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Eco-Friendly Plastic Brick

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ABSTRACT: In this experiment, a portion of clay is replaced by 5%, 10%, 15% waste plastic by weight from the surrounding to make eco-friendly plastic bricks.The eco-friendly plastic brick is burnt in the laboratory-foundry-furnace and tested for various parameters to compare with the standard clay brick for suitability in terms of strength and porosity (i.e., water absorbing capacity).The test results showed that the water absorption decreased from 16.03% to 7.95% and similarly the compressive strength also decreased from 5.48 N/mm2 to 3.7N/mm2 as the plastic in the eco-friendly brick structure increased.The present analysis for the composition of clay and plastic bricks gave the water absorption below the maximum allowable water absorption i.e., 20% as per IS 12894: 1990 for standard bricks. The efflorescence on dry bricks was found satisfactory as no white patches were observed after water immersion. Eco-friendly brick has immense future potential such as setting up of eco-friendly brick-based industries/start-ups through Swachh Bharat Mission.

KEYWORDS: Waste plastic, waste plastic status, brick, brick strength, eco-friendly plastic brick

I. INTRODUCTION

Plastic is a very common material which is now widely used by everyone in the world. Common plastic items used are covers, bottles and food packages. Its use in daily life is increasing; Plastic is being used a lot everywhere. Plastics can be found in many places in the modern world, including homes, automobiles, jobs, electronics, children's toys and in gardens. Plastic also surrounds most of our food. The biggest problem with plastic is its decomposition. It takes thousands of years to decompose which creates land as well as water pollution for the environment. Plastic is made from polymer chemicals and they are non-biodegradable. Plastic production has been increasing rapidly since the 1950s. The amount of plastic produced has doubled every 15 years. This is the fastest growth of any man-made material so far. The world is estimated to generate about 100 million tons of plastic every year and 10 percent of that plastic ends up in the oceans. The literature says that about 79 percent of plastics end up in landfills and that around 9 to 10% of plastics are recycled worldwide. More than one percent of total plastic has ever been recycled.The government has notified the Plastic Waste Management Amendment Rules, 2021, which ban single-use plastic items by 2022. The thickness of plastic carry bags will be increased from 50 microns to 75 microns with effect from September 30, 2021 and to 120 microns from December, 2022, as per notification dated 12 August [1].

The properties of plastic are very unique as it combines with all kinds of materials. Plastic is a composition of synthetic and semi-synthetic organic compounds. They are malleable and ductile and turn into any solid material. Looking at the challenges, there is a great need to use advanced technologies and methods to dispose waste plastic properly. Incinerators are used for waste plastic disposal in India which burns at high temperature releases the gases during process pollute the air and water. Though the use of plastic cannot be banned but it can be reused in many ways like clay bricks/tiles, concrete bricks, fly ash bricks, and foam bricks.Generally, two types of plastics namely high-density polyethylene (HDPE) and low-density polyethylene (LDPE) are used for the manufacture of bricks.

In this research waste plastics in the form of polythene, plastic bottles, which are not recycled, are used. Waste plastic is collected and shredded in a shredder machine to make powder. The crushed plastic powder is mixed with clay in different proportions to make bricks. Brick is made with different composition of clay and plastic to find the best-known ratio of clay and plastic for replacement of standard brick. Eco-friendly brick is subsequently

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compared with standard brick for compressive strength, water absorption test, fluorescence test, soundness test and tensile test of brick; etc. The researches done by scientists on the use of plastics and manufacturing of plastic bricks are given in next paragraph.

Turkeswari Uvarajan et al. [2]has summarised an effective way to utilise plastic waste, reusing plastic waste for the production of construction material such as bricks and paving blocks and its impacts to environment. This review found that limited studies had been conducted on the usage of plastic waste (PW) in the production of the paving block though the durable properties of PW enable them to be an ideal material to be used in the construction where the addition of PW enhances the overall strength. However, the smooth and low adhesion property of PW prevents them from binding with other components resulting in lower compressive strength. PW increases the porosity by creating voids due to the low affinity nature of plastics, thus increasing the water absorption rate. For instance, the high content of PW decreases the adhesion force and creates voids, increasing the porosity and water absorption but decreasing overall compressive strength. Further studies are required on plastic added construction material considering different parameters such as fire resistance, flexural strength, leaching properties and skid resistance.

