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Reduction of Environmental Pollution and Soil Conservation in Indian Brick Sector: A Guiding Step for Small Scale Production

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ABSTRACT
Bricks are extensively used building material all over the world due to their low price, frequent availability and ease of handling. There are more than 150,000 brick kilns in India producing about 300 billon bricks annually, employing about 18 million workers and consuming about 40 million tons of coal annually. It is also estimated that the clay fired brick sector in India is estimated to consume as high as 800 million tons of clay annually [1]. The main focus is on the red brick because it is a low maintenance, permanent, durable building material that won't rot rust, burn, corrode, decay, or encourage mold growth. Also these bricks are fire resistant and easily reusable. However, as a matter of fact, they also consume huge quantity of clay. Thus, there is an urgency to conserve the top soil and to reduce the environmental pollution produced by it. Adding waste material to the clay can be an alternative because it reduces the consumption of clay and also proper utilization of waste can be achieved, thus, reducing the environmental pollution. This paper presents the comparative study of different samples of bricks produced by replacing some proportion of clay with the waste materials. Different types of wastes and additives are used as partial replacement of fresh clay. The bricks prepared by incorporating the waste materials are analyzed for their physical, chemical and mechanical properties and the results are compared with those obtained from the control samples. The brick specimen is evaluated for their compressive strength, water absorption, thermal conductivity, efflorescence, baking temperature, etc.
Keywords – Red clay brick, environmental pollution, top soil, brick industry, small scale production

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I. Introduction

The excessive consumption of clay for manufacturing of bricks causes the problem of reducing natural soil level. Bricks characterization is greatly affected by the properties of raw materials, techniques of manufacturing and burning temperature of kiln. Constituents like silica, alumina, lime and iron oxides are present in clay in varying quantity, which affect the qualities of the bricks.

To meet the requirements of fast-growing population, many industries and buildings are being constructed and bricks lay the basic foundation of the entire structure. The problem associated with the normal red brick is the design and percentage composition of raw materials. And as a result, after thermal power plant, these bricks are the second highest source of pollution generation. Apart from this, it also causes soil erosion, thus, degrading the quality of land and crops. So, in this study the aim is to conserve the land and environment. This can be achieved by few modifications in design in such a way that the soil content requirement is low and maintaining the strength of brick by altering the compositions or adding some particles like slurry, fly ash, sludge, slag, ceramics or glass etc. The use of waste raw materials along with clay is common practice to modify the properties of the bricks. This also results in safe disposal of the wastes. Wastes being used are RHA, sugar cane bagasse ash, marble powder, waste glass sludge, fly ash, paper wastes, wood ash, quarry dust, nano clay, and many others.

Many researchers world over are exploring new ways to suggest alternates of clay as constituent of bricks. The previous works that have been done on changing the composition of a red clay brick by adding different waste material are:-

1.1 Rice Husk Ash mixed with clay

De Silva et al. have reported that the transverse breaking load on bricks rises by 45.97% if 20% RHA is mixed with clay and the interior temperature condenses by 4% as a result of blending 10% RHA with clay [2]. The use of RHA also increases the porosity resulting in lightweight materials [3]. RHA in bricks tends to decrease the firing time from 6 to 4 hours to produce well burnt bricks [4]. Sugar Cane Bagasse Ash produces lighter bricks, having insulating properties, withstanding the critical weather and the efflorescence.

1.2 Silica Fumes mixed with clay

The brick manufactured using a blend of 60% clay with 40% SF results in the same water absorption and apparent porosity as that of control bricks: This could save as much as 40% fresh clay along with the safe disposal of silica fumes, which itself is an industrial waste [5].

1.3 Fly ash mixed with clay

Use of fly ash yields light weight bricks with less efflorescence; although the strength is also reduced but by adding up to one fifth of clay mass, the obtained strength meets the building codes. Fly ash increases the water absorption, however, up to 5% replacement, the manufactured bricks offer high climate resistance [6]. Bottom or Fly pine-Olive pruning ash produces environment-friendly and environmentally responsive bricks however, the water absorption also increases if more than 10% replacement is used [7]. A 10% replacement of clay by olive ash produces bricks, having compressive strength as much as 41.9 MPa with a reduction of 4% in the bulk density [8].

