



REUSE OF PAPER AS A NON-CONVENTIONAL LOW-COST MATERIAL

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Abstract: The mining and building industry have exploited most of the natural resources. These two sectors cause more pollution to the environment. Considering natural resource conservation, we are in a position to reduce the consumption of nature. In India, most of the buildings have concrete structures for which raw materials are taken from nature. In order to preserve the resources for future generations, we have to find alternatives for the materials used in concrete. Our research used paper bricks made from recycled paper mills, newspapers, and sugarcane bagasse. We have made some experiments from the paper brick and have discussed them in detail.

I. INTRODUCTION

The increasing population and the decline in the availability of natural resources has forced us to bring an alternative solution to the use of non-renewable sources. One of the basic needs of human life is shelter. As the cost of construction materials, lack of available resources and the cost involved in the process are questioning the shelter for the people. To make the use of resources wisely and sustainably, it is essential to reuse the materials. In this research, paper bricks are considered as an alternative to the regular clay or sand brick. The clay and sand are always the fertile matter for the agricultural use. Most of the developed nations have stopped the usage of soil for brick industry. One alternate to the sand or clay brick is usage of paper waste for manufacturing of brick.

A huge quantity of the sludge produced by paper mills is considered as one of the most serious environmental problems. These sludge and waste form the landfills, thus degrading the environment. These waste materials and the newspaper is used for brick manufacturing in this research and the results and discussions are presented in the economical and reuse point of view.

1.1 Paper Sludge for Paper Brick:

A brick made of 90% recycled paper mill waste or paper sludge and 10% cement. The slurry is mechanically mixed, pressed into molds, and left in the sun to dry. Paper sludge means industrial by-product from paper manufacturing. It mainly consists of cellulose fiber and inorganic materials. The moisture content normally present in paper sludge may vary from 60-75%. However, this value can be reduced to as low as 35% by dewatering processes. The inorganic components are mainly kaolinite and calcium carbonate which reflects surface coating agents during the original paper making. In addition, paper sludge also contains heavy metals from inking activities such as writing and painting. Manufacturing of 1 ton of paper = 300Kg dry sludge. 3-8 cycles of possible recycling. Present use of residual sludge is in landfill and incineration for energy recovery.

Source: Paper sludge is a byproduct of the paper recycling process. It consists of the solid material separated from wastewater during paper production.

Composition: Paper sludge typically contains cellulose fibers, clay, and various additives used in the paper-making process.

Benefits: Incorporating paper sludge into brick manufacturing can enhance the properties of the bricks. The cellulose fibers can contribute to the structural integrity, and the clay content helps with binding during the firing process.

1.2 Reuse of Sludge and used paper:

High volume of waste from the paper industry and the used paper itself can be significantly used in the construction sector. This increases the potential for reuse which includes solution of waste management problem, reduced use of new resource for construction industry, reduction in CO₂ emission, supplementary cementations material, partial replacement of binders in concrete, raw material for clay brick manufacturing, production of ceramics, soil stabilization in road works.

1.3 Physical properties: Paper sludge along with cement gives a good compressive strength, lighter weight. It also reduces CO₂ emission.

II. Making Wall Panel using Paper Brick and Sludge:

Materials used for the Research:

For making of paper brick, the materials used are newspaper, paper sludge, straw mat, bamboo, sugarcane bagasse for the purpose of binding.

2.1. Practical Research and the steps involved:

Step 1: Take a bucket of water, nearly 9 liters, and 3 kg of newspapers. Tear the newspapers into medium size. Soak it into the water for nearly three days and the paper becomes a sludge partially. To get nice sludge it has to be ground by a mixer grinder. Then add small quantity of saw dust and salt, as it will be an insect and pest proof.

Step 2: A plastic box is taken to make a mould, and holed in the bottom side of plastic box in order to drain the water. Use thermocol as a lid to close the mould box tightly, if needed place some weights for compression. By doing so, this paper sludge can be compressed. It is very important to compress as it gives strength to paper brick to make a strong wall panel, i.e., compression gives more strength. To make ease of drying smaller plastic moulds were used.

