ECOFRIENDLY BRICK CONSTRUCTION USING WASTE MATERIALS

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Abstract - *Reuse of waste generated from industrial and agricultural activities as building materials appears to be viable solution to problem of pollution and waste disposal. In India it has been estimated that nearly 30% of the daily production turns on waste during the manufacturing, transportation and usage. From decades burnt clay bricks have been used in the building construction and it helps to reduce the energy consumption of buildings due to its excellent thermal insulation property. As a result of this, there is still an existing demand for clay bricks and huge quantity of soil is being exploited for its production. Wide use of ceramic tiles, marbles, etc. results in the production of huge quantity of ceramic powder, marble dust which are found to be difficult for disposal. Also rice milling industries generates rice husk ash which is also considered as a waste product. This study focuses on the investigation of properties of clay brick produced by the partial replacement of the clay with rice husk ash(RHA), ceramic powder(CP) and marble dust(MP) in varying percentages of 0%, 4%, 8% and 12%. Properties such as compressive strength, water absorption, initial rate of absorption, efflorescence, linear shrinkage, bulk density and apparent porosity of modified clay bricks are determined.*

Key Words: *Reuse, waste materials, Brick properties, Industrial waste, Environmental pollution*

1. INTRODUCTION

Housing is one of the basic requirements for human survival. Masonry is an inevitable component of housing. Among different types of masonries, brick masonry is one of the most widely used in our country, because of low cost, easy availability of raw materials, good strength, easy construction with less supervision, good sound and heat insulation properties, and availability of manpower. Brick masonry is a composite material of systematic arrangement of brick units and mortar joints. The behaviour of masonry is dependent on the properties of its constituents such as brick units and mortar separately and together as a unified mass. Burnt clay bricks are widely used around the globe but in recent years many other varieties of bricks have been developed.

Brick is one of the oldest manufactured building materials in the world. The fired bricks were further developed as archaeological traces discovered in early civilizations, such as the Euphrates, the Tigris and the Indus that used both fired and unfired bricks. The development of different types of bricks continued in most countries in the world and bricks were part of the cargo of the First Fleet to Australia, along with brick moulds and a skilled brick maker. Bricks have continuously been used by most cultures throughout the ages for buildings due to their outstanding physical and engineering properties. Brick is one of the most demanding masonry units. It has the widest range of products, with its unlimited assortment of patterns, textures and coolers. In 1996, the industry produced 300 million bricks in Victoria, which were about 55% of the potential production of the facilities available. The export markets included Japan, New Zealand, the Middle East and other Asian countries. Brick is durable and has developed with time. With the advancements in technology, it led to the development of concrete, mortar, cellular and hollow blocks. The main advantage of using clay bricks is its thermal insulation property. It helps the building to remain cool during summers. As a result of this, there is still a rising demand for clay brick. The main raw material for bricks is clay besides clayey soils, soft slate and shale, which are usually obtained from open pits which may include disruption of drainage, vegetation and wildlife habitat. Soil used for brick making vary broadly in their composition and are dependent on the locality from which the soil originates. Different proportions of clays are composed mainly of silica, alumina, lime, iron, manganese, sulphur and phosphates.

2. OBJECTIVE

Utilization of waste in the production of bricks can help in the conservation of natural resource like clay. Since the present scenario is dumping the waste landfill sites, it leads to cause various environment problems. The main objective of this research is to investigate the properties of bricks produced by partial replacement of clay with ceramic powder, marble powder and rice husk ash

3. METHODOLOGY

3.1. MATERIAL COLLECTION

Common clay (soil), rice husk ash, ceramic waste powder and marble dust were used as raw materials. Soil was collected from kiln located near Velloor, Kerala. Rice husk ash was collected from Nellad rice mills, Kerala. Ceramic waste powder was collected from Cochin Special Economic Zone, Kerala and marble dust was collected from intercity enterprises, Chennai.

A. CLAY

Soil used for brick manufacturing can be of any type with good plasticity. Clay, loam and laterite are the most commonly used types of soil. Fig. 1 shows the clay used for this study.

Fig -1: Soil used for the preparation of brick

Properties of clay was studied by conducting experiments like specific gravity and Atterberg's limits. IS 2720(Part III) was used to determine the specific gravity. IS 2720(Part V) was used to determine the Atterberg limits. The results of the properties of clay is shown in table 1.

Table -1: Material Properties of Clay

Properties		Values
Specific gravity		2.7
OMC (%)		28.81
Dry density (g/cc)		1.68
Atterberg limits (%)	Liquid limit	53
	Plastic limit	24.46
	Plasticity index	28.54
Particle size distribution	Silt size particles (%)	60
	Clay size particles (%)	40

Using plasticity chart according to ISC, 'A line' was drawn with plasticity index equal to 28.54 and it was observed that the soil belongs to the clay of high plastic (CH).

