Performance assessment on manufacturing of unfired bricks using industrial wastes

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Abstract. This paper presents eco-friendly unburnt bricks made up of fly ash, waste plastic powder, waste glass powder, lime, gypsum and crusher sand as alternatives to conventional burnt clay bricks for sustainable development. The research focuses on the maximum utilization of industrial waste in eco-friendly unburnt brick production. Materials are characterized according to their chemical and geotechnical properties. In this research, we use a milled waste glass powder of size less than 600μm and plastic powder obtained from plastic waste of size less than 600μm are added along with crushed sand, gypsum, lime and fly ash with various mix proportions concerning FaL-G mix concept. All the proportions were taken on a weight basis. Compressive strength, water absorption, and efflorescence are the key parameters chosen for comparing the innovative brick with conventional fly ash brick. There are five different mixes (Type A, B, C, D & E) are made in this research. The plastic and glass powders are replaced by crusher sand at the increased rate of 2% in every mix whereas 2%,4%,6%,8%, and 10%. It was found that the type B bricks have 17.63% strength was increased when compared to base mix. From the test results, type B bricks have enhanced mechanical performance when compared to all other mixes.

Keywords: waste plastic powder; waste glass powder; crushing strength; water absorption; efflorescence

1 Introduction

In the field of construction, many materials are used as a building material like wood, bamboo, heavy rocks etc. As the civilisation improvises, the usage of efficient materials along with their strength is analysed which leads to the birth of clay bricks. Bricks are the ancient as well as the up-to -date efficient building member commonly used in and around world. Bricks are usually adapted for its composition which provides strength and durability [1-3]. Reusing waste makes sense from several perspectives, including reduce pollution caused by piled-up garbage; Reduce the amount of energy used in manufacturing processes [4]. Production recycling of waste products is one method of addressing the major concerns of solid waste management [5]. The major materials include the Silica (SiO_2) and Lime (CaO) which prevents the brick from warping, shrinking, and cracking and resistant to corrosion. The amount of 20% to 30% of Alumina (Al_2O_3) in the brick provides the essential plasticity which helps the brick to mould in the perfect shape [6,7]. Similar to any other cementing material, bricks made of clay that contains too much alumina may shrink, warp, or fracture when dried and burned. The other materials like iron oxide (Fe_2O_3) which are used in the production involves in imparting when bricks are burned, they turn red. The durability and impermeability of the bricks are improved by the proper iron content. The bricks' yellow color is caused by the minimal amount of magnesium, which also decreases shrinkage. Bricks deteriorate when there is an excess of it. Bricks are known for its specific properties which are evolved by burning it above 2000°C and dry cured to attain its

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characteristics [8]. Those include the water absorption, colour, density, compression, flexural, thermal properties, and durability. Instead of its strength and durability, the conventional bricks are strengthless in tension and the porousness in the bricks helps to absorb the humidity during the rainy days which affects the quality of the conventional bricks [9]. As the world supports alternative materials for everything, the conventional bricks have numerous varieties of alternatives manufacturing of fly-ash bricks by using neyveli lignite coal ash where the fly ash carries mere advantages of the conventional bricks. The fly ash which is collected and produced from the coal power plants are used as an alternative material for the bricks. As the coal is ignited and the power plant produces its demand, the injected coal is burnt and produces two types of ashes, they include fly ash and bottom ash. The fly ash is made of minute particles which gives dense to the concrete and reduces the permeability [10]. The fly ash produces low heat of hydration which helps the concrete to prevent the thermal cracking and the fly ash is resistant to sulphate and acidic attacks. About 15% to 35% of the fly ash is replaced with clay, which is then tested for strength and durability. By protecting the environment, the use of fly ash bricks results in the conservation of natural resources such as clay. The fly ash brick is simply a pozzolana cement concrete mix that takes a long time to set. The technique for making fly ash in cement plants is the same as the process for creating cement, with the exception that clay and limestone are burned alongside coal and gypsum. Fly ash, which consists of burned clay oxidized particles (derived from burning coal that contains clay from mines), should also be mixed with the fly ash. A slow setting pozzolana cement is produced when hydrated lime powder and gypsum are mixed and ground in a pan [11-13]. In a hydraulic press that is specially made to deliver high pressure loads at a slow rate, in the range of 350 kg/square inch, the mix is compressed at low pressure and low moisture content. The maximum strength of fly ash bricks is achieved at this rate of pressure and with the pressure held for the desired amount of time.

