

DESIGN, ANALYSIS and TESTING OF RECYCLED RIC-7 FLY ASH BRICKS

¹DABBIRU RAVI VIKRANTH

Associate Professor,

^{1,2}Department of Mechanical Engineering, SVP Engineering College, Visakhapatnam, INDIA

²M. CHAITANYA MAYEE

Associate Professor & HoD,

Abstract:

Waste Management relies on 5R's (**R**educe, **R**ecycle, **R**euse, **R**ecover, and **R**esidual Management). High Power to Weight Ratio (P/W), Torque to Weight Ratio (T/W), durability have added more plastic to metal or plastic to non – metal composites production. Plastic based products are filling the landfills and even polluting the marine environment. A startling inference by Department of Health Services, USA, by 2030, one thirds of the world's oceans would be filled with plastic debris and the plastic debris are going to out run the total marine species. There are certain variants of plastic debris, which take more than 350 years to be bio-degradable. Besides Odour, landfill gases responsible for acute or chronic respiratory disorders, carcinomas etc. Plastic materials are classified on 1 – 7 scale, of which Poly Vinyl Chloride (#RIC3), Polystyrene (#RIC6) and Bisphenol-S (BPS - #RIC7) are highly toxic and cannot be used.

The study also presents results of experimental work on bricks made of thermoplastic granules constituting 0 to 15% by weight, fly ash 15%, cement 15% and silica etc. Bricks of 190 x 90 x 90 mm size are casted by pre – heating the homogeneous mixture and impregnating with Cement or Concrete and curing for 28 days. The compressive strengths after addition of waste plastic to the extent of 15% by weight is about 17MPa [in lieu of ASTM standards]. The integration of a Phase Change Materials (PCM) layer e.g. $\text{CaCl}_2 \cdot 6\text{H}_2\text{O}$ into an external building wall diminished the amplitude of the instantaneous heat flux through the wall. The considered model consists of usual brick with square holes used as construction materials for residential buildings, some of these square holes are filled with PCM. The results depicted central spattered PCM improves considerably the thermal inertia of brick. A recycled RIC -7: fly ash impregnated in concrete material achieves a number of goals i.e. promoting ecological protection, low pollution, and conservation of resources. Moreover, the prime characteristics found are lightweight, of low thermal conductivity, and of appreciable mechanical strengths.

Keywords: Plastic Brick, PCM, Compressive Strength, Thermal Conductivity, Thermal Flux, Extruding Machine etc.

I. INTRODUCTION

Department of Health reports methane and carbon dioxide as the major gases produced and makeup to 90 to 98% of landfill gas. Nitrogen, oxygen, ammonia, sulphides, hydrogen and various other gases are also produced in small volumes. Besides odour, landfill gases can also impact health causing problems that can be acute or chronic which is a major concern. Landfill causing fire is also a recurring problem. The University of Iowa ^[7] reports that there are more than 8000 landfill fires occurring every year in U.S. Smoke from these fires can cause respiratory diseases if they are contaminated by chemicals, and water in fire suppression efforts can spread leachate pollution of soil and water sources. Not only air quality is affected by landfills, but also is a major source of groundwater contamination. It is reported that leachates from landfills contain heavy metals like barium, chromium, cobalt, nickel, and lead which enters the soil and into the groundwater contaminating it. Ammonia which is one of the common gases found in landfills converts itself into nitrogen causing eutrophication, where algal growth increases deprives saturated oxygen killing marine life. Moreover, toxins in leachates can kill wild and domestic animals that drink these waters. In humans also, its side effects are felt, they cause nausea, stomach pain, rashes, fevers and headaches. This generally happens because surface water and groundwater are connected and hence pollutants can move back and forth.

Global production of plastic has registered clear increasing trend during the recent years (year 2011: 279mt; 2012: 288mt; 2013: 299mt; 2014: 311mt, and 2015: 322mt) ^[4]. The conveniences with which plastic can be used in multifarious applications, which is only growing with new innovative use such as in filament of 3D printing, are likely to increase consumption in the future. Thus, unless recycling gains momentum, the amount of littered waste is likely to increase compounding the environmental challenge.