Step 3: Finally straw bale mat is used as a binding material. The paper bricks are plastered using cement and paper sludge on one side of the mat and on another side traditional concrete is used. Totally 2 kg of cement and 1 plate of sand is consumed. After plastering outside of both sides, a paper wall panel is obtained and it acts as a main wall for low-cost material.



Fig. 1. Practical Research Part 1

2.2 Practical Research Part 2:

Step1: Take a bucket of water, soak pieces of chart paper waste, into the bucket for four days, then grind these waste paper nicely, along with this cotton waste is also used with the mixture.

Step2: A rectangular wooden box is taken and holed in the size of 5mm at the bottom, in order to dry the water entirely. Then the grinded waste is filled in the rectangular wooden the mould and compressed using thermocol. Once all the water is drained, then the rectangular mould is removed.

Step3: Sugarcane bagasse and bamboo is used as a binding material to make the compressed mould.

Step4: Plastering is done by Cement, lime, sand, and water, in the ratio of 1:2:3 and one inch plastering is done on both sides of the paper panel

Step5: Finally, emulsion paint double coating is done on either side of the panel.

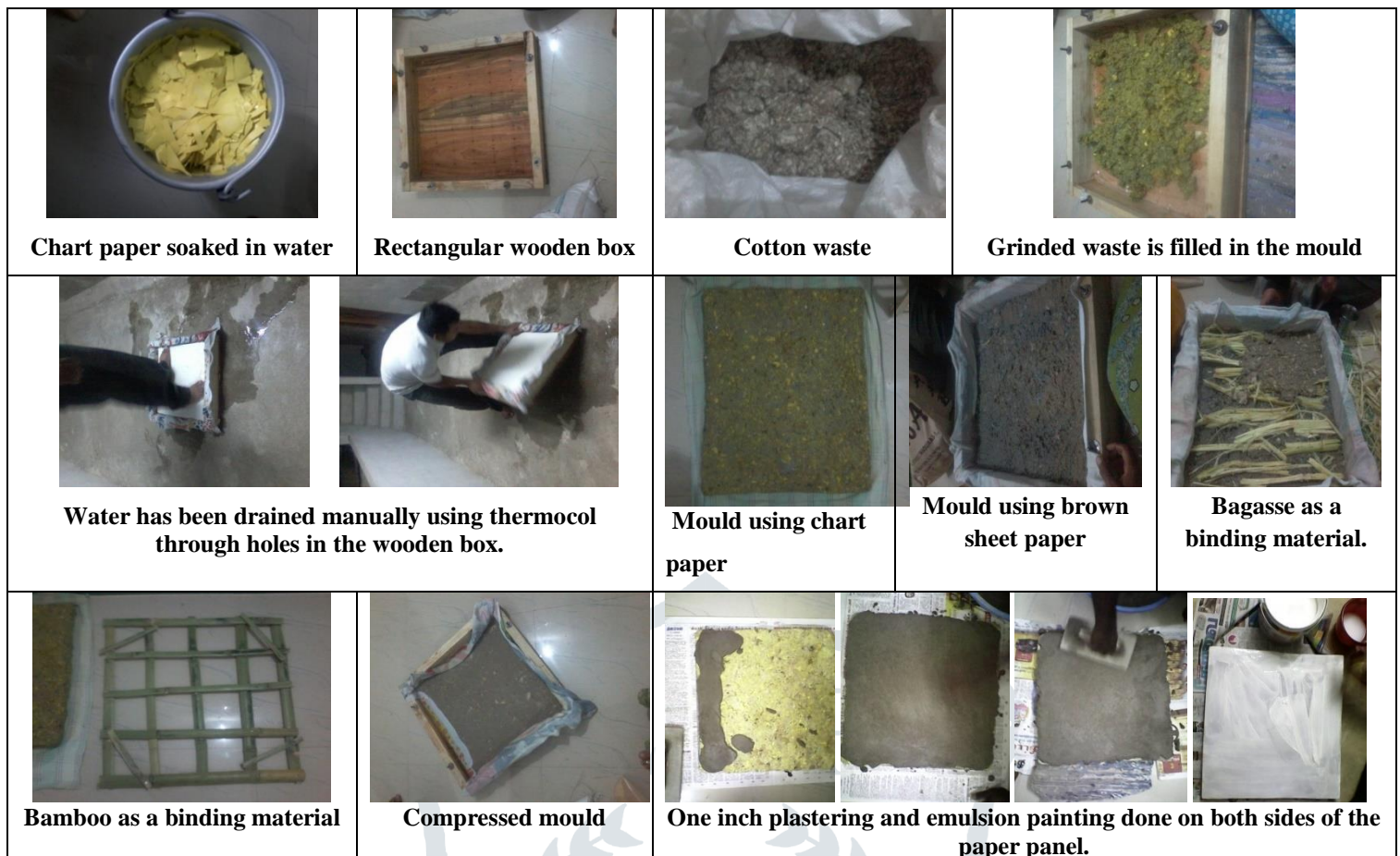


