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Preparation of Light Weight Bricks by Using Agro-Waste Materials

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Abstract: Bricks are the most important component in the building industry, for which several types are available across the world depending upon the availability of the basic manufacturing materials. In India, burnt clay bricks are the most sought-after type for which enormous quantities of top fertile soil is being harnessed. Efforts are being made to reduce the self-weight of these bricks while retaining the strength requirements. The present study is an effort to utilize the locally available agro-waste materials along with the native black cotton soil. Trial mixes were investigated for their relative effectiveness in order to get the optimum mix combination. In the first trial, the black cotton soil mixed with 10% RH and 10% RHA, the dry density is obtained as 1.32 g/cc. In the second trial, in order to reduce the dry density further, the RH & RHA contents were increased to 20% at which the dry density is obtained as 0.90 g/cc. Despite the encouraging reduction in self-weight, the burnt bricks at 800^0 C were observed to be subjected to self-cracking after exposing them to environment within 24 hours. In order to overcome the cracking problem, the straw fibers were tried along with the RH & RHA. Even then, the problem of self-cracking could not be overcome. In further trials, locally available red soil is mixed with black cotton soil by 10%-20% and also the burning temperature is increased up to 1000^0 C by which the cracking problem could be overcome while maintaining the lower density. The strength of the bricks is obtained as about 73.49 kg/cm^2 satisfying the requirement for the II- class bricks as per IS:1077 (1992).

Keywords: Rice Husk (RH), Rice Husk Ash (RHA), Rice Straw, Block Cotton Soil, Red Soil.

1 Introduction

Bricks are universally accepted walling materials across the world. Traditionally mud bricks were used[1 & 2] and subsequently the burnt bricks were promoted to overcome the limitations of unburnt bricks[3]. With ever growing housing demand to cater the needs of growing population, multi-storied structures gained prominence. For these structures, the walls are partition walls without much demand for their strength and accordingly, several commercial bricks in place of clay bricks were emerged[4]. For this purpose, light weight bricks are preferred in order to reduce the self-weight of these multi-storied structures[4-6].

Despite the availability of several types of commercial bricks in the market, burnt clay bricks are still the most sought-after walling material[3&7]. Several adjustments in the composition of brick - earth using the locally available minerals, particles and organic fibers were made by people of different regions of the world in order to get different benefits such as strength and light weight of mud bricks[8]. In this connection efforts are still being made to make these burnt clay bricks more eco- friendly by reducing their self-weight along with thermal comfort[9 &10] by adjusting their pore structure. Agro - waste materials have been widely tried in the brick making in order to reduce the self-weight[8,4&2] and fuel consumption. Rice - husk[9&11] and Rice- husk – ash[5,12&13] were investigated individually for this purpose.

In the present work, an attempt is made to prepare the light weight bricks using the locally available black cotton soil by admixing with it the Rice-husk, Rice-husk-Ash and straw fibers in different combinations [11]. Also, a fraction of red soil was added to overcome the self-cracking phenomenon of the prepared bricks made of black cotton soil. The engineering properties such as the compressive strength and water absorption were determined for the prepared bricks.

2 Materials used

2.1 Black cotton soil

Locally available Black Cotton soil is used for making the light weight bricks by admixing with it the agro-waste materials. The properties of the soil are placed in Table 1.

2.2 Red soil

Locally available red soil is used along with black cotton soil for the preparation of light weight bricks and its properties are presented in Table 1.

Table1**:** Properties of soils used

PROPERTY	**BC Soil**	**Red Soil**
Particle Size Analysis		
Gravel (>4.75 mm)%	5	1
Sand (4.75 mm – 0.075 mm)%	34	59
Silt (0.075 mm – 0.002 mm)%	50	33
Clay (<0.002 mm)%	11	7
Specific gravity	2.70	2.75
Liquid limit (%)	38	36
Plastic limit (%)	21	23
Plasticity index	17	13
IS soil Classification	CI	SC

2.3 Rice Husk

Rice husk (RH) is a byproduct generated during the milling of rice grains. It consists of silica, lignin and other hard substances that protect the seed during the germination. About 760 million tonnes of rice is being produced globally each year. Rice husk constitutes around 20 percent of the rice paddy which translates to about 152 million tonnes of rice husk trash produced every year[11]. For the present work, locally available rice husk is used in the preparation of light weight bricks (Fig. 1).

Fig. 1: Rice Husk

Fig. 2: Rice Husk Ash

2.4 Rice husk Ash

Burning of rice husk results in the Rice Husk Ash (RHA) and its weight is only a very small fraction of roughly 25% of the weight of original husk (Fig. 2). Only silica makes up about 80–95 percent of the RHA[7]. Depending up on the burning temperature and duration, the silica content may have different physical/chemical properties[2]. Burning the husk at 550^0C –800°C produces the amorphous ash, and at higher temperatures, the crystalline ash.