B. RICE HUSK ASH(RHA)

Rice Husk Ash (RHA) is obtained from the burning of rice husk. The husk is a by-product of the rice milling industry. About 100 tonnes of rice husk is generated annually in the world. For every 1000kg of paddy milled, about 220 kg (22%) of husk is produced, and when this husk is burnt in the boilers, about 55 kg (25%) of RHA is generated. Figure 2 shows a sample of rice husk ash

Fig -2: Rice husk ash

C. CERAMIC POWDER (CP)

Ceramic production is 100 Million ton per year worldwide. In ceramic industry, about 15%-30% waste material generated from the total production. Figure 3.4 shows a sample of ceramic powder

Fig -3: Ceramic powder

D. MARBLE DUST (MD)

Marble powder is produced from the marble processing plants during the cutting, shaping and polishing. During this process, about 20-25% of the processed marble is turn into the powder form. India being the topmost exporter of marble, every year million tons of marble waste form processing plants are released. The disposal of this waste marble on soils causes reduction in permeability and contaminates the over ground water when deposited along catchment area. Thus, utilizing these marble waste in construction industry itself would help to protect the environment from dumpsites of marble and also limit the excessive mining of natural resources of sand. Fig. 4 shows a sample of marble dust.

Fig -4: Marble dust

Table -2: Chemical composition of rice husk ash, ceramic powder, marble dust

Constituent	rice husk ash	ceramic powder	marble dust
Silica – SiO_2	92.23	63.36	28.35
Alumina – Al_2O_3	2.54	18.20	0.42
Calcium oxide – Ca O	1.58	1.74	40.45
Magnesium oxide- Mg O	1.53	2.04	16.25
Potassium oxide – Ka O	1.91	3.87	0.21
Ferric oxide - Fe_2O_3	0.21	2.77	0.55

3.2. PREPARATION OF BRICKS

Bricks prepared are hand moulded and are burnt in the kiln. Raw materials are mixed manually by varying the proportion of ceramic powder, marble dust, rice husk ash with clay. The mix proportion used for the preparation of brick is shown in table 4.1. The mixture was prepared with the predetermined optimum moisture content. Mould size was selected as 230 x 110 x 70 mm, which is the size of non-modular bricks as per IS 1077:1992. The bricks were air dried until it is left with less moisture content. The bricks were dried for 10 days and were transported to the kiln, where it is burned at around 980^{0}C. Bricks are taken out from kiln after cooling.

Table -3: Mix Proportion for the Preparation of Bricks

Clay (%)	Powder of ceramic waste (%)	Powder of marble waste (%)	Rice husk ash (%)
100	0	0	0
96	4	4	4
92	8	8	8
88	12	12	12

4. EXPERIMENTAL INVESTIGATION

Several experimental tests was conducted on brick units to determine the mechanical properties such as compressive strength, water absorption, efflorescence, initial rate of absorption, bulk density, apparent porosity and linear shrinkage. A total of 60 brick units comprising of pure clay and replaced clay bricks are tested.

4.1. COMPRESSIVE STRENGTH

The compressive strength was determined according to IS 3495 (PART I):1992. The compressive strength of the bricks depends mainly on the density and porosity of the bricks. The reduction in compressive strength may be caused due to the decomposition of organic matter. The compressive strength values showed a linear relationship with the water absorption values.

Table -4: Compressive strength values for bricks

Clay content (%)	Replacing material (%)	Compressive strength (N/ mm^2)
100	0	12.33
96	RHA - 4	12.23
92	RHA - 8	11.94
88	RHA - 12	10.85
96	CP - 4	12.00
92	CP - 8	11.80
88	CP - 12	11.25
96	MD - 4	12.04
92	MD - 8	11.32
88	MD - 12	10.72

The values show that the compressive strength for the brick made with pure clay has the highest strength of 12.33 N/mm^2. The compressive strength of bricks decreased with the increase in RHA, Ceramic powder and Marble dust content as shown in fig.5. Although the compressive strength reduced up to 10.85%, 11.25% and 10.72% for RHA, ceramic powder and marble dust respectively, it was found that all the bricks satisfied the minimum compressive strength requirement as per IS 1077:1992. As per IS 1077:1992 the minimum compressive strength required for first class brick is 10.5 N/mm^2. Among the various materials 4% of RHA, Ceramic powder and Marble dust has maximum compressive strength.