Shu-lun MAK et al. [3]aimed to review and investigate the feasibility of utilizing waste plastic in making construction bricks. The use of waste plastic in making the sand-plastic bricks will enhance the protection of the environment from the effects of waste plastic that normally takes several millennials to degrade. Laura Marsiglio et al. [4]hasinvestigated the viability of recycled polyethylene terephthalate (PET) bricks as a replacement for concrete masonry units as a building material. It is validated that recycled plastic bricks have the potential to divert valuable post-consumer plastic waste from landfills, locked up this plastic for decades to come. The compressive strengths of the two materials are compared using both published data and a computational analysis. The toxic substances released during production and post-production of concrete and PET are examined, to gain a deeper understanding of the overall impact these materials have on human health.P.O. Awoyeraa et al. [5]studied about plastic waste beingextremely threatening to the environment and its inhabitants. A major victim of this menace is the marine environment. Plastic wastes cause detrimental effects such as flooding and poisoning of the animals in the marine ecosystem and risks seafood to human health. It is concluded that the use of plastic wastes for construction applications will improve the sustainability of the environment significantly, and also serve as a reliable source of materials for construction purposes. Syarifah Keumala Intan et al. [6]studied about continuously used PET and LDPE, without good recycling as plastic waste and building material waste by making them into a mixture to be used as bricks. A maximum compressive strength of 10.5 MPa is obtained at the ratio of 6:4 when the ratios of PET and LDPE plastic to building material waste were taken as 9:1, 8:2, 7:3, 6:4 and 5:5.The primary data source on the generation of plastics is the American Chemistry Council [7]. In 2018, plastics generation was 35.7 million tons in the United States, which was 12.2 percent of MSW generation. Ashish Kumar Parashar [8] studied from UN report that every year the globe uses 500 billion plastic bags while, half of the plastic utilized is of single use only. In India, 70 percent of total plastic used is discarded as a waste. Around, 9.47 million tonnes per annum (TPA) of waste plastic is generated in the country, which is about 25940 tonnes per day (TPD). The characteristics of bricks made of Sand, Moorum, Quarry dust and Iron chips with varying volume of Plastic as 20%, 25%, 30% and 35% was studied and concluded that the bricks having 30% plastic with 70% Moorum gives maximum compressive strength and for bricks 35% of plastic with 65% Sand give minimum compressive strength in 7 days. The study also indicated that bricks made from plastic were susceptible against temperature to be used in the cold region.

D. Srinivasa Rao et al. [9] says plastic sand bricks are useful for construction industry when we compare them with fly ash bricks and class III clay bricks. Plastic waste, which is available everywhere, can be put into brick for effective use. Plastic bricks can help reduce environmental pollution, making the environment clean and healthy. Plastic sand bricks reduce the use of clay in the manufacture of bricks. Siti Nabilah Amir et al. [10] outlined the utilization of municipal plastic waste (MPW) to produce a high durability and quality of bricks to achieve the optimum balance in terms of cost and functionality. L. Billygraham Singh et al. [11] suggest that making bricks from sand and plastic waste can be an alternative to the conventional clay bricks available. Compared with ordinary clay bricks, sand plastic bricks have low water absorption, bulk density and obvious porosity. Sand plastic bricks have higher compressive strength than normal clay bricks. The waste plastic available everywhere can be put to efficient use in making bricks. Sand plastic bricks can help in reducing environmental pollution thereby making the environment clean and

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healthy.Lalith Prashanth R. et al. [12] states that since plastics are used as a partial replacement for quarry dust, the bricks are economical and the cost of the brick is lower than that of ordinary fly ash bricks. As plastic is added as a partial replacement for mine dust, the weight of the brick is reduced. Ronak Shah et al. [13] say, this process helps in reducing the problem of plastic waste disposal as it utilizes the waste in its best form and converts waste material into useful construction material. Claudiu Aciu et al. [14] has demonstrated the optimal recipes for the manufactureof ecological mortars by PVC waste recycling. Mortars containing PVC waste have the advantage that theirproduction is less polluting, as it does not involve high energy consumption.