1.4 Dust mixed with clay

Fiber reinforced bricks can be used in critical climatic areas, where room temperature has to be kept constant [9]. Saw Dust and Marble powder increase the water absorption and the porosity [10]. Quarry dust (minor wastes found through mining out of stones, formation of gravels and other construction materials) if used up to 10% replacement results in the production of bricks having good physical and mechanical characteristics [11]. Nano-Clay can increase the strength of the brick up to 4 times. Inert bricks having commercial characteristics can be produced by adding steel dust [12].

1.5 Sludge mixed with clay

Paper trashes reduce the thermal conductivity and the density of the bricks. However, it also reduces the compressive strength, increase the rate of absorption and porosity [13]. Sewage sludge can also be intermixed with clay to yield lighter bricks; the bricks need less heat to bake [14]. Organic Residues (Saw Dust, Tobacco and Grass) can also be used as pore developing agents providing bricks for light bulk structure [15].

1.6 Glass mixed with clay

Unwanted glass sludge boosts the compressive strength by 23%, reduces the porosity and the cost [16].

In this research, the prime focus is only on the red brick for a very simple reason. The demand for red brick is progressive. Though many other alternatives are coming up but eventually due to high localized popularity and mindset for red bricks, the other alternatives fails to overpower the consumption of red bricks. The data suggests that 180 billion tones of red clay bricks are consumed annually and rest all other bricks only constitutes 70 billion tones of annual consumption [17].

Also, the adhesive and cohesive properties of brick are so good that it can easily be added and mixed with the additives. On the other hand, the fly ash bricks can only be added with ash and cement. Thus, analysis remains very narrow and brief in case of fly ash bricks. Apart from this, the urban sector is entirely dependent on red bricks due to its localized popularity and also the urban sector is developing day by day which leads to construction of buildings, structures, etc and for that red brick is highly preferred.

In this study, to prevent the harmful degradation of soil along with the emission of harmful effluents, the percentage use of clay have been reduced by replacing the clay with some different and definite quantity of waste material and out of all the samples only two samples are selected for testing and analysis. These samples are

- Clay mixed with fly ash
- Clay mixed with glass waste
- Clay mixed with sand

II. Advantages of Red Clay Bricks

Brick is a low maintenance, permanent, durable building material that won't rot rust, burn, corrode, decay, or encourage mold growth.

Clay brick's durability and 100-plus year life cycle reduces the need for replacement, thereby eliminating further manufacturing energy required for replacement products.

Raw material is easily available. Cost of maintenance is very low for red bricks. These bricks are fire resistant, easily reusable and have a better soundness [18].

III. Research Significance

The objective is to make environmentally friendly, long-lasting bricks that reduce the energy requirements and the costs associated with the disposal of waste materials. The work is intended to reduce the eco harming agents and protect the natural soil.

The other main objective of this research is to utilize the bricks in works like ground-works, manholes, sewers, retaining walls and damp-proof courses apart from making buildings and construction. The main scope of this study is –

- Reduction in environmental pollution
- Reduction in soil degradation
- Low weight of the bricks
- Easy transportation
- High compressive strength of bricks

3.1 Experimental Procedure

It is important to understand some basic terms before directly approaching for analyzing the brick samples and their preparation. Thus, it becomes necessary to get some prior knowledge about the characteristics and properties of red clay bricks. Following are the characteristics of red clay bricks. It should have a rectangular shape, regular surface and red coloured appearance. It should confirm in size to the specified dimensions (19 x 9 x 9 cm). It should be properly burnt. This can be ascertained by holding two bricks freely, one in each hand, and striking them. A sharp metallic sound indicates good burning whereas a dull thud would indicate incomplete burning. Absorption should not exceed 25 percent in any case. A good building brick should possess requisite compressive strength, which in no case should be less than 35 kg/cm^2 . Brick should be hard enough so that it is not scratched by a finger nail. A good brick has a uniform colour and structure through its body [19].
The following fig. 1 shows the flowchart used to prepare the brick using waste material.