3 Methodology

Sample preparation: The test specimens were prepared as per the following proportions.

Trail -1: BC soil+4% Rice Husk ash, CI soil+ 8% Rice Husk, CI soil+ 8% RHA, CI soil+ 10 RH+ 10% RHA
Trail -2: BC soil+20% RH +20% RHA, soil+30% RH +30% RHA and soil+30% RH +20% RHA
Trail -3: BC soil+20% Rice Husk+20% Rice Husk ash+4% Rice straw
Trail -4: BC soil: 20% Rice Husk: 20%Rice Husk ash
Trail -5: BC soil: Red soil (60:40) + 20%Rice Husk+20% Rice Husk Ash

The respective samples were air dried before keeping them in oven at 105^{0}C - 110^{0}C. After oven drying for 24 hours, the samples were burnt at the desired temperature of 800^{0}C- 1000^{0}C for 24 hours. These burnt samples were subsequently subjected to the relevant tests. Before the actual testing of brick specimens, trial balls of the desired mixes were burnt in order to have the preliminary idea of their physical condition during the process. The necessary corrections were made based on these preliminary observations on trial balls (Figs. 3 and 4).

Fig. 3: Trial balls before burning

Fig. 4: Trial balls after burning

4 Results and Discussion

The observations made and results obtained from the experimental work carried out to prepare light weight bricks using agro-waste materials along with locally available black cotton soil are presented below.

4.1 Variation of unit weight of mixes

In order to get the least possible dry density for different trial mix combinations, balls of these mixes were prepared at suitable moulding water content. These soil mix balls were air dried until the surface in dry and then were kept in oven for 24 hours at 105-110^{0}C. Later these oven dried trial balls were burnt at 800^{0}C, 900^{0}C and 1000^{0}C temperatures.

Trail-I Mixes: The results obtained from this set of mixes are presented in Table-2. It can be seen from Table 2 that for the soil+4% RHA and soil+8% RHA, the dry densities are obtained as 1.847 g/cc & 1.59 g/cc respectively. similarly, for soil+8% RH, the dry density is obtained as 1.48 g/cc. For soil+10% RH +10% RHA, the dry density of 1.32 g/cc is obtained. Based on these trials, for the mix resulted in lower density, further studies were carried out.

Trial-2 mixes: Under these trials, soil+20% RH +20% RHA, soil+30% RH +30% RHA and soil+30% RH +20% RHA mixes were used to prepare the experimental trail balls and after oven drying as mentioned previously, these balls were burnt at 800^{0}C for 24 hours. As can be seen from Table-3 that for the mix of soil+20% RH +20% RHA, the lower dry densities of 0.91 g/cc is obtained. For the mix that resulted in the lowest dry density, the straw content of 4% was further added for subsequent investigation.

Trial-3 mixes: Under these trials, four experimental balls were prepared with 4% straw content with a variation in burning temperature of 800^{0}C & 900^{0}C. As could be seen from Table 4, The dry densities were significantly reduced up to 0.66 g/cc which indicate that the straw combination is very effective to reduce the dry density. Water absorption was found by soaking dry burnt samples in water for 24 hours as shown in Fig.5.

Table 2. Mix combinations (BC soil+ Rice Husk+ Rice Husk ash)

Sample No	Soil	(RH) in %	(RHA) in %	Temperature (°C) for 24 hrs	Water absorption (%)	Dry Density (g/cc)
1	BC Soil	-	4	800	25	1.847
2	BC Soil	8	-	800	24	1.483
3	BC Soil	-	8	800	28	1.59
4	BC Soil	10	10	800	27	1.32

Table 3. Mix combination (BC soil+ Rice Husk+ Rice Husk ash)

Sample No	Soil	Rice Husk (RH) %	Rice Husk Ash (RHA) %	Temperature (°C) for 24 hrs	Water absorption (%)	Dry Density (g/cc)
1	BC Soil	20	20	800	28	0.90
2	BC Soil	30	30	800	29	1.044
3	BC Soil	30	20	800	25	0.91

Fig.5: Dry specimens

Table.4: Mix combination BRRR (BC soil: Rice Husk: Rice Husk ash: Rice straw = (56:20:20:4)

S.NO	Mix Combination	Dry Density (g/cc)	Temperature (°C) for 24 hrs	Water absorption (%)	Ringing sound	Compressive Strength (kg/cm^2)
1	BRRR -1	0.69	800	31.5	Clear ring sound	17.29
2	BRRR -2	0.66	800	32	do	16.64
3	BRRR -3	0.69	900	30	do	23.97
4	BRRR -4	0.74	900	28	do	29.97

Eight samples were prepared for the fourth trial in two different sets of combinations. In 1st combination (BRR-1 to 4), the burning temperature of 900^0C was maintained for 24 hours and for the 2nd combination, the burning duration was increased to 48 hours. The compressive strength results corresponding to 48 hours of burning are higher than those corresponding to 24 hours of burning (table 5). Keeping this in view, the brick cubes were burnt for 48 hours.