Fig. 2. Practical Research Part 2

Following the above step bricks in the shape of cube, Cylindrical, Slab and Hollow block are prepared.

Paper cube: A cubical shaped brick is created using newspaper and cement in a pure iron mould with a size of 150mmx150mmx150mm and for compressing thermocol is used.

Cylinder: A Cylindrical brick is created using the x ray sheet and for compressing thermocol is used. It has been used as a combination of both newspaper, sawdust having a size of 150mmx300mm.

Slab: Slab is created using the rectangular wooden box, for pressing thermocol have been used, holes in the wooden box are used to drain the water. A combination of newspaper, cement, and sand sawdust is used. Also, bamboo sticks are used for the reinforcement. The size of slab is about 700mmx300mmx450mm.

Hollow block: Hollow block is created in the size of 170mm130mmx150mm. It is composed of waste paper and cement, added in a less percentage.



Fig. 3. Paper brick in shape of Cube, Cylinder, Hollow Block and Slab

III. Composition of Materials used:

The table below indicates the composition and the cost involved in making of paper bricks in the shape of Cube, Cylinder, Hollow block and slab.

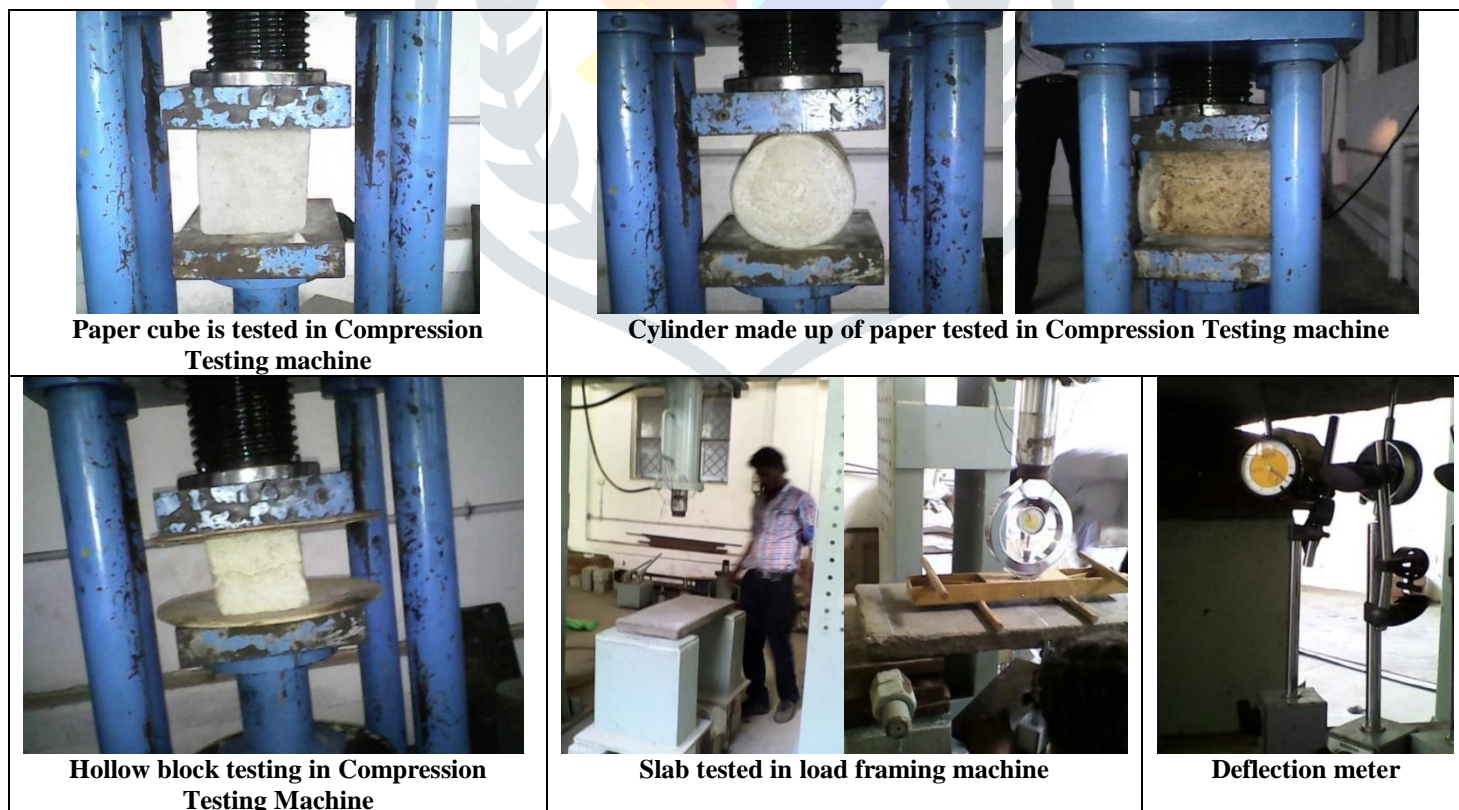
Table 1. Composition of materials and the cost estimation