The majority of soils can be satisfactorily stabilised by cement-lime, according to recent research [14]. To ascertain their optimal requirements for properties, however, it is essential to carry out extended soil tests in the laboratory. Soil-based blocks can be used as an alternative to bricks in the construction of normal buildings, but their usage should be avoided in insulated load-bearing columns, columns, or other heavy load structures (Indian Standard: 1725, 1997). According to the study's findings, industrial waste should be used as much as possible to make unburnt bricks [15].

2 Materials used

At the beginning of the study, all materials were separately collected, properly stored, and acquired fresh. The current study fly ash of Class F procured from the Mettur Thermal Power Station in Tamil Nadu, India. The chemical properties of the ash is depicted in Table 1. The specific gravity of fly ash is 2.10 and it is not plastic. It was found that the optimal moisture content (OMC) and maximum dry density (MDD) were 31% and 12.4 kN/m^3, respectively. Table 3 lists a few geotechnical characteristics. They have a good colour equivalent to cement, are symmetrical in shape and finish, and therefore do not require plastering for construction. They are dense, evenly shaped with or without a frog, and free of noticeable fractures, organic particles, stones, and free lime nodules. They seem to be less porous and lighter than normal clay bricks. By using admixtures at various stages of the brick-making process, fly ash's colour may be changed. Most of them are similar in size to sand particles, yet they occur in a range of sizes.

Table 1. Chemical composition of fly ash.

Oxides	Quantity (%)
SiO_2	48.5
Al_2O_3	26.01
MgO	1.41
Fe_2O_3	8.91
CaO	4.68
Loss of Ignition (LOI)	9.56
Others	0.93

The crushed sand is taken and it is procured from karur in necessary proportion and well graded. The sand should be free from impurities and organic matter that affects setting time of cement thus it attains required strength. The clay, dust and silt coatings are such impurities do not present in it. which also create bond with aggregate and cement paste. Using the state-of-the-art International Technology, Hard rock(granite) is used to manufacture crushed sand [16]. And obtained from High carbon steel hit rock and similar process like rock-on-rock undergoing natural process in river sand.

Gypsum is a soft mineral with such a moderate solubility in water. Temperature has an impact on this mineral's water solubility. So, when temperature goes up, gypsum, unlike other salts, will become less soluble in water. This is called as as retrograde solubility, and this is a unique characteristic of gypsum. Its colour is usually white, lifeless, or grey. But, attributed to the prevalence of impurities, it can sometimes be found in colours of pink, yellow, brown, and pale green [17]. Gypsum crystals have quite a translucent to glossy lustre which can be clear or translucent. Gypsum crystals can grown to be extremely massive, and these are some of the largest crystals found in nature [18]. Some crystals generally flexible and therefore can flex whenever force is exerted. Yet, since the crystals are not elastic, they do not return to their original shape when the pressure is lifted [19-20]. Their crystals are often found in the shape of flower petals. It is known for having a poor thermal conductivity; therefore it is used to build drywall and wallboards. Gypsum is a natural insulator as well. When gypsum is burned, it dehydrates and changes into calcium sulphate hemihydrates, also known as 'bassinette.' Anhydrous calcium sulphate, or anhydrite, is produced whenever this mineral is warmed further.

Depending on the method of formation, limestone could be crystalline, flexible, granular, or massive. Small cavities in the rock may be filled by calcite, quartz, dolomite, or barite crystals. Calcite can create mineral coatings that bind existing bedrock grains together or fill fractures when the conditions are right for precipitation. Limestones make about 10% of all rock layers. Because limestone is partially soluble, especially in acid, it forms a variety of erosion formations. Detroit Limestone and Chemical Company is home to the largest global limestone quarry. ls crushed for use in asphalt concrete and as a solid base for many roads. Table 2 shows the chemical properties of lime used and marketed lime in India and few geotechnical properties of lime and fly ash.