II. TYPES of PLASTICS

Plastic is categorized as Thermoset plastics and Thermoplastics. Plastics once melted can be easily moulded and then once if its again heated it again softens and can take any desired shape. Thermoset plastics, however once melted and takes any shape, it cannot be reheated. Thermoplastics include variety products such as PPS, LDPE, PVC, HDPE, PET etc. while Thermoset plastics include Nylon, Bakelite, etc. Hence, reducing the plastic waste is the need of the hour and plastic extrusion can be regarded as one of the most effective methods for reducing the plastic waste. Extruder machine can intake the waste plastic resourced from local landfill and converts it into various sustainable construction material.

Thermoplastics constitute about 80% of all plastic consumption and thermoset about 20%^[1], some of which are safe to recycle. Part of it remains littered, part used in illegal landfilling, and rest is incinerated for energy harvesting, giving off significant emission. In 2016, New Delhi in India became the most polluted city in the world due owing to the incineration of waste materials containing large percentage of waste plastic^[2]. Plastic bags choke drainage system, reduce water permeability of land affecting fertility, and increasing cost to Municipal Corporations to manage these wastes^[3]. PET particles in concrete reduce requirement of fine aggregate, increase resistance to corrosion—particularly against sulphuric acid—and make the concrete lighter^[2].

Besides supplementing natural aggregates, plastic impregnated construction materials make buildings thermally more efficient than traditional materials since plastics have low thermal conductivity (K). The K of common plastics are in the range of 0.15 to 0.55 Wm⁻¹K⁻¹ (Polyethylene terephthalate: 0.15–0.24 Epoxy: 0.17, PVC: 0.19, Acrylic: 0.20, Epoxy glass fibre: 0.23, Acrylic 6: 0.25, High density polyethylene: 0.50), much less than that of conventional concrete with K of around 1.8^[2]. Energy from buildings constitutes roughly 33% of total consumption out of which about half is lost through the walls^[3]. Lower the K more energy efficient is the building and less is the emission^[3] and the world is striving to evolve construction materials of low K^[3]. Substantial part of the cost of domestic heating or cooling and the resulting emission can be reduced by improving thermal insulation of building walls^[2]. Among the emerging materials for increasing thermal insulation are hollow bricks, perforated bricks, and porous bricks. Our country's biggest source of electricity is obtained via thermal power plants; unfortunately locally procured Indian Coal is high in ash content and low calorific value. Fly ash is slag from thermal power plant. Fly ash causes air, water and soil pollution when it is exposed to environment

III. PRESENT SCENARIO

Conventional Red Bricks are of size 190 x 90 x 90 mm with a weight between 2.68 – 3.00 kg. With cement mortar plastered on top of the brick, the final brick size would be 200 x 100 x 100 mm. Cement Bricks or fly ash bricks are primarily hollow in nature. Large scale plastic debris from multifarious products and fly ash from thermal power plants are the principal pollutants of environment. Transforming the environmental pollutants to a usable form i.e. parking pavers, plastic bricks, parking tiles etc. is a commercially viable alternative. Local sourcing of the raw materials reduces the input costs. The higher the compression in extruder chamber; the greater the compressive strength of the plastic-sand aggregate. The plastic pellets are melted at temperatures ranging from 90^oc – 120^oc. Plastic can be impregnated in Cement or Concrete blocks and cured upto 28 days. Compressive Strength, Thermal Conductivity, Water Absorption, Heat from Hydration etc. can be tested and validated using both theoretical and practical experimentations.

