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Experimental study and evaluation of optimum mix proportion of "Papercrete blocks"

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Abstract— Papercrete is a newly developed construction material made basically of waste paper, cement and water. Contractors in U.S. are already using papercrete to build low cost houses relying on empirical knowledge of its structural properties. This study is aimed at describing the methodology for mix proportioning, finding out optimum proportion of mix by comparing compressive strength of blocks made up of various proportions in order to ensure economy, sustainability and structural strength to carry desired loads as a construction material. However, papercrete being a recently developed material, there are no written mixing and sampling standards available, therefore trial and error method along with data from available literature have been taken to arrive at the desired results.

Keywords- Waste paper, sustainability, compressive strength

I. INTRODUCTION

At present time, CO_2 emission due to ever increasing use of cement in construction industry has become a global issue [1]. At the same time, the necessity of low-cost housing has pushed people to look for alternative construction materials. In order to address these issues it has become imperative to push the boundaries of research in the field of innovative sustainable construction materials. This study is one of such kind of efforts. Papercrete is a new composite material comprising of waste paper as a partial replacement of portland cement [3]. Use of waste paper in papercrete not only justifies reduction in the amount of cement but also aims to be an environment friendly building material. [9]

According to the study carried out by 'Indian paper manufacturers association (IPMA)', in India only about 20% waste paper is being currently recovered annually. [2] Considering this scenario use of papercrete would provide a solution to the problems arising due to less reuse of waste paper leading to land issues and deforestation for obtaining more fresh paper. [11]

II. MATERIALS USED

a. Waste paper : For this study the waste paper was procured from " Padamji paper mill situated in pune , India ". The waste paper generated from this mill contains all the impurities and is wet in nature but still works out to be good for making these blocks which can be well supported by the results obtained[5].

b. Cement : The cement used for this study was obtained from an RMC plant situated in kothrud area, Pune. It was grey in colour and had little impurities in the form of sand particles and hence it was sieved before its use. [4]

c. Natural sand : This was also procured from the RMC plant situated in kothrud area, Pune. The sand was blackish with some white particles. It was sieved through 4.75mm IS sieve in order to remove coarser materials and impurities to obtain almost pure graded sand.[4]

III. EXPERIMENTAL PROGRAM

3.1 Papercrete Mix Proportions:

The paper pulp used was in wet form with its moisture content varying in the range of 50- 60%. However, depending on the environmental conditions it may vary to any extent. In papercrete, sand and paper are bound with each other with cement paste. [5]

In this study, for papercrete specimens tested, two mixing variables were decided; sand-binder ratio and paper-cement replacement ratio[8][10]. One more major variable that is normally considered is water-binder ratio when the paper is in dry condition and addition of water can be achieved in a controlled way as it is done externally depending on the requirement.[1] However, in order to directly make use of waste paper pulp(in wet form) obtained from the paper industry with an aim to reduce cost and time for drying of that paper pulp, an attempt is made in this study to achieve the highest possible strength of papercrete blocks with minimum manufacturing cost.

To make these blocks greener, maximum use of waste paper in the place of cement was the major cause of this study. Therefore, six mix-proportion samples were considered where paper-cement replacement ratio had been kept on an increasing scale from 0.5-6. To evaluate the effect of sand-binder ratio, six samples were divided into two sets namely set-A and set-B. Set-A comprises of first three samples (A1,A2,A3) where paper-cement ratio was comparatively low and three samples of set-B(B1,B2,B3), Here, considering the classic concept of concrete where the aggregates play an important role in achieving the desired strength.In this study similar assumption was applied as natural sand acts as an aggregate part. It prevents shrinkage of the blocks as wet paper tends to shrink during curing(drying) process and also prevents crack development by filling the void space in the matrix of paper and cement mix.[12]. Therefore, for set-A sand-binder ratio was kept above 1 in an increasing order for samples A1, A2 and A3 and for set-B it was kept below 1 in a decreasing order for samples B1, B2 and B3. The mix proportions for papercrete are shown in table 1.

