed on non-absorbent plate for squeezed out extra water content in paper sludge. This paper sludge obtained is then mixed with cement and fine aggregate to get a desired Papercrete mix.



Fig- 2 Soaked paper for preparation



Fig- 3 Squeezing out of extra water

Proportion of the mix: In the present investigation the mix proportions chosen is as follows. Cement: Fine aggregate: Paper sludge [1:1:1], Cement: Fine aggregate: Paper sludge [1:1.25:1.5]. The Papercrete mix prepared is then filled into the wooden modular brick mould of size 190mm x 90mm x 90mm. The paper sludge is replaced by coarse aggregate by 5%, 10%, 15% for each proportion are used for normal mix and aggregate based mix. Further the bricks casted for compression, water absorption and flame test.

3.2.3 Mixing of dry ingredients: Dry sand of required quantity is weighed and placed on flat non-

absorbent plate or floor, then the cement which is exactly weighed and placed over the sand. Both the ingredients are mixed thoroughly till uniform colour is obtained. Then the paper sludge is placed on dry ingredients and mixed thoroughly until uniform colour is obtained. Mixing of dry and wet ingredients is shown in figures.

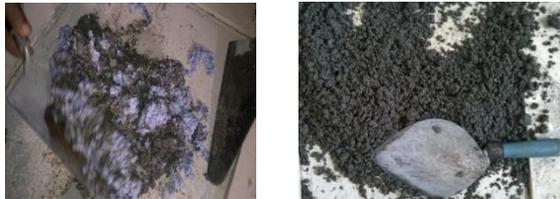


Fig-4 Papercrete mix for making bricks

Casting of bricks:

In these investigations, mixing was done manually. Modular brick mould is used for casting of bricks. The internal dimensions of modular brick mould is 190mm X 90mm X 90mm .The brick mould is placed on flat ground then the obtained mixer is poured into the mould within 30 minutes and tamped with wooden tamper. And the surface of the brick is finally finished with wooden tamper. Then the mould is removed. These bricks are allowed to sun drying for 14 days. After 14 days drying these bricks are used for performance of different tests for obtaining the results. And there was no special care was taken for curing, because paper used to hold water for long time. So, only sun drying was allowed.

Mould Specification: Brick mould is made with ply wood sheets of thickness 8mm.The base plate is attached at the bottom of the mould. The sheet is extended to outside for holding the mould while preparation of brick.



Fig – 5 Modular Brick Mould



Fig – 6 Modular Brick

OPTIMATIMIZATION OF MIX THROUGH PRILIMINARY TESTS:

As per Indian standards, BIS recommends (IS: 1077-1992 and IS: 3495-1992) three tests for clay bricks, i.e. determination of compressive strength, water absorption, efflorescence etc. Of these tests, efflorescence is observation test. In this regard, compressive strength and percentage of water absorption are the main criteria for influencing the optimization of Papercrete mix. In these stages, paper and cement are the main essential materials for Papercrete matrix

4. RESULTS AND DISSCUSSIONS In this section results of compressive strength of normal and aggregate based mixes are reported. In additions of it also covers water absorption, density variation and efflorescence and flame test results. Further the results obtained are reported in the form of tables and graphs for various combinations.

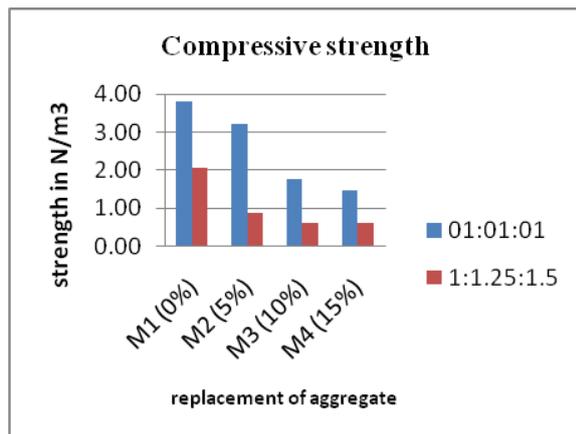
4.1 COMPRESSION TEST: This test only decides the strength of the brick. This test was carried out by a universal testing machine. This test was carried out on the 21st days from the date of casting. While testing the Papercrete brick great care must be taken, because Papercrete bricks never failed catastrophically, it just compressed like squeezing rubber. So load was applied up to full compression. When Papercrete brick failed at the higher load, the structure was not fully collapsed. Only the outer faces cracked and peeled out. A brick that is used for construction should have compressive strength more than 3.5 N/mm².