Kumar et al. [15]states thatfrom the compressive strength test results of plastic-soil bricks for various percentages of plastic content by weight of soil with constant binder content of 2% by weight of soil, it is observed that both 65 and 70% of plastic contain by weight of soil gives same compressive strength (8.16 N/mm^2), but 70% plastic is considered as optimum in view of workability criteria. From the results of the compressive strength test of plastic-clay bricks with a constant plastic content of 70% for different percentages of binder (bitumen) content depending on the weight of clay, it is observed that as the percentage of binder (bitumen) increases the compressive strength of the brick is also increased by 5% (10 N/mm^2), but further increase in bitumen decreases the strength (2.04N/mm^2). But economically, 2% bitumen content is taken as the optimal binder material, resulting in compressive strength 8.16 N/mm^2 which is higher than laterite stone (3.18 N/mm^2). It is observed from the results of water absorption test of plastic-clay bricks that water absorption also decreases with increase in the percentage of plastic content. Compressive strength test results for plastic-clay bricks with a plastic content of 70% with a binder (bitumen) content of 2% by weight of clay will give a compressive strength of 8.16N/mm^2 higher than that of laterite stone (3.18N/mm^2), and has less water absorption (0.9536%) than laterite stone (14.58%) so it can be a better alternative building material.

II. MATERIALS & METHODS

The recycled LDPE (low density polyethylene) type plastic material are collected from the factories, hospital, industries waste, food packages and plastic bottles. In this project plastic bags, cold drink bottles and water bottles thrown by students as a waste were collected from around hostels. Plastic except lesser than 50 microns were collected and kept in open sunlight to dry from moisture and wetness. It is experimented that making powder from plastics lesser than 50 microns is not possible by indigenous or conventional process. Shredding of plastics are done in shredder machine by tearing up the plastic into small pellets, preparing them for recycling into other products. The small pallets of waste plastic are converted into powder form to mix easily with the clay. In this project firstly shredded plastic was tried manually by hand but the required grain size of the plastic was impossible moreover it was cumbersome and time-consuming process. Alternatively, after a search R.P.G. Private limited an industrial unit which deals with mass scale shredding of waste plastic bottles situated on Meerut Delhi highway was approached with the collected plastic to form the plastic into fine sized grains. The grain size of the plastic is lesser than 1.5 mm. Clay is a fine-grained silicate mineral made after rocks break down. Clay often contains some water because the water molecules stick to the tiny grains. The clay used for making eco-friendly bricks was obtained from 'Luhanna' village near Etawah city. The properties of clay soil are shown in table 1.

Table 1 Clay soil properties for experiment

S. No.	Property	Experimental Value
1.	Liquid limit	33.82%
2.	Plastic limit	22.6%
3.	Plasticity index (I_p)	11.22
4.	Specific gravity	2.67 gm/cm^3
5.	Bulk density	1.4 gm/cm^3

Table 2 Clay and plastics proportions

Ratio	Size of brick	Volume of brick, m^3	Wt. of ten std. brick, kg	Sum of proportion	Amount of plastic, kg	Amount of clay
100% clay (std. brick)	0.24 × 0.12 × 0.08 m	0.002304	Wt. of ten brick @ (approx.) 3.6 kg each	-	-	-
(95:5)	0.24 × 0.12 × 0.08 m	0.002304	36	95+5=100	$\frac{\text{wt. of 10 std. brick}}{100} \times 5$ $= \frac{36}{100} \times 5 = 1.8$ kg	$\frac{\text{wt. of 10 std. brick}}{100} \times 95$ $= \frac{36}{100} \times 95 = 34.2$kg
(90:10)	0.24 × 0.12 × 0.08 m	0.002304	36	90+10=100	$\frac{\text{wt. of 10 std.brick}}{100} \times 10$ $= \frac{36}{100} \times 10 = 3.6$ kg	$\frac{\text{wt.of 10 std. brick}}{100} \times 90$ $= \frac{36}{100} \times 90 = 32.4$ kg
(85:15)	0.24 × 0.12 × 0.08 m	0.002304	36	85+15=100	$\frac{\text{wt. of 10 std. brick}}{100} \times 5$ $= \frac{36}{100} \times 15 = 5.4$ kg	$\frac{\text{wt. of 10 std. brick}}{100} \times 85$ $= \frac{36}{100} \times 85 = 30.6$ kg

The mining of clay was done and left in open sunlight to get soften by removing unwanted oxides. The main purpose of mixing the small parts of plastics with clay is to finally obtain a uniform mixture and homogeneous.

