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Research Article

EXPERIMENTAL INVESTIGATION OF PAPERCRETE

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A R T I C L E I N F O

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A B S T R A C T

The major Objective of the project is replacing the costly and scarce conventional building bricks by an innovative and alternative building bricks, which satisfies the following characteristics,

- ✓ Cost effective
- ✓ Environmental friendly
- ✓ Light weight
- ✓ Inflammable
- ✓ Less water absorption
- ✓ Easily available

The main objective of this project is optimizing the papercrete mix with desirable properties, which satisfies the above mentioned needs.

INTRODUCTION

Increase of population has made large demand on construction material and it leads to a chronic shortage of building materials and thereby increasing the construction cost due to the shortage. To solve this problem, engineers are not only challenged for the future homebuilding in term of construction cost control but also need to convert the industrial wastes to useful construction and building materials. The use of waste paper has role, in getting rid of their,huge quantities, which constitute a fundamental environmental problem because of thedifficulty of its degradation. Various attempts have been therefore made in the building material manufactures to use waste material products. According to Resource information system incorporated (RISI), paper recycling has been performed about 60% ~ 80% in many countries. The waste problem considered as one of the most crucial problems facing the world as a basis of the environmental contamination. The waste is usually defined as all remains objects resulted from production uses and transfer processes and in generalall scattered things and resources that must dispose to prevent the danger on the health of the human and save the social environmentin general.

Objective and Scope

Paper is made of wood cellulose which is considered as a fibrous material. After rock, cellulose is the second most abundant material on Earth. Cellulose is the main component derived from plant cell walls and is used in the manufacture of paper.

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Cellulose is a natural polymer, a long chain of linked sugar molecules made by the linking of smaller molecules. The formula for cellulose is C6H5O10.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 the –OH groups on adjacent chains, thus binding the chains together. The chains also pack regularly in places to form hard, stable crystalline regions that give the bundled chains even more stability and strength. This hydrogen bond gives the real strength to the Papercrete. Fibers and fibrils network to form a matrix, which becomes coated with Portland cement. When these fibers are coated with cement matrix it gives extra strength by encasing it.Therefore the principle on which this papercrete is made is that when this paper slurry (paper mixed with water) is mixed with some amount of Portland cement in less amount, the fibers of the paper gets encased in the cement and thus imparting strength to the papercrete.

MATERIALS AND TESTING

Cement

Cement is a binder, a substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together. Cement mixed with fine aggregate produces mortar for masonry, or with sand and gravel, produces concrete. Ordinary Portland Cement (OPC) is the most common cement used in the world because of the abundance and low cost to produce it. Portland PozzolanaCement (PPC) is a variation of the OPC which includes a mixture of a pozzuolanic material, usually fly ash is

added which can increase the strength of the concrete and reduce the amount of OPC used as shown in figure 1.

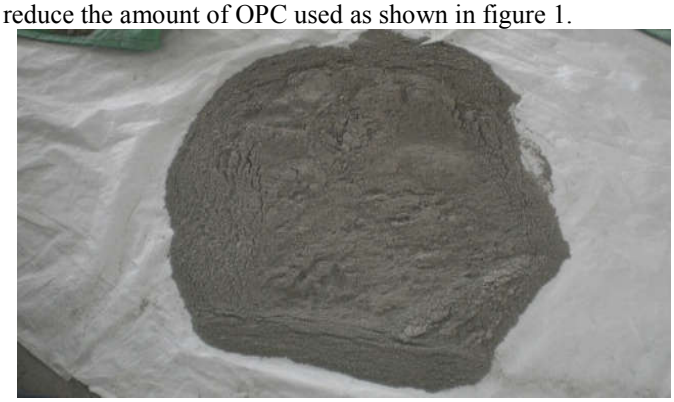

Figure 1 Cement

Fine Aggregate

Fine aggregate generally consists of natural sand or crushed stone with most particles passing through a 4.75 mm sieve. Sand which pass through a 4.75 mm sieve and retains on 2.36mm sieve are used. IS sieve 4.75mm was used to remove all coarse aggregates from the sand and soil by sieving. The fine aggregate that was locally available without any organic impurities and conforming to code is used.

According to size the fine aggregate may be described as coarse sand, medium sand and fine sand. IS specifications classify the fine aggregate into four types according to its grading as fine aggregate of grading Zone-1, Zone-4. The four grading zones become progressively finer from grading Zone-1, Zone-4. 90% to 100% of the fine aggregate passes 4.75 mm IS sieve and 0 to 15% passes 150 micron IS sieve depending upon its gradation as shown in figure 4.2.