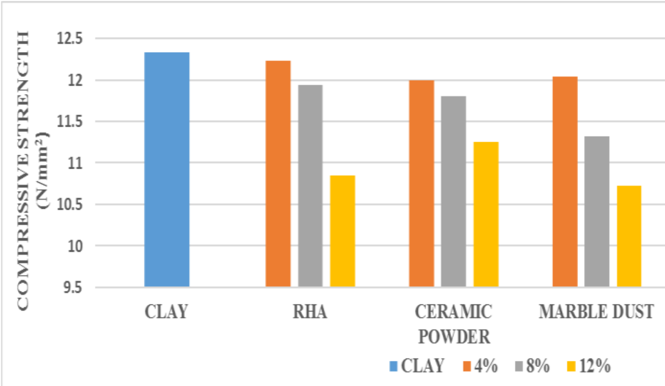

Fig -5: Variation of compressive strength with increase in RHA, Ceramic Powder and Marble dust content

4.2. WATER ABSORPTION

The water absorption was determined according to IS 3495 (PART II):1992. More the water absorption the weaker will be the brick. Water absorption of the bricks mainly depends up on the porosity. Thus, the increase in porosity might be the cause for the increase in water absorption.

Table -5: Water absorption test results

Clay content (%)	Replacing material (%)	Water absorption (%)
100	0	15.6
96	RHA - 4	16.2
92	RHA - 8	19.0
88	RHA - 12	21.0

96	CP - 4	16.8
92	CP - 8	18.4
88	CP - 12	20.0
96	MD - 4	16.4
92	MD - 8	18.0
88	MD - 12	19.8

Water absorption of the bricks should not be more than 20% by weight for first class bricks and not more than 22% by weight for the second class bricks. Here all the bricks have water absorption less than 20% except 12% of RHA and ceramic powder. Thus, it is evident that clay bricks produced by partial replacement of clay with RHA, Ceramic powder and Marble dust satisfies the first class standards of IS 1077:1992 except 12% of RHA and Ceramic powder.

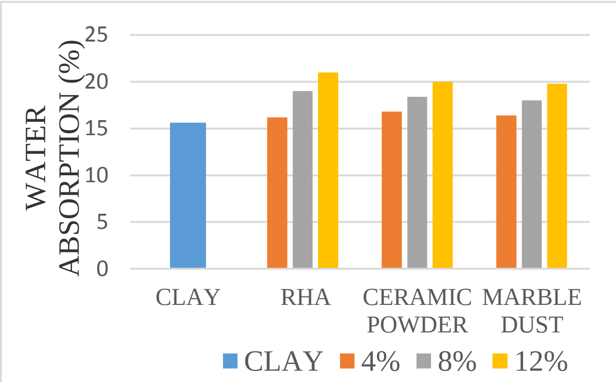

Fig - 6: Variation of water absorption with the increase in RHA, Ceramic Powder and Marble dust content

4.3. INITIAL RATE OF ABSORPTION(IRA)

Initial rate of absorption was conducted as per ASTM C67. It is important to find the initial rate of absorption to assist in mortar selection and material handling during construction. The observed values for initial rate of absorption is given in table 6 and the variation of IRA for the prepared bricks is shown in fig.7. As per the code the initial rate of absorption is found as following:

$$\text{Initial rate of absorption} = \frac{\text{Wet mass} - \text{Dry mass}}{\text{As x t}}$$

where "As" is the surface area of the brick

"t" is the duration at which water is absorbed from the container

Table -6: Initial rate of absorption for the tested bricks

Clay content (%)	Replacing material (%)	IRA (kg/ m^2/min)
100	0	0.56
96	RHA - 4	0.54
92	RHA - 8	0.63
88	RHA - 12	0.78
96	CP - 4	0.50
92	CP - 8	0.65
88	CP - 12	0.79
96	MD - 4	0.57
92	MD - 8	0.74
88	MD - 12	0.85

It was observed that the initial rate of absorption increased with the increase in RHA, Ceramic powder and Marble dust content. The minimum IRA was obtained for the brick without RHA, Ceramic powder and Marble dust content. This shows that the porosity of the bricks increased with the increase in RHA, Ceramic Powder and Marble Dust, which facilitates high absorption rate of the bricks through the pores. Permissible value for IRA is 0.25 kg/ m^2/min to 1.5 kg/ m^2/min. For all the bricks the IRA was found to be in permissible limit. Bricks used in such cases should be made wet before application. Also a little more water can be added to the mortar.