Generally, there are two types of mixing which are hand mixing and mechanical mixing. In hand mixing, plastic, clay and sand etc. is done with the help of hand whereas, in the mechanical mixing, the mixing is doing with help of machine. Machine mixing is faster and cheaper than hand mixing. It generally produces more strength and better workability. Here in this analysis, manual hand mixing process is incorporated. And mixing is done in three different proportions which are (a) 95:5 (95 parts of clay and 5 parts of plastics) (b) 90:10 and (c) 85:15. The clay and plastics proportions are calculated for the homogeneous mixture as shown at Table 2.

Hand mixing is done separately by the ratio of mixing on a smooth, clean and water tight platform of suitable size by spreading plastic on the clay evenly. The clay and plastics is mixed intimately with spade, turning the mixture over and over again until it is of even mixed uniformly. The whole mass is mixed three times by shovelling and turning over by twist from centre to side, then back to the centre and again to the sides. A hollow is made in the middle of the mixed pile. Three quarters of the total quantity of water required is added while the materials are turned in towards the centre with spades. The remaining water is added by a water-can fitted with rose head, slowly turning the whole mixture over and over again until a uniformly and consistency is obtained throughout the pile.The mould a hollow form of standard brick size (24 cm × 11 cm × 7 cm) was made of wood with a permissible allowance of 2 mm on both sides for giving a particular shape to mixed clay. The frog name 'CAET' inside the mould was carved out stands for Dr. Baba Sahab Bhim Rao Ambedkar College of Agricultural Engineering and Technology Etawah as shown at Fig. 2 and 3.

After completion of proper mixing, mix is placed into required mould using hand moulding process. Hand moulding of bricks is extensively used in India and the neighbouring countries. This is done on ground, known as Ground moulding. This method is adopted when a large and level area of land is available for the purpose. The area of land on which moulding is to be done is levelled, plastered smooth and sprinkled over with sand.Now sand is sprinkled on the walls inside the mould, which prevents the moulded bricks from sticking to the mould followed by a lump of well-prepared mixed material whose volume is a little more than that of the brick is rolled out in sand and with a jerk the lump is dashed into the mould in such a manner that the mould is completely filled with mix material. The moulder then gives blows with palm and wrist.The surplus soil is scrapped off and the top surface is levelled by a metal plate with a sharp edge or a thin wire stretched.After the brick has been moulded the mould is given a gentle stroke with something hard and then mould is lifted