Table 2. Chemical composition of lime used and marketed lime in India

Parameter (unit)	Used Lime	Marketed lime
pH	11.78	11.75
Conductivity (mS/cm)	4.40	6.92
Calcium carbonate (%)	67.2	88.0
Chloride (ppm)	700.0	802.15
Available phosphorus (ppm)	0.0	0.072
Available potassium (ppm)	29.3	108.0
Available calcium (ppm)	370.0	241.0
Available sodium (ppm)	35.1	136.0

Glass powder is obtained from crushing the beverage bottles. Glass powder is used to substitute fine aggregate in certain cases. The particles utilised varies in size of 0.006 to 1.18mm. The glass powder's specific gravity was determined to be 2.5. Sodium oxide (Na_2O), which is made from sodium carbonate (Na_2CO_3), calcium oxide (CaO), and a few additional compounds comprise approximately 75% of its composition. Non-materials that are frequently transparent and have several practical, technological, and aesthetic applications include windowpanes, tableware, and optoelectronics. The most well-known and historically most ancient varieties of glass are "silicate glasses," which are based on the chemical silica (silicon dioxide, or quartz), which is the main component of sand.

Table 3. Geotechnical properties of lime and fly ash

Properties	Material	
	Lime	Fly ash
Specific gravity	2.46	2.10
Plasticity index	Non-plastic	Non-plastic
Maximum dry unit weight (kN/m^3)	12.6	13.24
Optimum moisture content (%)	17.0	34.0
CBR value (%)	3.4	11.3

The monomer used to make polyethylene terephthalate (PET), which is made up of the ethylene molecule (CH_2 CH_2 --), two ester molecules COO --, and the terephthalate ring molecule, is ethylene terephthalate. Only one atomic species of PET can be found in the waste plastic powder: hydrogen, oxygen, and carbon. When burning PET, just CO_2 and water were produced (H_2O). As a consequence, even when PET is burnt, there is no possibility of harmful dioxide emissions, however in this test, only PET melting was needed. Plastics (or only PET melting was needed. Plastics (or polymers) have such a basic structure determined polymers) have such a basic structure determined by macromolecule chains produced by chemical by macromolecule chains produced by chemical reactions from monomer un reactions from monomer units.

Polymer addition its. Polymer addition (continuous or stepwise) and condensation (continuous or stepwise) and condensation polymerization are mainly two reactions for polymerization are mainly two reactions for chain assembly (polycondensation). Table 4 shows the physical properties of waste plastic powder.

Table 4. Physical properties of waste plastic powder

Parameter	Unit
Coefficient of Thermal Expansion	6.8 x 10^{-2}/ºC
Long Term Service Temperature	120 - 175ºC
Melting point	275ºC
Specific Gravity	1.28 – 1.39
Water Absorption	0.08 – 0.10%

Fig. 1 shows the materials used in this entire investigation. The water used for mixing and curing needs to be pure and free of any contaminants that could harm bricks, such as excessive amounts of alkalis, acids, oils, salt, organic components, and vegetative growth. For mixing, potable water is typically regarded as sufficient. Water should have a pH level that is at least 6.