IV. RECYCLING PLASTIC

Recycled Plastic - Fly Ash bricks are manufactured by two methods viz. (a) Vibro Press-machine plus manual operation and (b) Hydraulic Press- automated machine. For experimental and small scale brick making the Vibro press assembly was more suited and hence was used to cast the bricks. The waste polyethylene was collected from the HDPE garbage bins and local resourcing, which are later shredded into smaller particles of 2 x 2 mm size by using a shredding device known as Agglomerator. There are two sets of bricks, to be manufactured i.e. for general bricks and column bricks supporting Reinforced Cement Concrete (RCC) Loads. General bricks are made using Recycled Plastic, fly ash and Cement while Column Bricks are manufactured using Recycled Plastic, fly ash and cement/ concrete mix. Emphasis is given for general bricks, of which the weight proportions for a 100kg mixture is 45% by weight fly ash, 40% by weight crushed stone aggregate and 15% by weight OPC 53 grade cement. Shredded plastic will be added to the mixture as a percentage of the cement present in the mixture.



a) Shredded Polyethylene Waste in shredded form



b) The Shredded polyethylene being added to the mixture

The dimensions of the bricks are as per the IS 12894:2002, Clause 5.1.2 Dimensions and tolerance for non-modular bricks. A batch of 20 bricks for every varying proportion has been cast as per the IS5454:1978. Post Casting, the bricks are de-moulded and were allowed to cure at room temperature for a period of 24 hours. Destructive (Compressive Test, Hardness Test, Impact Resistance Test) and Non – Destructive tests (Water Absorption, Efflorescence, Fire Resistance Test) are performed on the brick samples for 7, 14, 21, 28 days respectively. The plastic : sand mixture is 1:4, cement : fly ash mixture is 1:5, cement to plastic mixture is 15%. Each brick is of weight 2.68 kg, hence the weight of each material used in manufacturing of plastic brick are;

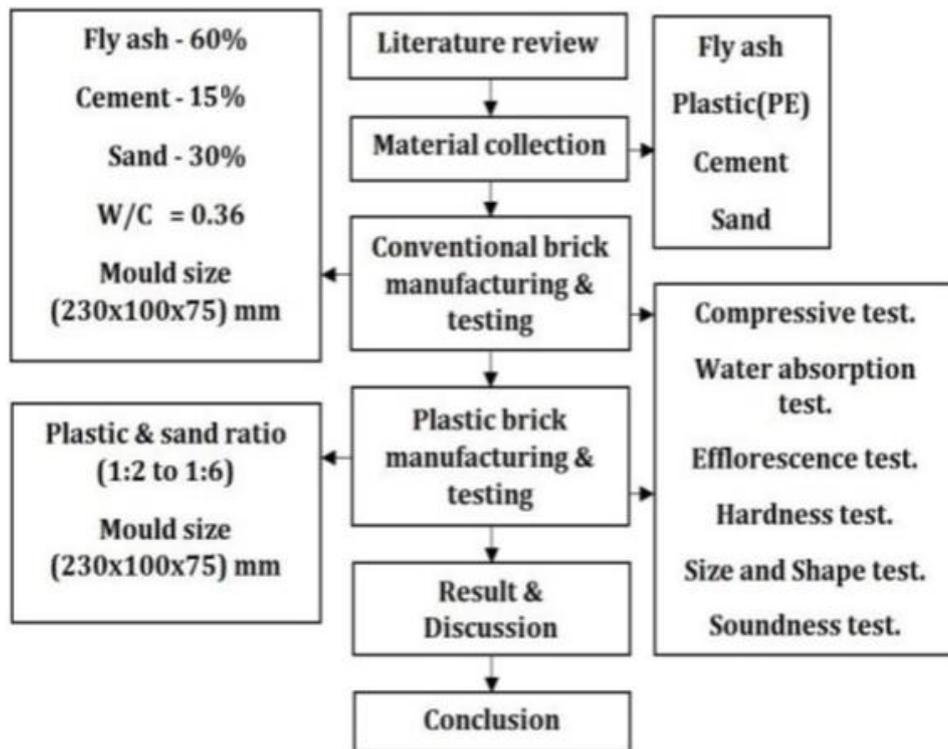


Fig. 2 : Methodology of Plastic Bricks (Manufacturing, Testing)

- Cement - 150 gms
- Fly Ash - 225 gms
- Recycled Plastic - 075 gms
- Sand - 2230 gms

The water ratio is 35% i.e. 157 ml of water to be mixed per brick. Once bricks are moulded, they are de-moulded and sent to curing tank.