Fig – 7 performance of coqpressive strength test on Papercrete brick

Table 4 Compressive strength results

Proportion	Normal mix				Aggregate based mix			
	M1 (0%)		M2 (5%)		M3 (10%)		M4 (15%)	
	Load (kN)	Strength (N/mm ²)	Load (kN)	Strength (N/mm ²)	Load (kN)	Strength (N/mm ²)	Load (kN)	Strength (N/mm ²)
1:1:1	65	3.80	55	3.216	30	1.75	35	1.461
1:1.25:1.5	35	2.04	10	0.87	10	0.58	15	0.58



Graph 1- Shows strengths for Different proportions of normal and aggregate based mix

Observation: From the above graph, observed that only 1 type of bricks got compressive strength more than 3.5 N/mm². But, they are not suitable for load bearing walls. Because, Papercrete bricks are having more elastic behavior at failure. It compresses like rubber. So at heavy load, the bricks may compress. Due to this compression the roof may be collapsed. So these bricks are suitable only for non-load bearing partition walls. M1 refers 0% replacement of aggregate resist high compressive strength because of pozzolanic reactivity.

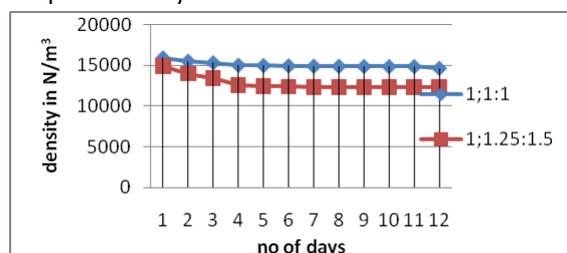
Table 5 density variation observations

M2 (5%) replacement				
No of days	1:1:1		1:1.25:1.5	
	Weight (N)	Density (N/m ³)	Weight (N)	Density (N/m ³)
1	28.91	15922.92	23.01	14954.035
2	24.86	15523.257	21.56	14010.643
3	23.59	15330.116	20.74	13481.578
4	23.12	15024.152	19.40	12608.304
5	23.06	14985.9	19.24	12506.315
6	23.00	14947.66	19.15	12448.947
7	22.93	14903.04	19.10	12417.076
8	22.91	14890.29	19.10	12410.7
9	22.88	14871.169	19.09	12404.327

10	22.86	14858.42	19.09	12404.32
11	22.85	14858.42	19.07	12391.578
12	22.53	14641.695	19.03	12366.081

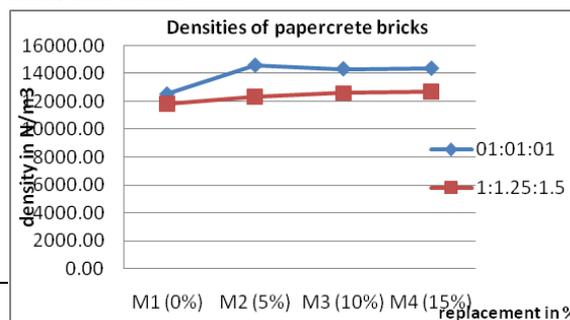
4.2. Density variation for aggregate based mix with 5% (M2) replacement proportions:

Graph 2 density variation observations



Observation: Density decreases with drying time and remains constant after certain days of drying and is about 14380.35(N/m³), 12621.052(N/m³) respectively for two proportions with 10% replacement by