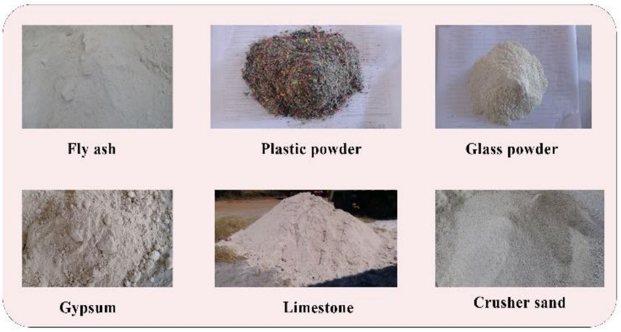

Fig. 1. Materials used in this investigation

3 Mix proportion and methodology

The necessary amount of water is added to a pan mixer, where the ingredients for intimate mixing—fly ash, lime, crushed sand, glass powder, plastic powder, and gypsum—are manually supplied. Fly ash makes up 60% of the mixture, followed by lime (15%), gypsum (5%), and crusher sand (20%), depending on the quality of the raw ingredients. In particular, the glass and plastic powder were replaced by crusher sand by 2%, 4%, 6%, 8%, and 10% respectively. The Mix IDs were base mix, Type A, B, C, D, and E. A pan mixture is used to combine the ingredients. Following mixing, the mixture is moved via a belt conveyor to the hydraulic/mechanical presses. The homogenised mortar is fed into the mould boxes through the roller mixer. Depending on the equipment, the brick is moulded by compressed via hydraulic compression, vibration, etc. Depending on whether they are made of lime or cement, the bricks are dried in the sun for 48 hours. The dry bricks are then stored and exposed to spray mist curing once or twice daily for 7 to 21 days in ambient temperatures [21]. Figures 2 and 3 depict a schematic representation of the brick-making process flow diagram and schematic diagram of brick samples. Table 5. shows the various mix proportion of the bricks. The plastic and glass waste powder are constantly mixed in all the proportions.

4 Results and discussion

All brick accordance with the requirement testing in conformance with Indian standard requirements.

4.1 Dimension Test

Procedures for measuring the size of bricks were based on Clause 5.2.1 of IS 12894:2002. In this test, measuring tape was a necessary tool. A total of 20 bricks—or more depending on the size of the stack—were randomly chosen for this test.

A steel tape or other non-extensible measuring tool long enough to measure the whole row at once is required to determine the total length of the constructed bricks. The use of a short rule or measure repeatedly is not authorised for measuring. [22].

Bricks may be measured individually to the nearest millimetre if measuring them in a single row is deemed impractical for whatever reason, the sample may be divided into rows of 10 bricks each. It is necessary to add up each of these measurements. Following the above-described steps, the bricks' dimensions were measured. The measurement's findings must adhere to the limits outlined in IS 12894:2002.

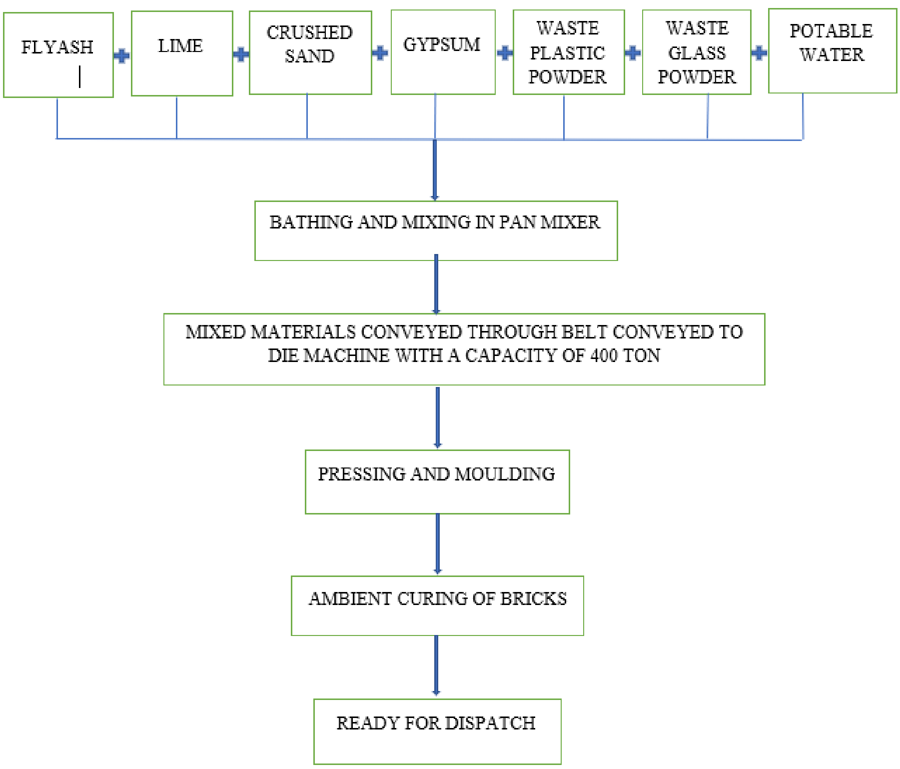

Fig. 2. Schematic flow diagram of manufacturing process of bricks

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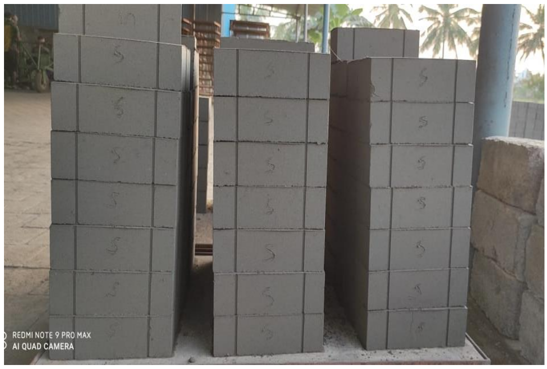