V. Plastic Extruding Machine

Plastic Extruder Machine owing to its complexity is one of the most intricate machines available. Principle operations which can be performed on the machine are mixing, extrusion, heating, moulding etc. Raw Materials are mixed in the Agglomerator. A funnel type Hooper 30 x 10 x 50 cm [outer major diameter x funnel diameter x height]. A Stainless Steel rod of diameter 25 mm and length 1.0 m is fed into the mixing chamber. The mixing chamber is of size 150 x 7.5 x 7.5 cm [length x breadth x width]. The temperature zone is from 90⁰c – 120⁰c. Electric Heaters with thermostatic control (03 no.) are strategically placed along the length of the chamber. The mixture from the hooper is fed into the chamber maintained at lower bound temperature of 90⁰c and gradually increased to upper bound temperature zone mentioned above. The plastic pellets in the mixture, are melted and thoroughly compressed using the Extrusion Screw. The Extrusion screw, compresses the plastic – fly ash – cement mixture with volumetric compression mentioned below.

$$(0.5) \times \pi^2 \times D^2 \times H \times N(\sin \Theta)(\cos \Theta) \text{ in}^3/\text{s}$$

- D - diameter of extrusion screw
- H - Height of Chamber
- N - rpm of Motor/ Extrusion screw.

For optimal utilization of the resources, generally the flight pitch is equal to the diameter of extrusion screw; which makes (Sin ΘCos Θ = 0.289). The shape factor is assumed to be 0.95.

$$0.95 \times (0.5) \times \pi^2 \times D^2 \times H \times N(0.289) \text{ in}^3/\text{s}$$

Manifold type heaters are used with thermostats. The thermostats once triggered; cuts off the heater supply and initiates axial fans fitted on the chamber for cooling. The operable temperature zones are as follows;

- a. First Heater : 90⁰c – 105⁰c
- b. Second Heater : 105⁰c – 110⁰c
- c. Third Heater : 110⁰c – 120⁰c

The other end of the chamber is fitted with nozzle of varying sizes and shapes depending on the type of brick and cast required ranging from Square Shape, Circular Shape, Bevel Shape, Ribbon shape, thread patterns etc.