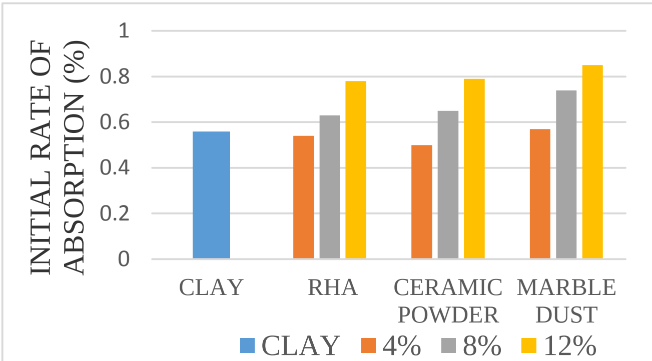

Fig -7: Variation of IRA with the increase in RHA, Ceramic Powder and Marble dust content

4.4. EFFLORESCENCE

The efflorescence was determined according to IS 3495 (PART II):1992. Efflorescence may be caused due to sulphates, nitrates and chlorides of magnesium, calcium, sodium or potassium which are commonly termed as alkaline salts. If these alkaline salts are present in higher percentage, it may results in the disintegration of the brick surface or plaster applied over it. After conducting the efflorescence test it was determined that all the bricks were showing "slight" efflorescence. Brick were entitled to show slight efflorescence, because only 10% of the brick surface was covered with alkaline salts. Therefore, bricks are in a range that does not affect the aesthetics of the building if used.

4.5. BULK DENSITY

Bulk density of brick is defined as dry weight of brick per unit volume of brick. High bulk density is an indication of less pore space. Higher the density, higher will be the compressive strength. This is evident from the compressive strength values obtained for the bricks. Table 7 shows the bulk density values of the bricks.

Table -7: Bulk density of the tested bricks

Clay content (%)	Replacing material (%)	Bulk density (g/cc)
100	0	1.79
96	RHA - 4	1.68
92	RHA - 8	1.62
88	RHA - 12	1.58
96	CP - 4	1.70
92	CP - 8	1.66
88	CP - 12	1.62
96	MD - 4	1.69
92	MD - 8	1.64
88	MD - 12	1.60

The bulk density of the bricks mainly depends on the method of manufacturing and the method of burning bricks. The variation of bulk density with the increase in RHA, Ceramic Powder and Marble Dust is shown in fig. 8. It is observed that with the increase in RHA, Ceramic Powder and Marble dust content, light weight bricks are obtained. Among the various material 12% RHA has the lowest bulk density of 1.58 g/cc which means it is more light weight. The bulk density values showed a linear relationship with the compressive strength values.

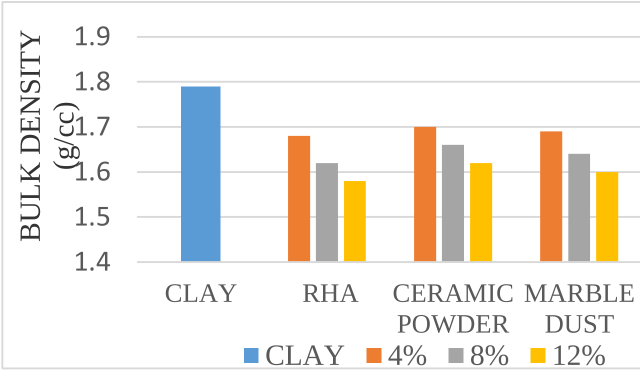

Fig -8: Variation of bulk density with increase in RHA, Ceramic Powder and Marble dust content

4.6. APPARENT POROSITY

Apparent porosity is the amount of voids or pores (open) within a volume of porous solid. As per ASTM C20 (2010), apparent porosity, P% = water absorption x bulk density.

Table -8: Apparent porosity for the tested bricks

Clay content (%)	Replacing material (%)	Apparent porosity (%)
100	0	27.92
96	RHA - 4	27.22
92	RHA - 8	30.78
88	RHA - 12	33.18
96	CP - 4	28.56
92	CP - 8	30.55
88	CP - 12	32.40
96	MD - 4	27.72
92	MD - 8	29.52
88	MD - 12	31.68

Apparent porosity of the bricks increased with the increase in RHA, Ceramic Powder and Marble dust content. Among the various materials tested, 12% RHA has the highest apparent porosity of 33.18%. Apparent porosity shows a linear relationship with the compressive strength values. Thermal insulation increases with the increase in porosity of the bricks. Thus, bricks can be used where good thermal insulation is required.