Slab (450mmx450mmx50mm)			Cube (practical cost in the current market) (150mmx150mmx150mm)		
Composition	Quantity	Cost Rs	Composition	Quantity	Cost Rs
Cotton	0.25kg	5	News paper	1 kg	8
Chart paper	8 Nos	50	Cement & Sand	0.25Kg	8
Plastering on both sides	50mm	90	Total		16
Total		230	Slab (700x300x450) mm		
Cylinder (d x h (150mmx300mm))			Composition	Quantity	Cost Rs
News paper	1.5 kg	12	Cement and Sand	2 kg	25
Saw dust	0.5Kg	5	Saw dust	0.5kg	10
X ray sheet	1 No.	30	News paper	3 kg	24
Thermo coal plastering on both side	25mm	90	Bamboo Stick	15 Nos	70
Total		140	Plastering on both side	25mm	150
			Total		280

IV. Practical Research Results and Discussion:

Test is conducted to examine the Strength, Water absorption, Fire resistance, Resistance against termites and pests and thermal conductivity. Paper cube and cylinder are tested in compression testing machine of capacity about 2,000KN (Karpagam civil engineering laboratory)

4.1 Compressive Strength: Compressive strength of bricks is the measure of how much load a brick can withstand without breaking. As per Indian code of standards, IS 3495 (Parts 1 to 4): 1991, the bricks when tested in, shall have a minimum average compressive strength of 7 N/mm² on net area.





Slab Starts to crack at 0.6 KN, Initial Crack:0.6KN, Ultimate load:1.4KN

Paper Brick Shape	Compression strength
Cube	19 KN
Cylinder	8 KN
Hollow block	25 KN

Fig. 4.1. Compression Strength under Compression Testing Machine,

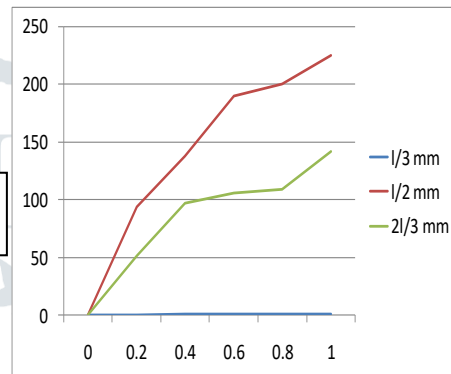
Note: Strength = load/area. Therefore, Compression strength for cube 0.8N/mm²

4.1.1. Compression strength comparison:

For partition walls like hollow clay block, aerated concrete block, fired clay brick the compression strength is (3 to 30 KN). Research results show that hollow block has more compression strength than the Cube and Cylinder, it has a compression strength equal to the brick.