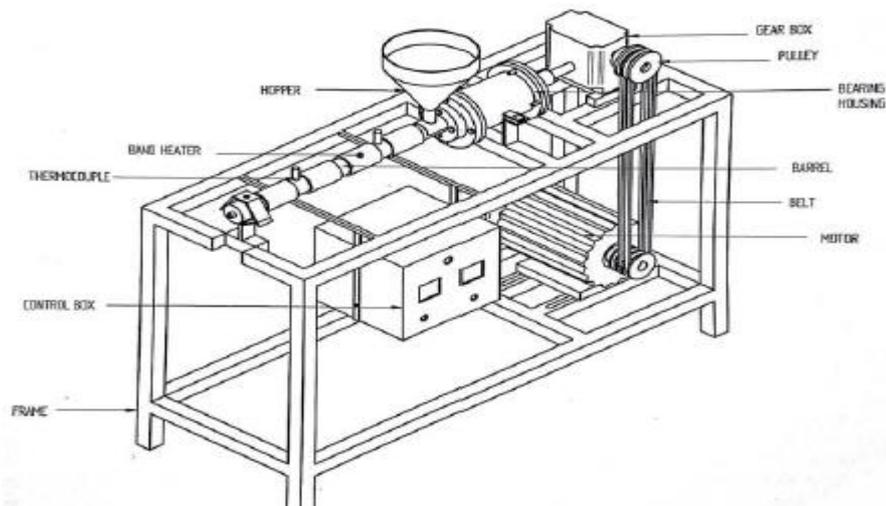


Fig. 3: Plastic Extruding Machine

A. MATERIAL SELECTION

Resin Identification Code (RIC) identifies type of plastic container/ bottle being used. It consists of a triangle and a number with in it ranging from 1 to 7. The symbol details about the chemical constituents, toxicity, and the possibility of leaching. The major materials classified under these numbers are: Polyethylene Terephthalate (PET) -1, High Density Polyethylene (HDPE) - 2, Poly Vinyl Chloride (PVC) - 3, Low Density Polyethylene (LDPE) - 4, Polypropylene (PP) - 5, Polystyrene - 6, and other miscellaneous resins including polycarbonate - 7. While plastic with symbols 1, 2, 4, and 5 are safe to be recycled, those with symbols 3, 6 and 7 are unsafe for recycling. The plastic with symbol 7 are particularly unsafe. For this paper, RIC 7 is selected. Polycarbonates produced by the reaction of Bisphenol A (BPA) and Phosgene (COCl_2). Polycarbonates contain polymers and carbonate group ($-\text{O}-(\text{C}=\text{O})-\text{O}-$). Low electrical and thermal conductivity and flame-retardant, it is used in variety of computers, peripherals including CDs, DVDs, electrical and telecommunications hardware, safety goggles, aviation etc.. Thus, their percentage in waste plastic, particularly in E-waste is considerably high. These plastics are best avoided for recycling into products of domestic consumption; since BPA is known to cause serious several health problems. Impregnating this type of plastic wastes into construction materials may be a safe means of disposal in terms of both arresting their harmful effect and pushing away the end-of-life by a long period while deriving economic values.

B. COMPONENTS OF MACHINE

Cutting of metals into different shapes and sizes as per the requirement of the machine is done using frame cutting and to join different parts of machinery drilling and welding operations are carried out. Parts used for the construction of machinery are strong enough to sustain high temperatures as well as abrasion. 38CrMoAl Alloy featuring nitrogen treatment is used for the construction of screw conveyor and barrel and the surface is treated with alloy as the possess high hardness. Uniform mixing and melting are done due to the new designs of the screw conveyor. Equipment's which are required for the regulation of machine

includes temperature control box, ceramic band heaters, gear box, etc. also, the functioning of feeding is highly improved due to the spiral barrel with a longitudinal groove.