Table 1. Mix proportions for papercrete

SET	Samples	Paper/Cement	Sand/Cement	Water/Cement	Paper(kg)	Cement(kg)	Sand(kg)	Water(lt)
A	A1	0.5	1.5	3	1	2	3	6
	A2	1	2	5.1	1	1	2	5.1
	A3	3	4	8	1	0.33	1.32	2.64
B	B1	4	0.5	8	2	0.5	0.25	4
	B2	5	0.625	10	2	0.4	0.25	4
	B3	6	0.75	12	2	0.33	0.25	4

3.2. Experimental Procedure:

Six papercrete blocks were caste for six samples in the mould (shown in figure 1) size of 19*19*9cm. To prevent lumps of wet paper from hindering the preparation of mix, the paper pulp was first mixed in a rotating drum (with blades attached inside) to separate the paper fibers. Then cement paste was prepared by adding water gradually. In the paste, sand was added and then paper

pulp was mixed in a concrete mixer (rotating drum) as shown in figure 2[7]. By observing the workability of mix, amount of water was added progressively in each step of various ingredients addition [6].

The cast specimens were kept under sun exposure for curing at an average temperature of 30˚c. The moulds were removed from specimens after seven days from casting [12]. The compression test was performed after 28 days in accordance with IS code [IS:516 1959].

Fig1. Moulds for casting papercrete blocks

Fig2. Preparation of mix in a concrete mixer

IV. EXPERIMENTAL RESULTS

The compression test was performed with compression testing machine as shown in figure 3. From the results, it can be observed that maximum compressive strength was obtained for a proportion of paper :cement :sand as 1:1:2. The results of compression test are entered in table 2.

Table 2. Compression test results

Sample	Paper/Cement	Sand/Cement	Water/Cement	Proportion (paper:cement:sand)	Compressive strength (MPa)
A1	0.5	1.5	3	1:02:03	1.44
A2	**1**	**2**	**5.1**	**1:01:02**	**1.64**
A3	3	4	8	1:0.33:1.32	1.2
B1	4	0.5	8	1:0.25:0.125	1.41
B2	5	0.625	10	1:0.2:0.125	1.23
B3	**6**	**0.75**	**12**	**1:0.165:0.125**	**1**

Fig3. Compression test assembly

From the results of compression test, optimum proportion with the highest compressive strength was obtained for sample A2 which had paper-cement replacement ratio as 1 and sand-cement ratio as 2. The lowest compressive strength was obtained for sample B3 which had highest paper-cement replacement ratio 6. It implies that paper in large amount along with high amount of water content reduces the strength. However, while testing the blocks it was observed that the blocks were wet from inside as shown in left side figure of fig.3, which is one of the reason for the reduced strength in all the blocks. Therefore, if the curing period is increased and the blocks are completely cured then higher compressive strength can be obtained.

V. CONCLUSION

In this paper, results of compression test of papercrete blocks are presented with an aim to find out optimum proportion of mix. From this investigation, the following conclusions can be drawn :

(1) The optimum proportion of mix with reference to the highest compressive strength (1.64 MPa) obtained is paper:cement:sand as 1:1:2.

(2) Average compressive strength for set-A which has sand/cement ratio above 1 with paper/cement replacement ratio low as compared to set-B is 1.42 MPa. It also has water/binder ratio low as compared to set-B which is a supplementary reason for the higher strength..

(3) The average compressive strength of set-B which has sand/cement ratio below 1 with paper/cement replacement as well as water/binder ratio higher then set-A is 1.21 MPa. This shows that as paper /cement replacement ratio increases beyond certain limit with higher water/binder ratio too leads to decrease in strength. This is because less amount of binder fails to completely cover all the paper particles and also amount of water being high, it not only increases curing period but also due to its evaporation during the curing process voids are generated in the blocks leading to reduction in strength.

(4)After observing the results considering economy, sample B1 gives comparatively good strength if more paper is required to be reused with sand/binder ratio also being relatively less. Therefore, with high paper/cement replacement ratio high strength can be achieved by keeping sand/binder ratio relatively higher. To arrive at the desired outcome for this statement , further research work in this

field would shed light on it.

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