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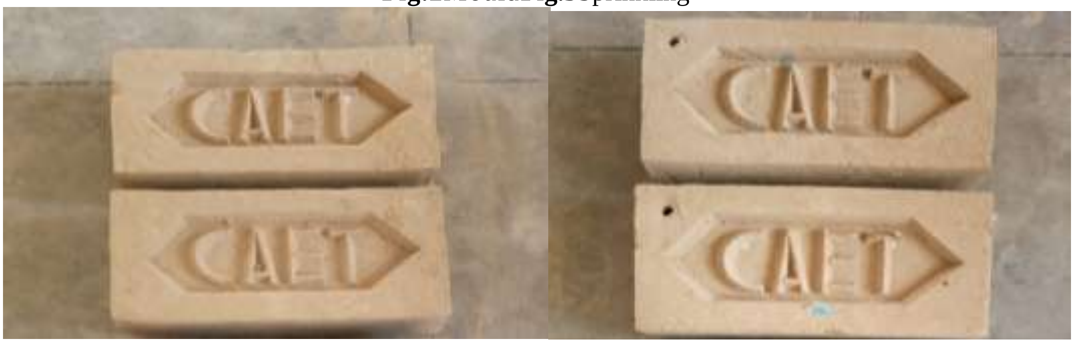
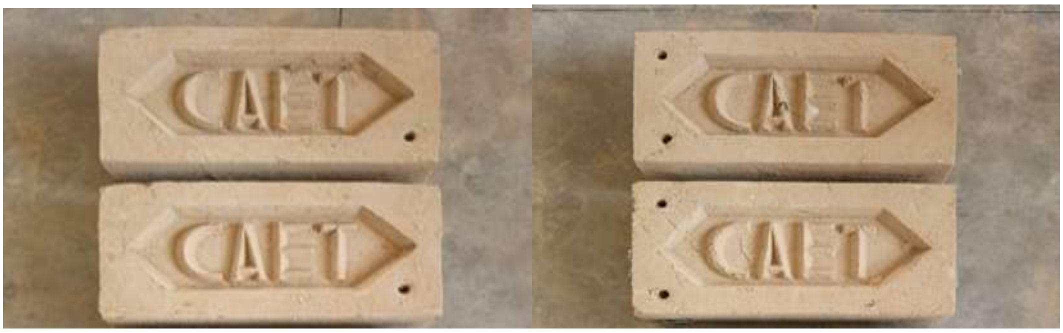
leaving the brick dry on the ground. The mould is placed nearby to mould another brick and the process is repeated. After the moulding brick were marked according to their mixed ratio. The standard brick (100% clay) had no mark. The 5% plastic and 95% clay brick had a mark of small circular dot on 'T' side of frog 'CAET' while the 10% plastic and 90% clay brick were marked a small circular dot on 'C' side of frog 'CAET'. The 15% plastic and 85% clay brick marked two small circular dots. Further, the bricks are kept in open sunlight for a period of 10-15 days for curing after the moulding process and marking is over. Curing process also depends upon the weather conditions. The curing of brick is shown in Fig. 4.


Fig.2 Mould**Fig.3**Sprinkling



Ratio 100:0 brick, 100% clayRatio 95:5 brick, (95% clay & 5% plastic)



Ratio 90:10 brick, (90 % clay & 10 % plastic)Ratio 85:15 brick, (85 % clay &15 % plastic)

Fig.4 Curing and drying

Table 3 Mechanical parameters of bricks burnt in laboratory-furnace

Sl. No.	Types of brick (Clay: Plastic)	Parameters	Experimental bricks value	Standard value (U.P. Nirman Nigam Ltd, Saifai Etawah laboratory data)
1.	100:0 brick 100% clay brick	Length	230 mm	225 mm
		Width	115 mm	112.5 mm
		Area	26450 mm^2	25312.5 mm^2
		Max load failure	250 KN	304-380 KN
		Compressive	9.48 N/mm^2	12-15 N/mm^2

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		strength		
2.	95:5 brick (95%clay & 5% plastic)	Length	228 mm	Not known as this value is to be corresponding to 5% of plastic mix.
		Width	116 mm	
		Area	26448 mm^2	
		Max load failure	230 KN	
		Compressive strength	8.72 N/mm^2	
3.	90:10 brick (90% clay & 10% plastic)	Length	230 mm	Not known as this value is to be corresponding to 10% of plastic mix.
		Width	115 mm	
		Area	26450 mm^2	
		Max load failure	220 KN	
		Compressive strength	8.3 N/mm^2	
4.	85:15 brick (85 % clay & 15% plastic)	Length	230 mm	Not known as this value is to be corresponding to 15% of plastic mix.
		Width	115 mm	
		Area	26450 mm^2	
		Max load failure	193 KN	
		Compressive strength	7.3 N/mm^2	

Note: Compressive Strength, C = $\frac{P}{A}$, Where, P = Maximum load, A= Average of the gross areas of the upper and lower surfaces of the brick.