Fig. 3. Schematic diagram of samples of bricks

Table 5. Mix Proportion

Materials	Base Mix	Type A	Type B	Type C	Type D	Type E
Fly ash	60	60	60	60	60	60
Crushed sand	20	16	12	8	4	0
Gypsum	5	5	5	5	5	5
Lime	15	15	15	15	15	15
Plastic powder	0	2	4	6	8	10
Glass powder	0	2	4	6	8	10

4.2 Compressive strength test

Compressive strength is one of the remarkable mechanical properties of brick. Therefore, the bricks are still used in construction of buildings. Building brick has an average compressive strength of 3-3.5 N/mm^2, according to IS 1077:1992. at M. Kumarasamy College of Engineering's concrete laboratory, every brick is checked using a 200 TON capacity compression testing machine. Fig. 4 shows the Test on compressive strength of bricks. Fig. 5 and 6 shows the compressive strength results of various mix and average compressive strength results of various mix . From the test results obtained, the replacement of plastic and glass powder influences the compressive strength.

The replacement of plastic and glass powder up to 2% and 4% has enhances the compressive strength of fly ash bricks. When compared to the base mix, the compressive strength was increased 5.9% for 2% replacement and 17.63% strength increased in 4% replacement. The replacement of 6%, 8% and 10% of plastic and glass powder decreases the strength of the bricks due to the insufficient bond development in the microstructure.

Fig. 4. Test on compressive strength of bricks

4.3 Water absorption test

Water absorption testing is particularly important for bricks, and the bricks were tested in accordance with the protocol published in 1976 (SP: 3495 (Part-2). The brick's ability to absorb water determines their quality. The bricks' water

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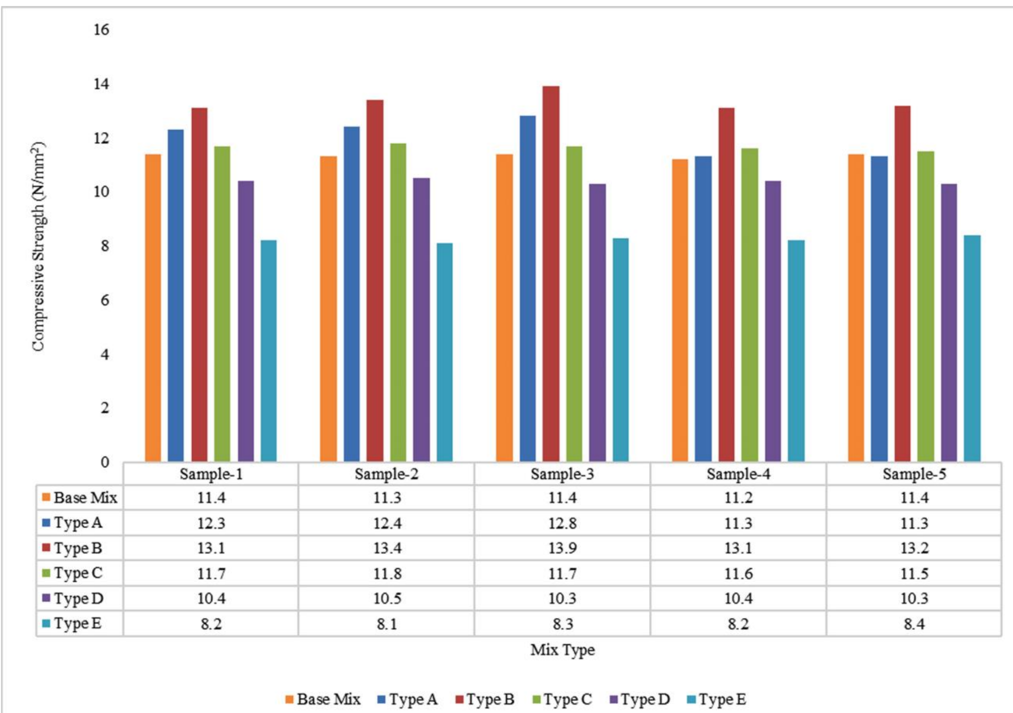
absorption should be lower than 20% after being submerged in water for 24 hours. Three bricks should be taken on average. Our bricks have a low water absorption property; they only absorb 7.73 to 12.54% of the water. Fig. 7 and 8 shows the water absorption results for various samples for various mix and average water absorption results for various mix.