Table 3. Slab Bending Moment Readings

Load KN	L/3 mm	L/2 mm	2L/3 mm	Remarks
0	0	0	0	
0.2	0.005	94	51	
0.4	0.95	138	97	
0.6	1.05	190	106	Initial crack
0.8	1.08	200	109	
1.0	1.34	225	142	
1.2	1.45	229	146	
1.4	1.49	234	150	Ultimate load



Graph 1. Slab bending Moment

4.2 Test Conducted for Wall Panel:

Water absorption test: Wall panel is kept near water tap for nearly 3 hours, nearly five percentage of water is absorbed by the wall panel.

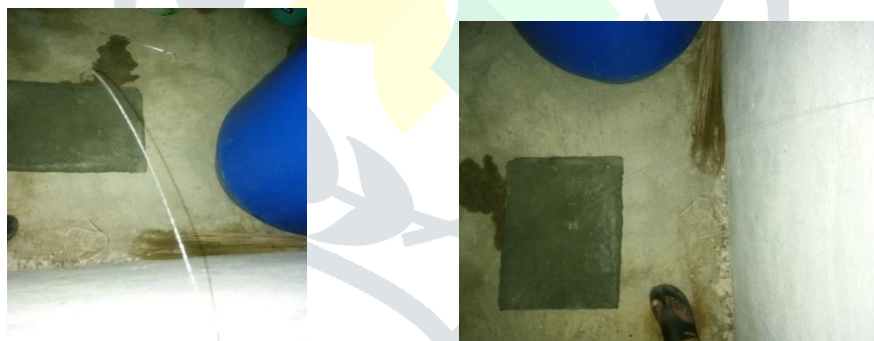


Fig.4.2 Water absorption test

4.3. Light Weight of Waste Paper:

Table 3. Weight comparison for paper brick, concrete and Brick

Size in mm	Weight of paper models	Weight of Concrete	Weight of Brick
Cube (150x150x150)	0.815kg	8.25kg	
Cylinder (150x300)	1.385Kg	12.85Kg	
Slab(700x300x450)	8.305 Kg	25Kg	
Hollow block(170x130x150)	0.560 Kg		
Brick (230x110x90)			2.975Kg
Fly ash brick (230x110x90)			3.045Kg

By comparing the weight with other material, paper (cube, cylinder, slab) found to be light weight, so it is preferred for walls and roof as a filler slab material the entire load acting on the foundation will be less, so the reinforcement is lesser, and it will be more cost effective in framed structure buildings. Paper mash can be used as a decorative panel as a in filler material, in partition wall, different shapes can be used. By adding clay to the paper waste, weight of the clay block decreases correspondingly, with increasing thermal conductivity performance.

5. Research Applications:

This Site is located in Mettupalayam road, Coimbatore. It is designed for income tax people (HIG, MIG, LIGESWS). EWS is in the rear end of the site. Nearly 15% of the site area allocated for the EWS. Proposed Rural housing plan is given below and the research findings have been applied in foundation walls and roof.

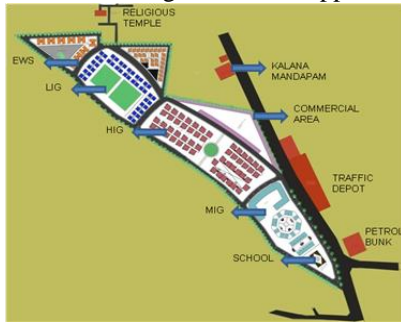


Fig 5.1. Proposed site @ Coimbatore



Fig 5.2. Proposed individual house plan.