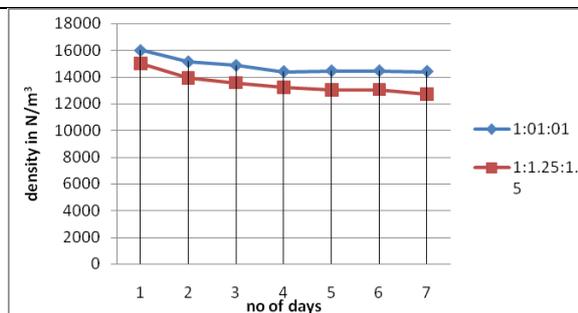
Aggregate mixes. From this graph observed that as the paper sludge proportion increases the density of brick decreases.



Observation: Density decreases as the Papercrete proportion increases in different proportions of normal and with 5%, 10%, 15% aggregate based mixes. Aggregate based bricks have more density than normal mix bricks because of aggregate. The density of Papercrete brick is 80% less than conventional clay brick.

4.2.3 Density variation for 15% (M4) replacement of aggregate:

No of days	M4 (15%) replacement			
	1:1:1		1:1.25:1.5	
	Weight (N)	Density (N/m ³)	Weight (N)	Density (N/m ³)
1	24.64	.6012.6	23.13	.5036.90
2	23.30	.5145.16	21.49	.3966.02
3	22.88	.4871.16	20.91	.3589.94
4	22.36	.4533.33	20.35	.3231.38
5	22.24	.4456.84	20.12	.3073.62
6	22.25	.4463.21	20.13	.3081.27



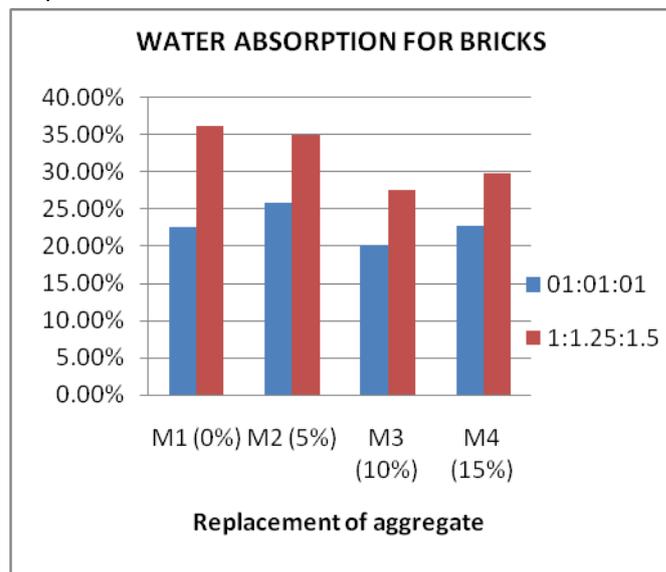
Graph 4 Shows Density variations for 15% replacement with aggregate

Observation: Density decreases with drying time and remains constant after certain days of drying and is about 14418.59(N/m³), 12729.94(N/m³) respectively for two proportions with 15% replacement by aggregate mixes.

4.3 WATER ABSORPTION RESULTS:

Water Absorption Test is used to find out the water absorption ratio. Because the brick, which are absorbing more water cannot be used in water logging area or exterior walls which is open to sky. The bricks from all the proportion were tested. As per standard, the bricks should not absorb water more than 20% of its weight, but from the table results, bricks exceeded water absorption ratio more than 20%. In this, the mix that contains only paper and cement absorbs water more than its weight. And the normal mixes that were mixed in 1:1:1, 1:1.25:1.5 which ratio absorbed more water. So these bricks are not suitable for water logging and exterior walls.

These bricks can be used for interior partition walls only.



Graph 5 Shows Water absorption for different proportions in %

Observation: From the above graph, it is observed that as the quantity of paper sludge increases, water absorption also increases. 1:1.25:1.5 proportion absorbed more water because of having more paper sludge than 1:1:1 proportion. Papercrete bricks absorb 15% water more than conventional bricks.