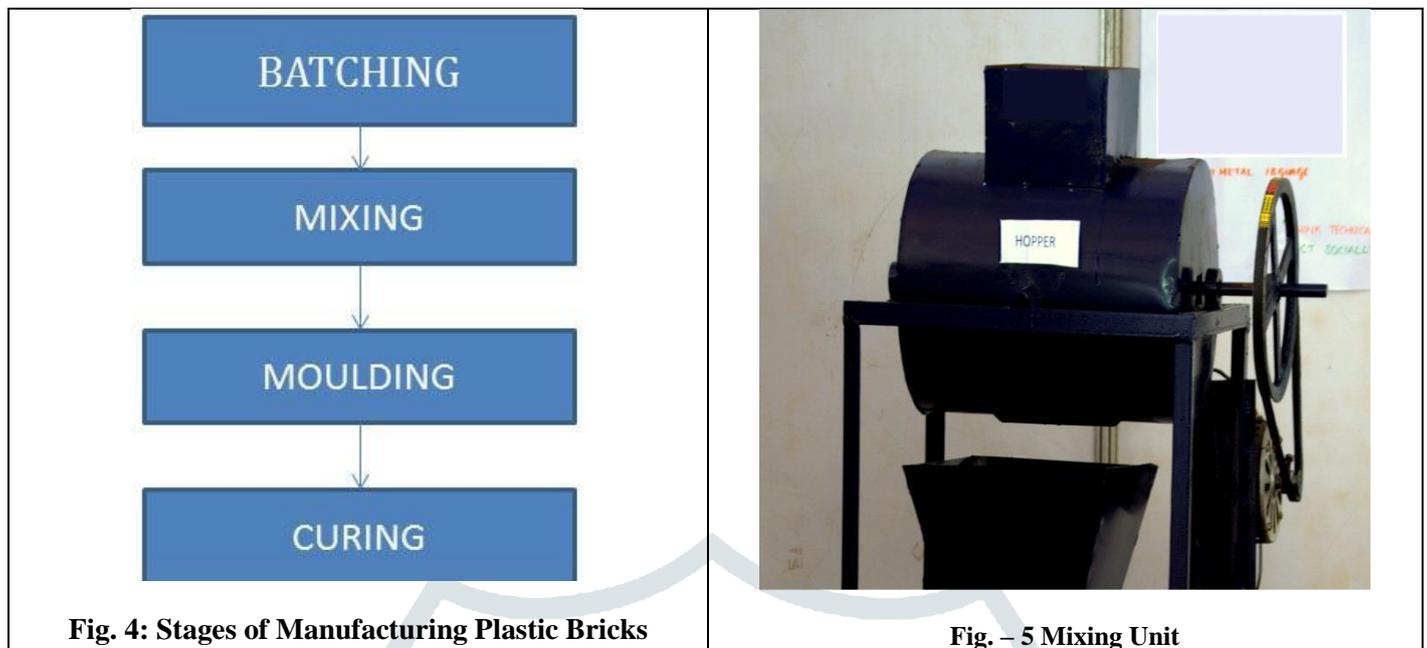


Fig. 4: Stages of Manufacturing Plastic Bricks

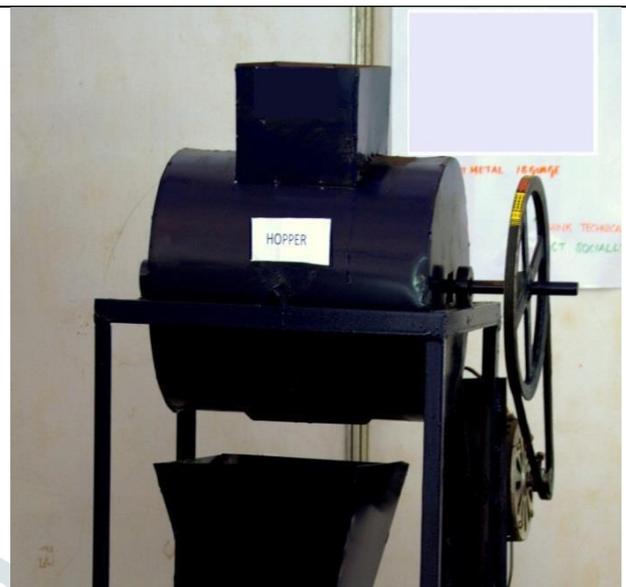


Fig. – 5 Mixing Unit

a. Mixing Unit

It is a device that homogeneously combines cement and aggregates such as sand or gravel, and plastic to form a mixture. A typical mixer uses revolving pipes of protruding parts to mix the components. The sieved sand along with cement and fly ash are added together in mixing unit along with the plastic chips from the cutting unit. The cement is added to act as a binder. Mixing is to be carried out for about 15 minutes in the unit.

b. Extruding Unit

This type of device is capable of melting out and pumping a polymeric material with good control of the heating and of the pumping speed. When the material enters through the feed throat (an opening near the rear of the barrel) comes into contact with the screw. The rotating screw forces the mix forward into the barrel which is heated to the desired melt temperature of the molten plastic. A heating profile is set for the barrel in which three independent controlled heater zones gradually increase the temperature of the barrel from the rear (where the mix enters) to the front. This allows the plastic chips in the mix to melt gradually as they are pushed through the barrel and lowers the risk of overheating which may cause degradation in the polymer. If the extrusion line is running a certain material fast enough, the heaters can be shut off by the thermocouple and the melt temperature maintained by pressure and friction alone inside the barrel. Fig-6 shows EXTRUDING UNIT.

- c. **Heaters & Control Knobs** The heaters are provided in Extruder. It is provided in the model in order to provide sufficient heat so that the plastic waste in the mix gets melted.