Fig.5 Laboratory-Furnace **Fig. 6**Laboratory-furnace burnt brick

Burning is the last stage of brick making which usually imparts hardness and strength to the bricks. In general, bricks are burnt in brick-field-kilns. The eco-friendly brick was burnt in the laboratory-furnace after drying the furnace with the help of coal and wood to remove the moisture from the furnace.The bricks inside the furnace were placed vertically at a certain distance between one brick and another and coal was filled in the blanks to ensure uniform burning of the bricks. The bricks were arranged in layers in a zig-zag manner and the spaces were filled with coal and wood in alternate positions. After the bricks are packed inside the laboratory-furnace, the furnace is covered with the help of refractory bricks and a mixture of straw, clay and cow dung to prevent the heat energy of the laboratory-furnace from escaping to the surrounding.

Usually, the normal clay bricks are required to have a temperature of 800-1200 °C but the laboratory-furnace could not generate a temperature above 400°C. The bricks were burnt for 3 days at a temperature of about 350°C-400°C with the help of coal and wood with a cooling time

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of 8 to12 days in the furnace. The laboratory-furnace and burnt bricks are shown in Fig. 5 and 6.

III. TESTING AND COMPARISON

The burnt brick was tested for various strength parameters such as compressive strength, water absorption test, efflorescence test, soundness test, and hardness test. Compressive strength, or compression strength is the capacity of a brick to withstand loads tending to produce cracks is done on compression strength test machine as shown at Table 3.

The plastic bricks which were tested for its strength as shown in above table, the compressive strength value is lower than standard one i.e., 15 N/mm^2. Generally, it is taken as 11 N/mm^2. The reason for lower value may be because these bricks were burnt in laboratory-furnace under the temperature hardly attainable from 350 – 400 °C (approximately) though this is supposed to be around 1100 °C. Water Absorption test on brick was conducted to determine the moisture absorbed by the brick when subjected to extreme conditions like rain. The absorption test can be used as an indicator of the durability properties of the brick such as quality, degree of burning, and behaviour of brick in weathering.

The water absorbed by the brick specimen, W= $\frac{M_2-M_1}{M_1}$ x 100, where, M_1 = Dry Weight after oven drying of brick at 105-110^{O}C, and M_2 = Wet Weight of brick after immersion of brick in water for 24 hours, is shown at Fig. 7 and table 4.

Ratio 100:0 brick 100% clay   Ratio 85:15 brick

Fig.7 Water absorption test

Table 4 Water absorptionof bricks burnt in laboratory-furnace

Sl. No.	Types of Brick (Clay: Plastic)	Dry weight (Kg) M_1	Wet weight (Kg) M_2	Weight increases(M_2-M_1)	% of Water Absorption
1.	100:0 Brick	3.044	3.532	0.488	16.03%
2.	95:5 Brick	3.080	3.536	0.456	14.80%
3.	90:10 Brick	3.048	3.474	0.426	13.97%

4.	85:15 Brick	3.144	3.394	0.25	7.95%

(a) 100 % clay brick (100:0) (c)90 % clay 10 % plastic brick (90:10)

(b) 95 % clay 5 % plastic brick (95:5)(d) 85 % clay 15 % plastic brick (85:15)

Fig. 8 Soundness test

A soundness brick test is conducted by striking two bricks together as shown at Fig. 8. The striking of brick should emit a ringing sound. On the testing of soundness, we heard a good sound of brick. A clear ringing sound similar to a bell was heard in 100:0 bricks A clear sound was heard but the pitch was less than that of 100:0 brick in 95:5 brick. A low-pitched sound is noticed in the case of 90:10 brick. A low sound was heard which was almost unnoticeable in 85:15 brick.

The hardness of bricks generally implies the resistance of bricks to scratch. For this test, the brick is scratched with a sharp tool or fingernail. If the scratching does not leave behind any impression on the brick, it is considered as a hard brick. A very light abrasion was found as shown in Fig. 9(a) after scratching the brick with nail in 100:0 brick. A noticeable scratch was found as shown in Fig. 9(b) after scratching the brick with nail in 95:5 brick. A slight scratch was made after scratching the brick in 90:10 brick as shown in Fig. 9(c). A clearly visible scratch was found after scratching the brick in 85:15 brick as shown in Fig. 9(d).