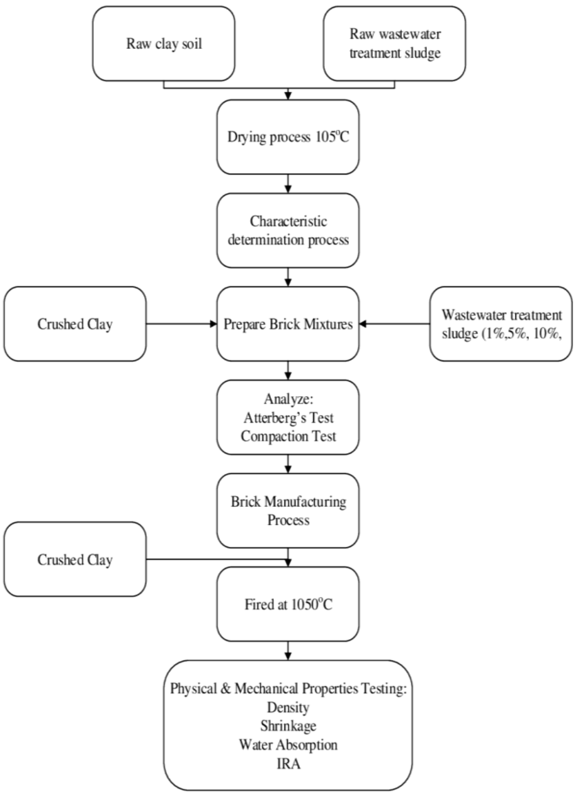

Fig. 1 Flowchart for preparing Brick using Waste Material

3.2 Materials

Fly ash is taken from the fly ash brick manufacturing plant near Etawah and Shikohabad. The glass waste is obtained from a glass manufacturing plant at Firozabad. Red clay brick is taken from brick manufacturing plant at Agra. These samples are mixed with the clay in different proportions and are tested at respective standards.

3.3 Properties of Bricks [20]

3.3.1 Physical Properties of Bricks.

(i) Shape - The standard shape of an ideal brick is rectangular having sharp edges. The surface of the bricks is regular and even.

(ii) Size - The size of brick used in construction varies from country to country and from place to place in the same country.

(iii) Colour - The most common colour of building bricks falls under the class red. It may vary from deep red to light red to purple.

(iv) Density - The density of bricks or weight per unit volume depends mostly on the type of clay used and the method of brick moulding.

The following table 1 shows composition of different bricks.

Table 1 Composition of different Bricks

Type of Bricks	**Silica (%)**	**Alumina (%)**	**Lime (%)**	**Iron Oxide**	**Sulphur (%)**	**Ash (%)**	**Stone Dust**
Fly ash Brick	-	-	5	-	2	60	30
Red Clay Brick	54. 23	22.78	2.8	< 7	3	-	-
Waste Glass	55. 68	14.89	5.34	0.5	-	-	3.03
Activated Alumina	5.5	13.53	15.9 2	1.38	-	-	2.47
Brick Kiln Dust	68. 25	2.3	0.1	8.1	-	-	-
Kraft Pulp Residue	51. 86	20.75	0.76	6.48	-	-	1.75
Waste Sludge	50. 25	11.65	0.68	5.45	-	-	1.55

3.3.2 Mechanical Brick Properties

(i) Compressive Strength of Bricks - The compressive strength of a brick depends on the composition of the clay and temperature of burning. It may vary from 35 kg/cm^2 to more than 200 kg/cm^2 in India.

(ii) Flexure Strength - It is specified that the flexural strength of a common brick shall not be less than 10 kg/cm^2.

3.3.3 Thermal Properties of Building Bricks

Besides being hard and strong, ideal bricks should also provide insulation against heat, cold and noise. The heat and sound conductivity of bricks vary with their density and porosity.