Fig. 6 – Extruding Unit

And further mixes it with aggregates and comes out. The heating in the model ranges from 0 to 100°C. The temperature is controlled with two knobs. Fig-7 shows HEATERS and Fig- 8 shows KNOBS to control the temperature.

VI. Type and location of PCM in the brick

The optimization of the type of PCM, suitable for the climatic conditions of Visakhapatnam coastal region is strongly related to the location of the PCM in brick. $\text{CaCl}_2 \cdot 6\text{H}_2\text{O}$ with melting temperature of 29.9° c were tested in three positions i.e. near outer, in the middle and near the inner wall of brick. Graph is plotted with Thermal Flux (W/m^2) along Y axis and Time in hours along X-axis. Graph depicts the middle position gives the best results. The reduction in total heat flux for 24 hours is up to 82.1% compared to a brick without PCM.

VII. Types of Tests:

Quality of plastic bricks and plastic sand paver blocks following tests can be performed. In these tests some are performed in laboratory and the rest are on field.

A. Compressive test

This experimentation is performed to identify the Compressive Strength or Crushing Strength of Plastic Bricks.. Generally five specimens of bricks are taken to laboratory for testing and tested one by one. In this test, the brick

specimen is put on crushing machine and compressed till it breaks. The ultimate pressure at which brick is crushed is taken into account. All five brick specimens are tested one by one and average result is taken as brick's compressive /crushing strength. The plastic bricks of varying ratios are tested one after another and the proportion with high compression is selected



Fig -7: Heaters



Fig -8: Control Knobs

MIX DESIGNATION	PLASTIC SAND RATIO	COMPRESSIVE STRENGTH (N/mm ²)
101	1:2	4.65
102	1:3	4.78
103	1:4	5.12
104	1:5	4.92
105	1:6	3.17



SI.NO	TYPE OF BRICK	COMPRESSIVE STRENGTH (N/mm ²)
1	Fly ash	4.19
2	Burnt clay	3.15
3	Plastic brick	5.12

B. Water absorption test

In this test, the dry weight of the bricks is taken and they are immersed in water for 24 hours. They are wiped with cloth. The weight of the brick samples is computed. The variance of weight in dry and wet bricks percentage is calculated.

C. Efflorescence test

This test is performed to identify the presence of alkalis in the brick samples. Alkalis in bricks are harmful and they form a grey or white layer on brick surface by absorbing moisture. A brick is immersed in fresh water for 24 hours and then it's taken out from water and allowed to dry in shade. It could be observed that partial white patches are formed indicating low alkali content.

D. Fire resistance test

Sand imparts insulation against exposure to high temperature or fire. Though Plastics are highly susceptible to fire, but in case of Plastic sand bricks/Paver blocks the sand induces insulation. There is no change in the structural properties of

block of bricks up to 180°C above which visible cracks are seen and the blocks/bricks deteriorate with increase in temperature.

E. Hardness test

A scratch is made on the brick surface using hardened tool e.g. chisel, rebar rods etc. The test signifies the ease of making indentation i.e. easier to mark on the surface implies the brick is softer in nature while hard to make indentation then harder the material. Hardness Test also signifies the quality of the brick samples.

Acknowledgements

It brings great pleasure to acknowledge the support provided by Management and Staff of the Organization in turning this project to reality. Special mention goes to Ms. M. Chaitanya Mayee, HoD (Mechanical Engg.) & Shri R.S.Kiran for support extended in initiating and realizing the project work.

Conclusion:

The compressive strengths of plastic impregnated bricks reduce with increasing amount of plastic contents. However, compressive strength of bricks with plastic content of up to 15% are observed to conform the ASTM standards. Because of high porosity, water absorption rate is higher compared to control. But these bricks are to be used in specific context where water absorption is not a major concern. Once the process is adopted in practice, the technical advantages and the underlying economic benefits would help in natural evolution of collection and logistic system that will prevent littering of the plastic and unbridle dumping. With the use in bricks, waste plastic will rather become a resource.

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