4.4 Efflorescence test

It has been demonstrated that this technique can find soluble salt in a brick. Fluorescence is reported to be low, it is described as moderate, and contains approximately 50% white deposit. Includes about 10% white deposit surface. Incontinence is seen as significant and is described as thick on the surface [23]. Fluorescence is when water-soluble slates are carried away, deposited and gradually accumulate on the brick surface, forming an unpredictable contaminant. The bricks' base material may have been the source of soluble salts. But in most cases, salts originate from outside sources like groundwater. Bricks are exposed to contaminated air, motor products, and other contaminants [24]. Nil - When there is no visible deposit of efflorescence., Brick area exposed to less than 10 percent its tends to be slight, up to 50 percent means moderate, more than 50 percent means heavy efflorescence. Serious - When there is a high deposition of salts with the addition of salts and / or exposed surfaces. Table 6. shows the result of efflorescence.



	Sample-1	Sample-2	Sample-3	Sample-4	Sample-5
Base Mix	11.4	11.3	11.4	11.2	11.4
Type A	12.3	12.4	12.8	11.3	11.3
Type B	13.1	13.4	13.9	13.1	13.2
Type C	11.7	11.8	11.7	11.6	11.5
Type D	10.4	10.5	10.3	10.4	10.3
Type E	8.2	8.1	8.3	8.2	8.4