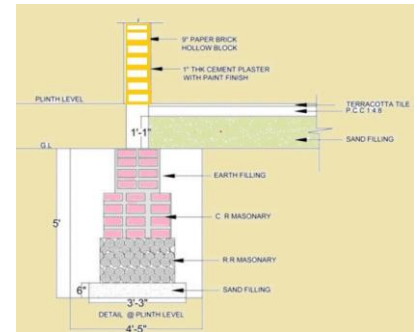


Fig 5.3. Foundation detail

Table 4. Cost details for foundation

Description of work	Quantity	Rate per cft	Amount
C.R Masonry	46	100	4,600
R.R Masonry	37	20	740

Plinth Area in sq.ft.	
Living room	140
Bed room	88
Kitchen	62
Toilet	20
Total	310

Foundation depth is nearly 5'0"x3'3". Six inches is used for sand filling, then R.R Masonry (Random rubble masonry), C.R Masonry (Coursed Rubble masonry), and above that terracotta tile flooring is used. Mostly for slopy roof, paper block is preferred, hollow block is used for both walls and roof, it saves the construction cost, plastering is done by cement and paper sludge, for insulation paint is used. Electrical services can be done by exposed PVC conducts.

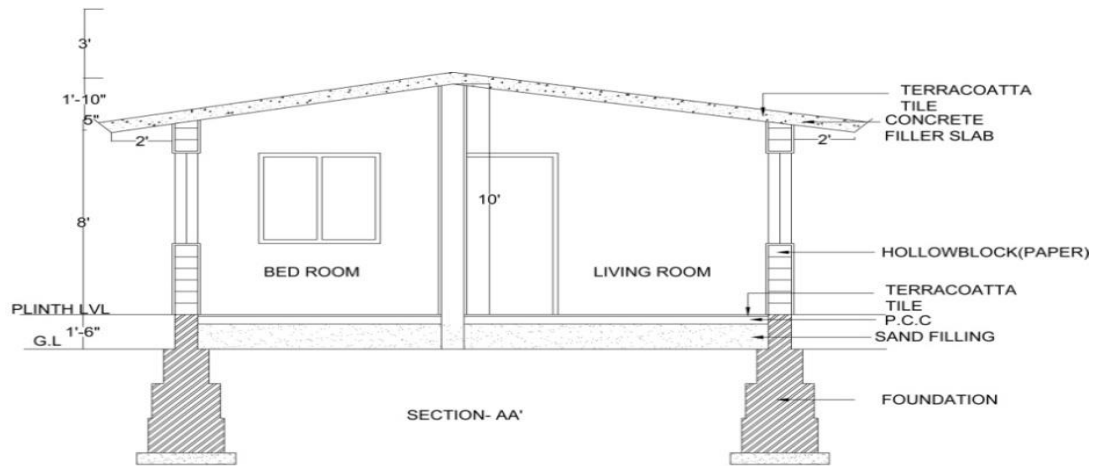


Fig 5.4 Section detail

5.1. Evaluation cost of the Construction Using Paper as a Building Material.

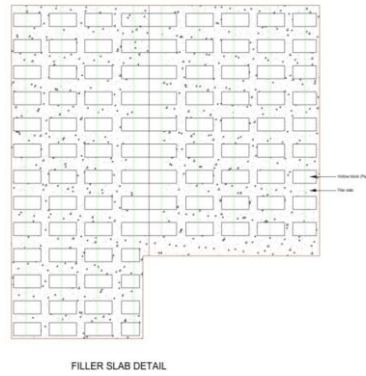
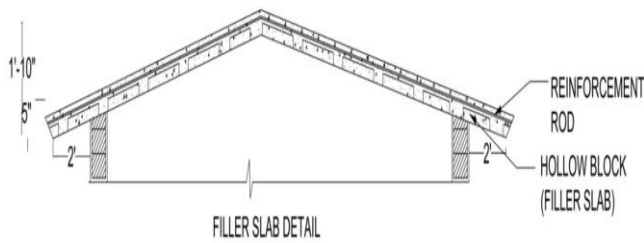
Table 5.1. Comparison of paper as a filler material with ordinary slab

Description of work	Quantity	Rate	Per	Amount
Filler Slab	420	60	1 Cft	25,200
Ordinary Slab	420	300	1 Cft	1,26,000

Hollow block made up of paper is used for walls, and the cost is very less than the ordinary brick work. In Ordinary roof slab per square feet is Rs 300. For Filler slab in this case per square feet is Rs. 60. It is less than one fourth of the cost of the ordinary slab.