3.3.4 Durability

(i) Absorption Value - This property is related to the porosity of the brick. Porosity is defined as the ratio of the volume of pores to the gross volume of the sample of the substance.

$$Absorption = W_2 - W_1 / W_1 \times 100$$

Where W2 is weight after 24 hours of immersion in water and W1 is the oven dry weight of the sample.

(ii) Efflorescence - It is a common disfiguring and deteriorating process of bricks in hot and humid weather. Brick surface gets covered with white or gray coloured patches of salts. These salts are present in the original brick clay. When rain water penetrates into the bricks, the salts get easily dissolved. After the rains, evaporation starts. The salts move out along with the water and form thin encrustations on the surface of the bricks.

3.4 Methods of testing a brick

3.4.1 Absorption Test - This test is conducted to find the amount of moisture content absorbed by brick under extreme conditions. In this test, sample dry bricks are taken and weighed. After weighing, these bricks are placed fully immersed in water for 24 hours. Then weigh the wet brick and note down its value. The difference between dry and wet brick weights will give the amount of water absorption.

3.4.2 Compressive Strength - Compressive strength is determined by placing brick in compression testing machine (CTM). After placing the brick in compression testing machine, apply load on it until brick breaks. Note down the value of failure load and find out the compressive strength value of brick. Minimum compressive strength of brick is 3.50N/mm^2.if it is less than 3.50 N/mm^2, then it is not useful for construction purpose.

3.4.3 Colour Test - A good brick should possess bright and uniform colour throughout its body. The colour should be shiny and provides a uniform texture to the bricks. Sun dry the bricks for 48 hours and then observe the colour.

3.4.4 Hardness Test - A good brick should resist scratches against sharp things. So, for this test a sharp tool or finger nail is used to make scratch on brick. If there is no scratch impression on brick then it is said to be hard brick.

3.4.5 Shape and Size Test - Standard brick size consists length x breadth x height as 19cm x 9cm x 9cm. To perform this test, select 20 bricks randomly from brick group and stack them along its length, breadth and height and compare. So, if all bricks are of similar size then they are qualified for construction work.

3.4.6 Soundness Test - In this test, 2 bricks are chosen randomly and struck with one another. Then sound produced should be clear bell ringing sound and brick should not break. Then it is said to be good brick.

3.4.7 Efflorescence Test - A good quality brick should not contain any soluble salts in it. If soluble salts are there, then it will cause efflorescence on brick surfaces. To know the presence of soluble salts in a brick, placed it in a water bath for 24 hours and dry it in shade. After drying, observe the brick surface thoroughly. If there is any white or grey colour deposits, then it contains soluble salts and not useful for construction.

The following table 2 shows the different standards using in testing.

Table 2. Standards of Testing

Standards	**Type of Tests**
ASTM C67 – 17	Baking Temperature
ASTM C20	Thermal Conductivity
ASTM C67 – 17	Water Absorption
ASTM C67 – 17	Efflorescence
ASTM C67 – 17	Compressive Strength
ASTM C597 – 02	Shape and Size

IV. Results and Discussions

After testing different composition of the bricks, the recorded data is represented in the tabular form and following observations are made. The table 3 shows baking temperature of bricks.

Table. 3 Baking Temperature of Bricks

Type of Bricks	**0%**	**5%**	**10‰**	**15%**	**100%**
Fly ash Brick	-	-	-	-	800 – 900 C
Red clay Brick	-	-	-	-	900 – 1200 C
Waste Glass Sludge Brick	-	-	-	850 C	-
Activated Alumina Sludge	-	-	900 C	-	-
Brick Kiln Dust Bricks	-	-	-	800 C	-
Kraft Pulp Residue Brick	-	600 C	-	-	-
Waste Sludge Bricks	-	-	800 – 900 C	-	-

The following fig. 2 shows graph between baking temperature and brick composition.