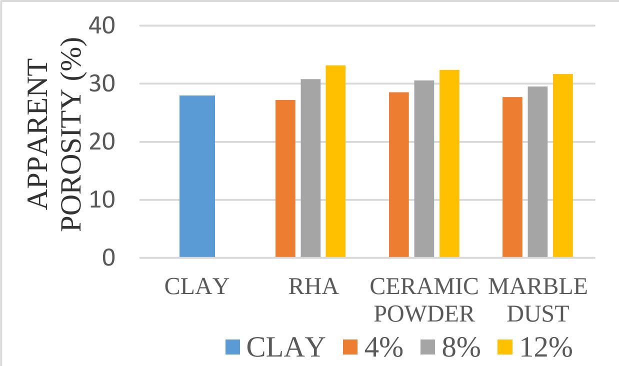

Fig -9: Variation of apparent porosity with increase in RHA, Ceramic Powder and Marble dust content

4.7. LINEAR SHRINKAGE

Linear shrinkage is defined as decrease in the dimension of a mass, expressed as a percentage of the original dimension, when the water content is reduced from a given value to the shrinkage limit. The purpose of this test is to obtain values of shrinkage after drying and firing of clays or bodies or both, under various processing conditions. It enables designers to determine the proper size of mould or die so as to produce a predetermined size of fired brick. As per ASTM C326 2003,

where, S_d = linear drying shrinkage in percentage

L_p = plastic length of test specimen,

L_d = dry length of test specimen.

Table -9: Linear shrinkage of the bricks

Clay content (%)	Replacing material (%)	L_p (m)	L_d (m)	S_d (%)
100	0	230	210	8.69
96	RHA - 4	230	210	8.69
92	RHA - 8	230	210	8.69
88	RHA - 12	230	212	7.82
96	CP - 4	230	210	8.69
92	CP - 8	230	213	7.39
88	CP - 12	230	212	7.82
96	MD - 4	230	210	8.69
92	MD - 8	230	213	7.39
88	MD - 12	230	213	7.39

It was found that when the clay was replaced with RHA by 12% of weight, the shrinkage value decreased from 8.69% to 7.82% and for clay replaced with ceramic powder and marble dust by 8% of weight, the shrinkage value decreased from 8.69% to 7.39%. Drying shrinkage occurs after the replacement of 12% of RHA and 8% of Ceramic powder and marble dust.

5. APPLICATION

The bricks in this study is hand moulded and are burnt in the kiln. All the bricks have crushing strength not less than 10.5 N/mm^2 and the water absorption of the bricks was less than 20% except 12% of RHA and ceramic powder. Therefore, all the bricks are classified as First class bricks except 12% of RHA and ceramic powder. In the case of structures subjected to lighter loads, it helps to reduce the dead load and finally helps in economic design of foundation of the buildings. The main applications of the bricks produced are:

- Construction of exterior wall brick works, facing works
- Construction of short columns and arches
- Construction of floors and reinforced brickwork

6. CONCLUSION

- Bricks produced by partial replacement of clay with RHA, Ceramic powder and Marble dust satisfied compressive strength of first class bricks requirement as per IS: 1077 1992. 4% of RHA, Ceramic powder and Marble dust has maximum compressive strength. Among which 4% RHA has the highest compressive strength of 12.23 N/mm^2.

- The water absorption of the bricks increased with the increase in RHA, Ceramic powder and Marble dust. It was found to be within permissible limit as per IS 1077:1992. All the bricks except 12% of RHA and ceramic powder satisfies the requirement of first class bricks.

- All bricks showed "slight" efflorescence. 10% of the brick surface was covered with alkaline salts therefore, bricks does not affect the aesthetics of the building if used.

- The initial rate of absorption revealed that all the bricks have to be wetted before use. Utilization of RHA, Ceramic powder and Marble dust in clay bricks helps in producing light weight bricks and can be used where thermal insulation is required. They can be used for the construction of exterior wall brick works.

- The bulk density of the bricks decreased with the increase in RHA, ceramic powder and marble dust. Out of various percentages 12% of RHA, ceramic powder and marble dust has least bulk density. Among which 12% RHA has the least bulk density of 1.58 g/cc. Hence, it can be used to produce light weight bricks.

- Apparent porosity increased with increase in RHA, Ceramic powder and Marble dust and can be used where good thermal insulation is required. 12% of RHA, ceramic powder and marble dust has the highest porosity. Among which 12% RHA has the highest bulk density of 33.18%.

- Linear shrinkage of the bricks decreased with increase in RHA, Ceramic powder and Marble dust. It was observed that the bricks can be replaced up to 8% RHA, 8% ceramic powder and 12% marble dust by weight and this can help in waste management as well production economic bricks.

- Utilization of rice husk ash and ceramic waste powder up to 8% replacement of clay in bricks and marble dust up to 12% replacement of clay in bricks helps in waste management and conservation of clay.

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