Table 5: BRR (BC soil: Rice Husk: Rice Husk ash = (60:20:20)

S. NO	Mix Combination	Dry Density (g/cc)	Temperature (°C)	Water absorption (%)	Ringing sound	Compressive Strength (kg/cm^2)
1	BRR -1	1.10	900	14.83	Clear ring sound	33.14
2	BRR-2	1	900	15.25	Clear ring sound	33.62
3	BRR -3	0.98	900	19.47	Clear ring sound	29.46
4	BRR -4	1.04	900	20.52	Clear ring sound	30.38
5	BRR -5	1..05	900	13.82	Clear ring sound	35.54
6	BRR -6	1.00	900	15.04	Clear ring sound	34.45
7	BRR -7	0.89	900	16.01	Clear ring sound	33.06
8	BRR -8	1.01	900	14.23	Clear ring sound	31.58

4.2 Difficulties encountered during experimentation

During the above experimentation, it was noted that the burnt balls were subjected to self-cracking within 24 hours of exposure to outside environment. Interestingly when the balls are wetted / soaked in water after cooling for 24 hours, no further cracking was noticed. The possible reason for self-cracking is due to the inadequate particulate bonding at the contacts that result in separation when exposed to atmosphere. However, this soaking cannot be relied up on in practice while handling large scale production. In order to overcome this defect, the black cotton soil was mixed with 20% red soil to which 20% RH and 20% RHA were added to prepare the trial balls again. These balls were observed to be free from self-cracking when the burning temperature was kept 1000^0C for 48 hours. Though the addition of straw is beneficial in getting lower dry densities, the strength is observed to be decreased significantly as discussed later. Hence, straw content was omitted for the selected mix.

4.3 Variation of compressive strength of mixes

For the successful crack-free combination of mix, the bricks/cubes were prepared and burnt at 1000^0C for 48 hours as shown in fig 6. The values of compressive strength are presented in table 6. It can be seen from Table 6 that the compressive strength of trial samples varied from 67.86 kg/cm^{2} - 73.49 kg/cm^2 and this range of strength is falling within the 2nd class brick as per IS:1077(1992). The water absorption of samples is in the range 17.26%-18.45% which is also within the allowable limit of 20% for 2nd class brick.

Few observations made with regard to the strength studies for the successful combination at the burning temperatures of 800^0C and 900^0C for which the lower strength values are obtained (Table 4). When 4% straw was added to the mix, the lower strength of about 24 kg/cm^2 is obtained though the light weight is possible for straw mix. Further, the water absorption for straw mix is also beyond the allowable limits.

Fig.6: Compressive strength test

Table.6: Final mix combination BSRR (BC soil: SC soil: Rice Husk: Rice Husk ash = 36:24:20:20)

S.NO	Mix Combination	Dry Density (g/cc)	Temperature (°C) for 48 hrs	Water absorption (%)	Ringing sound	Compressive Strength (kg/cm^2)
1	BSRR -1	1.09	1000	17.82	Clear ring sound	67.86
2	BSRR -2	0.99	1000	18.45	Clear ring sound	73.49
3	BSRR -3	1.08	1000	17.26	Clear ring sound	70.77

5 Conclusions

The following conclusions are drawn based on the laboratory testing for the preparation of light weight bricks using agro-waste materials.

1. Based on the trial mixes using RHA & RH along with B.C soil, the optimum mix that resulted in lower dry density of 0.98 g/cc is found to be for BC soil+20% RHA + 20% RH at 800^0 C of burning temperature.
2. The trial mix balls as mentioned above were subjected to self-cracking within 24 hours after removing them from the furnace. However, the same balls if water soaked after cooling for 24 hours, they are free from self-cracking. This phenomenon was observed for both 800^0 C and 900^0 C of burning temperature. Even when 4% straw fibers was mixed, the cracking could not be prevented though the dry density is significantly reduced to 0.66 g/cc.
3. In the trials when local red soil was mixed with BC soil +20% RHA +20% RA, the trial balls are not subjected to self-cracking at 900^0 C and 1000^0 C though it was subjected to self-cracking at 800^0 C with lower strength.
4. When the burning temperature is increased to 1000^0 C for 48 hours duration and also by the addition of 20% red soil to the optimum mix combination resulted in crack-free bricks.

5. Based on the optimum trial mix of BC soil + 20% red soil +20% RHA +20% RA, the final brick cubes were made and tested for their engineering properties and these brick cubes are satisfying the strength and water absorption criteria for 2nd class bricks as per IS code.

The present study reveals that the large quantities of agro-waste can be harnessed in brick making industry which enables to reduce the unit weight of bricks and also the brick burning fuel consumption due to its in-mixing with brick earth without compromising the strength requirement. The reduction in unit weight of bricks indicates the corresponding saving of the top fertile soil for brick making.

6 References

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