4.4 EFFLORACENCE RESULTS:

The soluble salts, if presents in bricks will cause efflorescence on the surface of bricks. For finding out the presence of soluble salts in a brick, this test was carried out. In this test fibrous concrete brick were immersed in water for 24 hours. Then the bricks were taken out and allowed to dry in shade. And there was no any grey or white deposit on the bricks surface. It results that the bricks are free from soluble salts.



Fig- 8 brick immersed in water for efflorescence test

Table 7 Water absorption observations for different proportions:

Mixes	Mixed proportions					
	1:1:1			1:1.25:1.5		
	Initial weight(kgs)	Final weight(kgs)	Water absorption(%) $\frac{(m2 - m1) * 100}{m1}$	Initial weight(kgs)	Final weight(kgs)	Water absorption(%) $\frac{(m2 - m1) * 100}{m1}$
M1	2.243	2.7048	22.51	1.914	2.606	36.15
M2	2.076	2.612	25.82	1.953	2.637	35.02
M3	2.343	2.817	20.23	1.980	2.525	27.52
M4	2.294	2.818	22.84	2.116	2.747	29.82

4.6 HARDNESS:

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 left on the fibrous concrete brick surface. So this test results that fibrous concrete bricks are sufficiently hard.

4.7 SOUNDNESS:

In this test two bricks from same proportion were taken and they were struck with each other. The bricks were not broken and a clear ringing sound was produced. So the bricks are good.

4.8 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

Observation:

In this test fibrous concrete brick were cut into equal parts. The fibrous concrete brick piece structure was homogenous, compact, and free from defects and this brick pieces look like a cake piece.

4.9 CUTTING AND GLUE:

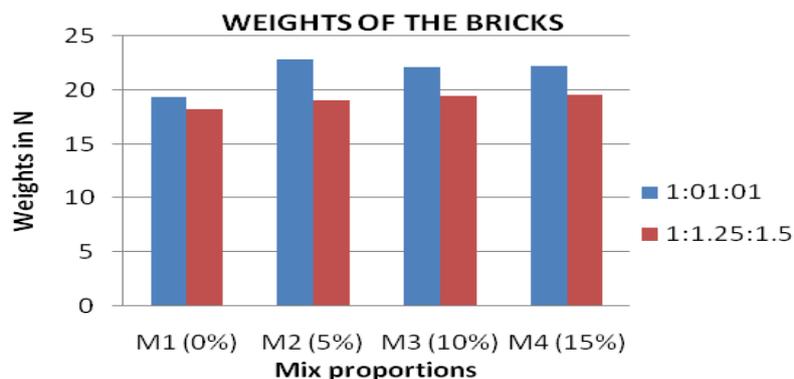
In site lot of bricks are wasted while cutting only. The labors could not able to cut the bricks exactly what they need. But, fibrous concrete bricks can be cut into exactly two pieces (Fig.4.9) by using conventional saw blades. So, we can get any shape and size of fibrous concrete brick.

4.10 WEIGHT:

Lightweight bricks are also the important objective of this project. So, all the bricks were tested whether they are having less weight or not. All the bricks were weighed in a well-conditioned electronic weighing machine. The following are the weight of the bricks

Table 8 Observations for weights of the bricks:

Mix proportions	Normal mix weights in(N)		Aggregate based mix weights in (N)	
	M1	M2	M3	M4
1:1:1	19.33	22.53	22.13	22.19
1:1.25:1.5	18.23	19.03	19.42	19.59



Graph 6 Shows Weights of the bricks in N for different proportions

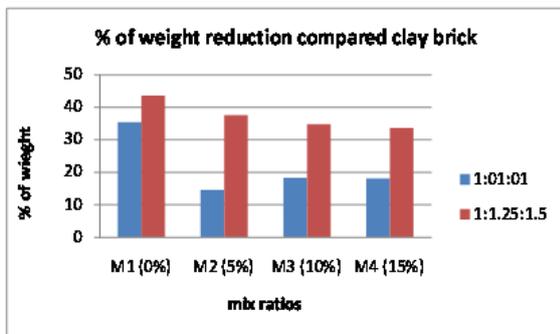
Observation: As the percentage of aggregate increases the weight of brick will also be increases. As the paper sludge increases the weight of the brick decreases.