Figure 2 Fine aggregate

Paper

Waste paper was collected from local sites. The materials that are used in this work should not cause any pollution to the environment. In the study, paper is the main constituent material. Paper is principally wood cellulose. Cellulose is a natural polymer. The cellulose chain bristles with polar-OH groups. These groups form hydrogen bonds with an OH group of adjacent groups binding the chain together. The chain also packs regularly in places to form hard, stable crystalline region that gives the bundled chains more stability and strength. The sample of Repulped Paper is shown in figure 3

Figure 3 Repulped Paper

TESTING OF MATERIALS

Specific gravity

Specific gravity is the ratio of the density of a substance to the density of reference substance. Equivalently, it is the ratio of the mass of a substance to the mass of a reference substance for the same given volume.

Specific gravity of cement

Procedure

1. Take a bottle to test the specific gravity of cement. The empty weight of the Le Chatelier Flask was taken as (w_1).
2. Some amount of cement was placed in the bottle and weighed as (w_2).
3. Sufficient kerosene was added to make it saturated. The sample was stirred thoroughly for removing entrapped air. The mold was filled with kerosene and weighed as (w_3).
4. It was emptied, cleaned well, filled water and weighed as (w_4) as shown in figure 4.

Figure 4 Specific gravity of cement

Calculation

Weight of empty bottle (W_1) = 37 gms
Weight of empty bottle + cement (W_2)= 73 gms
Weight of empty bottle + cement +Kerosene (W_3)= 104 gms
Weight of empty bottle + Kerosene (W_4)=77 gms

Specific gravity of cement= $\frac{(W2-W1)}{((W2-W1)-(W3-W4))}\times 0.79$

= $\frac{(73-37)}{((72-36)-(104-77))}\times 0.79$

= 3.16

The Specific gravity of cement is = **3.16.**

Consistency Test of Cement

Consistency Test of Cement is carried out in order to determine the percentage of water required for preparing cement pastes for other tests as shown in figure 5.

Procedure

1. Take an empty enameled pan free from dirt and other foreign particles.
2. Now take 400 gms of cement, and put that in the pan.
3. Add water, the quantity of water should be 28 percent by weight of cement.
4. Mix the cement and water thoroughly.
5. Now, fill the cement paste in the mould of Vicat apparatus, the interval between the adding of water to the commencement of filling the mould is known as the time of gauging and it should be between 3 to 4 minutes.
6. The Vicat apparatus consists of a frame to which is attached a movable rod weighing 400gms and having diameter and length as 10 mm and 50 mm respectively. An indicator is attached to the movable rod. This indicator moves on a vertical scale and it gives the penetration. The Vicat mould is in the form of a cylinder and it can be split into two halves. The Vicat mould is placed on a non-porous plate.
7. There are three attachments, square needle, plunger and needle with annular collar. The square needle is used for initial setting time test, the plunger is used for consistency test and the needle with annular collar is used for the final setting time test.
8. The plunger is attached to the movable rod of Vicat apparatus. The plunger is gently lowered on the paste in the mould.
9. The settlement of plunger is noted. If the penetration is between 5 mm to 7 mm from the top of mould, the water added is correct. If penetration is not proper, the process is repeated with different percentages of water till the desired penetration is obtained. This is the test procedure for Consistency Test of Cement. Table 4.1 shows the test specimen of consistency of cement.

Figure 5 Consistency Test of Cement

Calculation

Table 1 Consistency Test of Cement

Trial	water added (%)	Plunger Penetration (mm)
Trial 1	28	0
Trial 2	29	0
Trial 3	30	3
Trial 4	31	6
Trial 5	32	7

Percentage of water required to prepare a cement paste of standard consistency is **30%.**

Initial and final setting time of cement

Initial setting time duration is required to delay the process of hydration or hardening. Final setting time is the time when the paste completely loses its plasticity. It is the time taken for the cement paste or cement concrete to harden sufficiently and attain the shape of the mould in which it is cast.

Initial Setting Time of Cement Test Procedure

1. Take 300gms of cement and mix it with water percentage 0.85 times as mentioned in the consistency test of cement
2. Now the prepared cement paste is filled in the Vicat mould.
3. The square needle of cross-section 1 mm x 1 mm is attached to the movable rod of the Vicat apparatus.
4. Then the needle is allowed to quickly release and allowed to penetrate in the cement paste. In initial stage, the needle penetrates completely. It is then taken out and dropped at a fresh place. The test procedure is repeated at regular intervals till the needle does not penetrate completely. The needle should penetrate up to about 5 mm measured from the bottom.
5. The initial setting time is found out by taking the interval between the addition of water to cement and the stage when the needle stops to penetrate completely.

Table 2 Initial setting time of Cement

S.No	Time (minutes)	Depth of penetration in of needle from the bottom of the mould (mm)
1	5	0
2	10	2
3	15	2
4	20	2
5	25	4
6	30	5
7	35	7

Initial setting time of cement = **35 minutes.**

Final Setting Time of Cement Test Procedure

1. The initial test procedure is same that of the initial setting time test.
2. Instead of square needle, annular collar is used. The annular collar is attached to the movable rod of Vicat apparatus.
3. The annular rod is gently released. The time at which the annular rod makes an impression on test block and the collar fails to do so is noted.