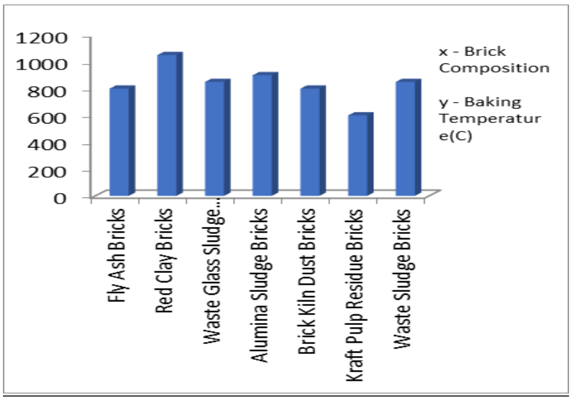

Fig.2 Graph between baking temperature and brick composition

A high class brick must have a moderate baking temperature. On observing table 4 the normal red clay brick has a very high baking temperature. Thus, to reduce this temperature various constituents can be added by replacing some amount of clay. On adding some additives, baking temperature reduces because the additives have their own self temperature which provides sufficient temperature to brick while baking.

Table. 4 Compressive Strength of Bricks (Mpa)

Type of Brick	**0%**	**5%**	**10%**	**15%**	**100%**
Fly ash Brick	-	-	-	-	10 – 12
Red Clay Brick	-	-	-	-	15 – 10 (1&2) 3 – 10 (3&4)
Waste Glass Sludge Brick	10	10.35	10.85	11.25	-
Activated Alumina Sludge Brick	10	9.3	5.4	3.5	-
Brick Kiln Dust Brick	10	8.5	7.85	7.05	-
Kraft Pulp Residue Brick	12	10.85	9.3	8.25	-
Waste Sludge Brick	12	10.43	8.15	7.25	-

The following table 5 and table 6 shows the percentage water absorption of bricks and thermal conductivity of bricks (W/Mk).

Table 5 Percentage Water Absorption of Bricks

Type of Bricks	**0%**	**5%**	**10%**	**15%**	**100%**
Fly ash Brick	-	-	-	-	6 – 12 %
Red Clay Brick	-	-	-	-	20 – 25 %
Waste Glass Sludge Brick	15%	18.75%	23%	26.35%	-
Activated Alumina Sludge Brick	12.92%	18.25%	23%	28.6%	-
Brick Kiln Dust Brick	20%	22%	23.5%	24.75%	-
Kraft Pulp Residue Brick	14.46%	23.47	28.66%	37.74%	-
Waste Sludge Brick	19.3%	20.35%	21%	21.65%	-

Type of Bricks	0%	5%	10%	15%	100%
Fly ash Brick	-	-	-	-	0.36
Red Clay Brick	-	-	-	-	0.6 – 1.25
Waste Glass Sludge Brick	0.53	0.55	0.56	0.59	-
Activated Alumina Sludge Brick	0.26	0.22	0.19	0.16	-
Brick Kiln Dust Brick	0.45	0.36	0.28	0.22	-
Kraft Pulp Residue Brick	0.5	0.46	0.38	0.32	-
Engineering Brick	0.45	0.42	0.38	0.35	-

Table 6 Thermal Conductivity of Bricks (W/Mk)

The following fig. 3 shows graphs graph between compressive strength and brick composition, fig. 4 shows graph between water absorption and brick composition and fig. 5 shows graph between thermal conductivity and brick composition respectively.