4.10.1 WEIGHT COMPARISION WITH CLAY BRICK:

Lightweight bricks are also the important objective of this project. So, all the bricks were tested whether they are having less weight or not. All the bricks were weighed in a well-conditioned electronic weighing machine. The ordinary conventional bricks weight varies from 30 to 35 N. but the Papercrete bricks weight varies from 18 to 23N. The maximum weight is less than 20N only. In this above proportions M1 bricks are having 2/3 rd of the conventional brick weight only. Aggregate based bricks are having weight 3/5th of conventional brick weight only. So this bricks are light weight and it will also reduce total cost of construction due to the reduction in dead load.

Table 4.11 observations for weights for respective mix proportions

Mixes	1:1:1		1:1.25:1.5	
	Weight N	Weight reduction (%)	Weight N	Weight reduction (%)
M1 (0%)	19.33	35.48	18.23	43.66
M2 (5%)	22.85	14.62	19.03	37.63
M3 (10%)	22.13	18.35	19.42	34.86
M4 (15%)	19.42	18.03	19.59	33.69



Graph 7 Graph Shows fibrous brick compared with clay bricks

Observation:

From the above figure, it is observed that as the quantity of paper increases, the weight of the brick decreases. The Papercrete bricks having less than 40% weight of conventional clay brick.

4.11 FIRE RESISTANCE:

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 not for padobe brick. Because padobe brick was 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 cloths and all the foreign matters were removed.
- Then the flammable sticks were fired. After that, the bricks were held on the flame for ten minutes.
- After five minutes fixing was stopped and the bricks were observed.

Observations:

From the above from test, it was observed that the fibrous concrete bricks did not burn with an open flame. They smoldered like charcoal. But these brick would be reduced to ashes after burning several hours. If the interior plaster and exterior stucco is provided on the fibrous concrete bricks, the bricks won't burn. The only weak point is inside the block, near electrical outlets, switches and other places where wires gives through walls, into boxes etc. Properly wired places never cause fire. If we apply the plaster without any hole or leakage on the bricks, it won't burn or smolder inside. Because there will be lack of oxygen for burning.



Fig - 9 Performance of fire

5. CONCLUSIONS

In this project experimental results for the properties of Papercrete bricks under uniaxial compression loading are presented. From this

investigation the flowing conclusions can be derived on the basis of laboratory tests are shown below.

- ✓ A Papercrete brick consists of recycled materials and therefore cost is very low compared to conventional bricks.
- ✓ Papercrete can easily be molded into any shape, bricks are much easier for someone to lift to any desired height and very good surface finish can be achieved.
- ✓ Papercrete bricks are suitable for non-load bearing walls only.
- ✓ Papercrete has good fire resistance.
- ✓ The Papercrete bricks are good sound absorbent; hence paper is used in these bricks. So, these bricks can be used in auditoriums.
- ✓ The weight of this brick is 2/3rd to 3/5th lesser than conventional clay brick.
- ✓ Due to less weight of these bricks, the total dead load of the building will be reduced.
- ✓ Since, these bricks are relatively weight and more flexible, these bricks are potentially ideal material for earthquake prone areas.
- ✓ Papercrete brick does not expand or contract, so sheets of glass or glass block can be embedded in and trimmed with Papercrete.
- ✓ Since, the waste materials are used, it will reduce the landfills and pollution.
- ✓ Using the Papercrete brick in a building, total cost will be reduced from 20% to 25%
- ✓ These bricks are not suitable for water logging and external walls. It can be used in inner partition walls.
- ✓ These bricks are termite proof; hence the paper was mixed with cement in Papercrete brick.

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