4. The final setting time is found out by taking the difference between the time at which water is added to cement and time as recorded.

S.no	Time (minutes)	Penetration (mm)
1	0	55
2	15	53
3	30	50
4	45	46
5	60	43
6	240	35
7	250	32
8	260	28
9	270	24
10	285	20
11	300	18
12	330	10
13	360	7

The final setting time for ordinary cement should be **6 hours.**

Specific gravity of fine aggregate

Take a pycnometer to test the specific gravity of sand. The empty weight of the bottle was taken as (w_1). Some amount of fine aggregate was placed in the bottle and weighed as (w_2).sufficient water was added to make it saturated. The sample was stirred thoroughly for removing entrapped air. The mould was filled with water and weighed as (w_3). It was emptied, cleaned well, filled with water and weighed as (w_4). as shown in figure 4.5.

Figure 6 Specific gravity of fine aggregate

Calculation

Empty weight of bottle (W_1) = 624 gms
Weight of bottle + sand (W_2) = 1430 gms
Weight of bottle + sand +water (W_3) = 1900 gms
Weight of bottle + water (W_4) = 1440 gms

$$\text{Specific gravity of sand} = \frac{(W2-W1)}{((W2-W1)-(W3-W4))}$$

$$= \frac{(1435-630)}{((1435-630)-(1903-1449))}$$

The Specific gravity of fine aggregate = 2.29.

Table 4 Fineness modulas

Sieve size (mm)	Weight retained (gms)	Percentage of Weight retained (%)	Cumulative percentage of Weight retained (%)
4.75	0	0	0
2.36	7.8	0.78	0.78
1.18	64.4	6.44	7.22
0.6	157.6	15.76	21.98
0.3	510	51.0	73.98
0.15	1.4	0.14	74.12
0.075	217.2	21.72	96.84
Pan	41.6	4.16	100
Total	1000	100	378.92

C
Fi
100

Fineness modulus of Fine Aggregate = **3.75.**

Specimen Preparation

Specimens were prepared in mortar cubes of size 100 mm X 100 mm X 100 mm and the compressive strength at the age of 28 days strength were tested of 1000kN capacity. In order to prepare the specimen for determining the compressive strength, wooden mould of standard size were used and it has been filled with a fresh cement mortar. The compaction is carried out manually and the top surface was leveled and finished .The specimens were demoulded approximately after 24hrs of their casting and cured in air for 28days.

Experimental Investigation

Compressive Strength Test

The following Table 5 shows the compressive strength of the cubes.

Table 5 Compression Strength Test for 28 days Variations

Mix Designation	Area mm^2	Failure Load kN	Compression Strength N/mm^2	Average Compression StrengthN/mm^2
		16	1.6	
M5	10000	17.5	1.75	1.72
		18	1.8	
		22	2.2	
M9	10000	21	2.1	2.2
		23	2.3	
		26	2.6	
M13	10000	27	2.7	2.63
		26	2.6	

Thus it is found that along with the above mixes, it is preferable to use the 3rd proportion, to make it economical as well as strength.

Acid Resistant Test

Table 6

Sample	weight after 28 days curing (kg)	Weight after 7 days of acid exposure (kg)
MIX 1	1.22	1.35
MIX 2	1.36	1.52
MIX 3	1.41	1.81

Water absorption test

Table 7

S.No	Proportion	Water absorption (%)
1	Clay soil (100%) + 0% of paper mill sludge	14.2
2	Clay soil (95%) + 5% of paper mill sludge	16.5
3	Clay soil (90%) + 10% of paper mill sludge	18.6

Fig 7 Papercrete after fire test

RESULTS AND DISCUSSION

From the fire test, it was observed that the Papercrete blocks did not burn with an open flame.

- ✓ They smoldered like charcoal. It will eventually be reduced to ashes, but a single block will take several hours to be consumed.
- ✓ If the interior plaster and exterior stucco is provided on the blocks, the blocks won't burn. The only weak point is inside the blocks near electrical outlets, switches and other places where wires gives through walls, into boxes etc. Properly wired places never cause fire.
- ✓ This is not to say that papercrete will never burn. Any material will burn or melt if enough heat is applied - even rock. But for all practical purposes, papercrete is relatively safe without being treated. It's even more safe with the boric acid solution coated.

CONCLUSION

The following conclusions drawn based on the results of the present study. Increase of air curing increases the chloride penetrability. The high volume of paper mixes showed significantly lower chloride ion permeability than normal conventional mixes. All the mixes were assessed to have very low chloride permeability as per ASTM C 1202–94 assessment criteria, with RCPT values lesser than 1000 coulombs after 28-days of curing. As a future scope same mixes can be analysed for corrosion under accelerated curing conditions and life of the structure can be predicted

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