Fig. 5. Compressive strength results of various samples for various mix

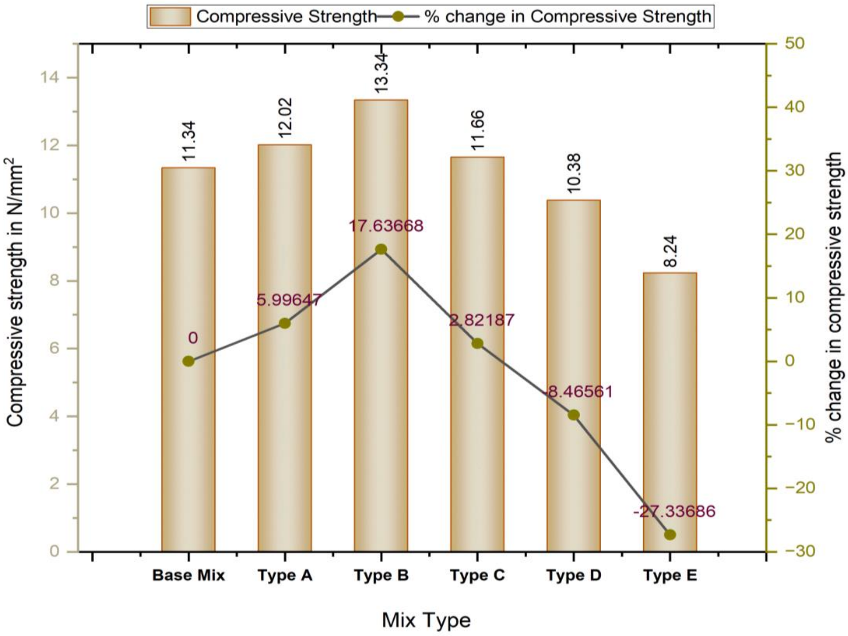


Fig. 6. Average compressive strength results of various mix

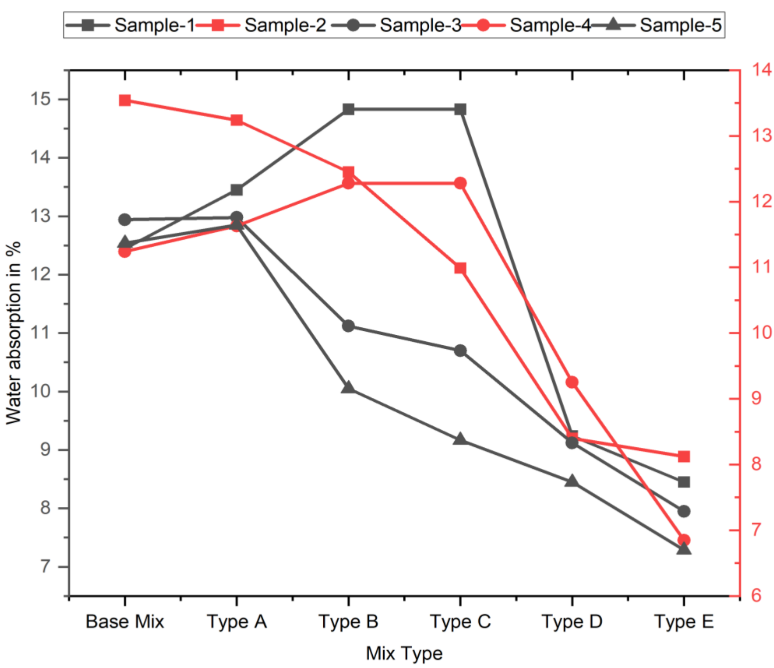


Fig. 7. Water absorption results for various samples for various mix

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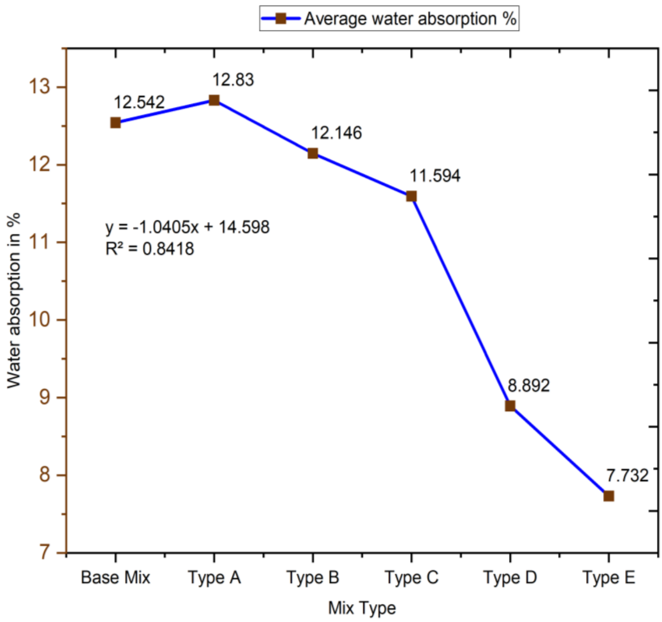

Fig. 8. Average water absorption results for various mix

Table 6. Result of efflorescence

S.No	Specimen	Observations
1	A	Mild
2	B	Mild
3	C	Mild
4	D	Mild
5	E	Mild

4.5 Uniformity test

A good brick should have rectangular plane surface and uniform in size. A good brick will have uniform colour throughout as shown in Fig. 9.

Fig. 9. Uniformity of brick specimes

5 Conclusion

In conclusion, the results of the tests done on bricks are listed below:

- In the compressive strength test type B mix obtained 13.34 N/mm^2 which is higher when compared to other mixes A, B, D and E.
- It was found that type B brick samples have enhanced mechanical performance and it is 17.63% strength increment when compared to the base mix and which is higher in all other types.
- In water absorption test also type B bricks showed low water absorption values when compared to other samples of bricks.
- The type B bricks also had good shape and size and passes soundness and hardness test than other samples.
- So, the Type B bricks can be used for construction works along with less cost. From the test results 2% of crusher sand is replaced by plastic and glass powder have the enhanced mechanical performance. Thus, plastic and glass which are non-degradable has a high value in our bricks. So future pollution can be controlled in our project using theses wastes.

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Not Applicable.

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