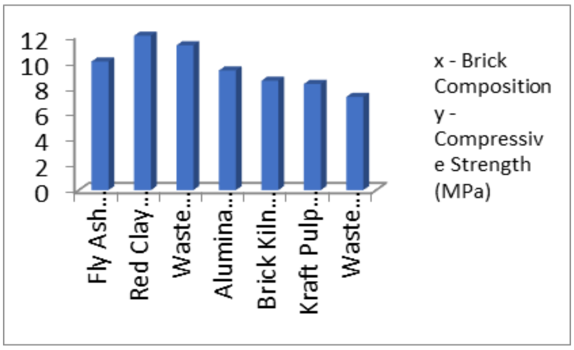

Fig.3 Graph between compressive strength and brick composition

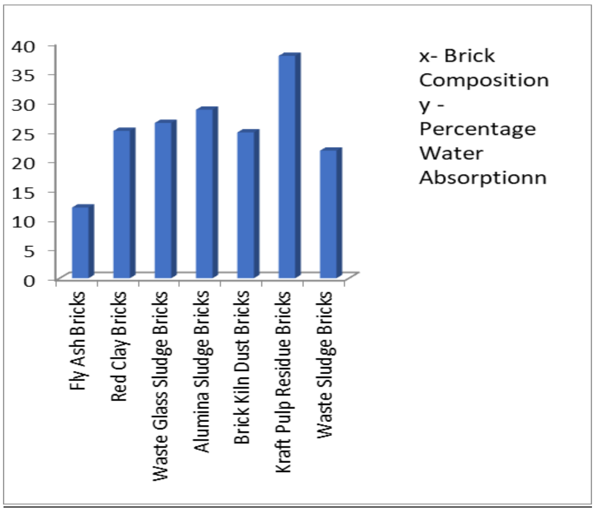

Fig.4 Graph between water absorption and brick composition

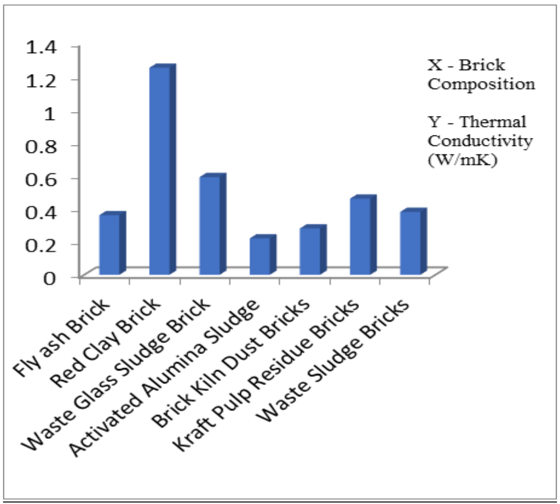

Fig.5 Graph between thermal conductivity and brick composition

V. Conclusions

This research work is aimed to investigate the properties of red clay bricks using different type of wastes. The partial replacement of clay by wastes can enhance the sustainability of brick masonry structures. By recycling, the landfill problems as well as potential health hazards associated with wastes can be successfully mitigated. Additionally, significant fresh clay deposits can also be preserved.

On the basis of the experimental results, following conclusions can be drawn:

- From compressive strength study, it was observed that the strength of bricks decreased with increase in sludge concentration.

- On adding kraft pulp residue to the clay, the compressive strength decreases. Pore formation takes place, thus, increasing the water absorption capacity. However, baking temperature reduces.

- The bricks incorporating brick kiln dust have porous structure, and are suitable for moderate weather resistance and insulation purposes. The unit weight of the brick decreases with increase in the replacement of clay by brick kiln dust. The initial rate of absorption and the rate of absorption increase with increase in the quantity of brick kiln dust. Compressive strength decreases after incorporation of brick kiln dust in the bricks.

- On adding activated alumina sludge, the brick porosity increases. Compressive strength is reduced. Reduction in flexural strength and thermal conductivity. On adding glass waste to the red clay brick, the compressive strength is best obtained at 15% replacement of clay. However, the cost of glass waste is high but it eliminates the harmful effects of soil erosion and environmental pollution up to a great extent.

- On adding fly ash to the red clay bricks, the results obtained are best. The compressive strength is maintained between 10-12 MPa which comes under the category of second class bricks. Also, the bricks obtained are lighter in weight, thus, it makes transportation of bricks easy. These bricks occupy large area which eventually leads to less number of joints.

- Paper trashes reduce the thermal conductivity and the density of the bricks. However, it also reduces the compressive strength, increase the rate of absorption and porosity.

- Sewage sludge can also be intermixed with clay to yield lighter bricks; the bricks need less heat to bake.

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