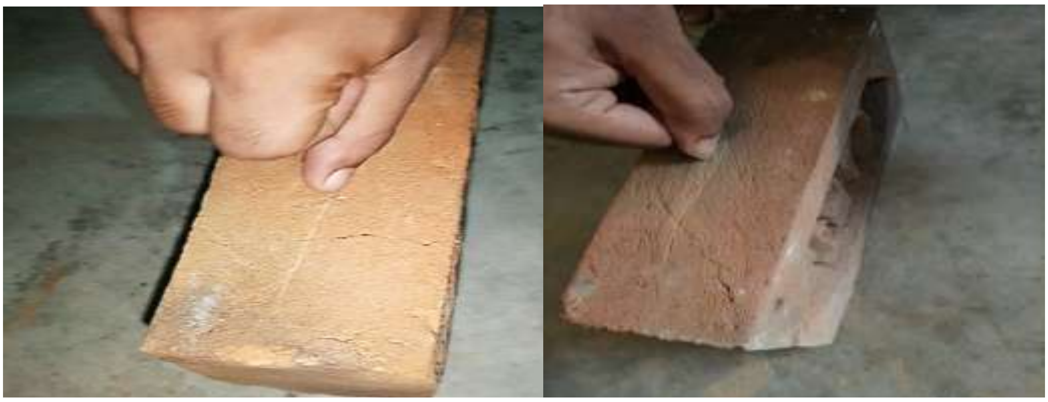
The waste plastic is utilised in manufacturing of brick in various ratios to substitute for normal bricks. The eco-friendly bricks after proper curing were burnt in a small laboratory-furnace. The bricks in laboratory-furnace could not be burnt beyond an extent of 30 % as maximum temperature could not be raised more than 400^{O}C. Due to this the desired properties of eco-friendly brick were not attainable as expected for comparison to properties of traditionally normal bricks. The weight of eco-friendly brick surprisingly increases with increased percentage of waste plastic in the composition. This is due to uneven and non-uniform burning of eco-friendly bricks. The striking sound of brick is not as clear as a ringing bell due to poor burning. Likewise, a light abrasion was made by nail on the surface of bricks for hardness test.

IV. CONCLUSIONS

The conclusion derived from the current study for different composition of clay with waste plastic is evaluated. It has been observed that water absorption of eco- friendly bricks decreases from 16.03 to 7.95% while increasing percentage of waste plastic powder in the composition of eco-friendly bricks. Similarly, compressive strength of eco-friendly brick decreases from 9.48 to

7.3N/mm^2 when plastic percentage is increased to the brick composition though according to literature, compressive strength of plastic brick is 5.6 N/mm^2 and that compressive strength of plastic soil brick is 3.18 N/mm^2. The current analysis for composition of clay and plastic bricks gave water absorption lesser than maximum allowable water absorption for standard bricks i.e., 20% as per IS 12894: 1990 thus satisfying the IS requirement. The efflorescence on dried bricks was found satisfactory as no white patches were observed after water immersion.

The analysis revealed that this brick can effectively be used as replacement of standard brick. Since plastics are used as a partial replacement of clay the bricks are economical. Bricks in furnace could hardly burnt 30% as required temperature was unattainable even then the results were encouraging. Eco-friendly brick has enormous scope of future such as utilizing the waste plastic, establishing the eco-friendly brick-based industry /start-ups through Swachh Bharat Mission. Eco-friendly plastic bricks give hope and a way to work on innovative things related to the waste plastic and try to invent some new constructional materials which shows remarkable response in future industry and changes the thoughts of the researchers and consuming sectors. Eco-friendly brick can be used framed structures as a partition wall, construction of eco-friendly benches in the parks, construction of eco-friendly tracks for running and jogging in place of concrete or stone tracks. The researches on composition of plastic with clay be furthered to give a chance to 'think local as well as global'. These eco-friendly bricks can be used in water tanks as it has more porosity compared to clay bricks to cool the water by evaporative cooling.



(a) 100 % clay brick (100:0)(b) 95 % clay 5 % plastic brick (95:5).

(c) 90 % clay 10 % plastic brick (90:10)(d) 85 % clay 15 % plastic brick (85:15)

Fig.9 Hardness test

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