Table 5.2. Comparison of paper hollow block with ordinary brick work

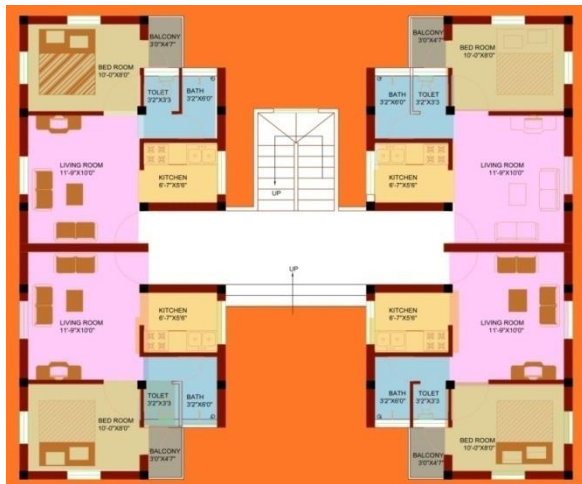
Quantity	Rate per cu.ft		Amount	
	9" thickness	4.5" thickness	9" thickness	4.5" thickness
Paper Hollow block	533	80	42,640	79,950
Ordinary Brick	80	40	3,200	8,800



Living room	21
Bed room	80
Kitchen	31
Toilet	10
Bath	17
Total	159
Carpet area for the floor plan	

Fig.5.5. Filler slab details.

5.2. Proposal: Individual House Plan (Rajiv Awas Yojana)



One brick cost around	Rs. 6/- to 8/-
Paper hollow block	Rs. 3/-
Single unit inside partition wall	880 C.ft
Material costs save around	Rs. 3/-
Cost comparison between Brick and Hollow Block for Single Partition Wall	

Fig. 5.5 Typical Floor Plan

Framed structure building: Inner partition wall is made with paper hollow block, for outer walls, out of two rows, for one row hollow blocks made in paper is used.

5.3. Overall cost estimation for a single house:

If paper brick is used as a construction material from the foundation walls and roof, then the estimated cost for a single house is given below in a tabulate column. Paper sludge is used for plastering purpose, and for foundation paper sludge along with cement material is used.

Table 5.3 Over all estimation for a single house with paper as a construction material

Sl. No	Description of work	Quantity	Rate	Per	Amount in Rs
1)	Earth work Excavation for foundation	506.25	15	1 cft	7,593.75 /-
2)	Sand Filling for foundation and basement	353	30	1 cft	10,590 /-
3)	R.R Masonry	46	100	1 cft	4,600 /-
4)	C.R Masonry	37	20	1 cft	740 /-
5)	Brick pier	63	60	1 cft	3,780/-
6)	Plinth beam	66	250	1 cft	16,500/-
7)	Roof slab (filler slab)	420	60	1 sft	25,200/-
8)	Paper Hollow block work in C.M :1:6 (9" thk)	533	80	1 cft	42,640/-
9)	Paper Hollow block work in C.M:1:6(4.5" thk)	80	40	1 cft	3,200/-
10)	Wall outer	1001	30	1 sft	30,030/-
11)	Wall Inner	1127	30	1 sft	33,810/-
12)	Doors & windows using Ferro cement	70	70	1 sft	4,900/-
13)	Flooring (Terracotta tile)	373	20	1 sft	7460/-
14)	Outer wall painting with exterior over a coat of primer	1001	16	1 sft	16,016/-
15)	Electrification arrangements			L.S	7000/-
16)	Plumbing			L.S	10000/-
17)	Septic tank			L.S	3000/-
	Total				2,27,059.75/-

5.4. Cost savings:

- In Government Rural scheme, construction cost per square feet is Rs 600
- Area of the proposed house = 514 Sq. ft

- Total Construction Cost $514 \times 600 = \text{Rs.}3,08,400/-$
- Estimate cost in proposal $514 \times 440 = \text{Rs.}2,27,059.75/-$
- By using paper brick as a material in construction the cost is reduced nearly 30-40 %

6. Conclusion:

In this paper, it is clear that instead of using concrete from the natural resources, construction materials are made from the dumped waste, it is better to reuse and recycle the waste product and use it productively. From the economy point of view also, the research findings have helped reduce the construction cost significantly. In this way, further exploitation of natural resources will be reduced thus conserving the nature. And also using the waste produce reduces the dumping and hence creating a healthy environment.

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