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MANUFACTURE OF BRICKS WITH PARTIAL REPLACEMENT OF CLAY WITH WASTE GLASS POWDER

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Abstract: - Brick is one of the very common and important construction material which is used in all masonry work. A large land area is used for acquiring clay for brick making. The word replacement has become the very common thing worldwide. More land area is being acquired for clay in brick making. To make this reduced replacement of waste materials can be done. The partial replacement of Waste Glass Powder (WGP) is the main aim of this project. The Waste Glass Powder was partially replaced as 25%, 30%, 35%, 40%, 45% and 50%. The waste glass powder is also called as fused silica glass powder. The WGP was taken and mixed with clay in correct proportions. The mixture was left for curing for one day. Then the mixture was mixed with water to get correct consistency. This was then molded into bricks with a mould of size 190x90x90 mm. After the molding the bricks are kept for sun drying for seven days. Then the dried bricks are kept in a Bull's Trench Kiln for seven days at 900°C temperature. After seven days of baking the bricks were taken out for testing using Compression Testing Machine. The test results were obtained. The replacement of Waste Glass Powder has equalised the compressive strength and other properties of normal fired clay brick. By this study it is clear that a greater amount of waste glass can be used in the form of a powder as a partial replacement in clay bricks.

Introduction

A brick is a block or a single unit of a kneaded Clay-bearing soil, sand and lime, or concrete material, fire hardened or air dried, used in masonry construction as shown in figure (1.1). Lightweight bricks (also called lightweight blocks) are made from expanded clay aggregate. Fired brick are the most numerous type and are laid in courses and numerous patterns known as bonds, collectively known as brickwork, and may be laid in various kinds of mortar to hold the bricks together to make a durable structure. Brick are produced in numerous classes, types, materials, and sizes which vary with region and time period, and are produced in bulk quantities. Two most basic categories of brick are fired and non-fired brick. Fired brick are one of the longest lasting and strongest building materials sometimes referred to as artificial stone and have been used since circa 5000 BC. Air dried bricks have a history older than fired bricks, are known by the synonyms mud brick and adobe, and have an additional ingredient of a mechanical binder such as straw.

Figure 1.1 Construction using bricks

NEED FOR THE STUDY

More land is being used for getting clay for making brick. When glass powder is used as the partial replacement, the use of clay is reduced. Waste glass can easily be discarded in powdered form. A new combination in the brick manufacturing is obtained. When Glass powder used with ceramic and clay it gives a very fine finishing and glassy appearance for the brick. High strength can be obtained, so it can be used in the main elements of a structure. High compressive strength of the brick compared to normal brick. No dumping of waste glass is needed, since it is used as replacement in clay bricks, concrete, etc. cost of manufacturing is also reduced. To attain the weight of the brick equal to the normal brick.

SCOPE

- Rapid increase in the population and various design standards of constructional activity, bricks have taken various changes in the past centuries.
- The strength of bricks directly depends up on the quality of clay used with the views of replacement and it has taken new ages now-a-days. The possible use of machine crushed waste glasses, which is obtained by machine crushing and getting it an powdered form.
- The performance of fired bricks with WGP replacement on compressive strength and the properties of the bricks. Waste glass powder is rapidly obtained in the form of waste glass pieces, containers and other waste glass products. This may cause environmental loading and disposal problems at the disposing sites, this have been changed in to useful resource and used in the brick making.
- The cost and other properties of the bricks are equalised to the normal bricks. The property of the manufactured brick has compromised with the normal brick.

OBJECTIVE

This study involves the addition of waste glass powder (WGP) with clay in fired bricks. therefore the investigation had few typical objectives.

- To investigate the compressive strength of the fired clay brick.
- To investigate the physical properties of bricks.

In general the brick will be made with clay but in this investigation a replacement of 0%,25%,30%,35%,40%,45% and 50% of WGP is done and is designated as 1,2,3,4,5,6 and N.B. The effect of compression strength and the physical properties of the bricks are studied.

BRICKS

HISTORY OF BRICKS

The history of bricks varies from time to time. According to the type of construction, the bricks were manufactured. The bricks are being used for more than 5000 years. Different places had various other types of bricks in use. Some of them are listed below which says the history of bricks of various countries and places.

MIDDLE EAST

The earliest bricks were dried brick, meaning they were formed from clay-bearing earth or mud and dried (usually in the sun) until they were strong enough for use. The oldest discovered bricks, originally made from shaped mud and dating before 7500 BC, were found at Tell Aswad, in the upper Tigris region and in southeast Anatolia close to Diyarbakir. Other more recent findings, dated between 7,000 and 6,395 BC, come from Jericho, Catal Huyuk, the ancient Egyptian fortress of Buhen, and the ancient Indus Valley cities of Mohenjo-daro, Harappa, and Mehrgarh. Ceramic or fired brick was used as early as 2900 BC in early Indus Valley cities.

CHINA

In pre-modern China, bricks were being used from the second millennium BCE at a site near Xi'an. Bricks were produced on a larger scale under the Western Zhou dynasty about 3,000 years ago, and evidence for some of the first fired bricks ever produced has been discovered in ruins dating back to the Zhou. The carpenter's manual Yingzao Fashi, published in 1103 at the time of the Song Dynasty described the brick making process and glazing techniques then in use. Using the 17th century encyclopaedic text Tiangong Kaiwu, historian Timothy Brook outlined the brick production process of Ming Dynasty China.

In the 21st century, the ILAB has recorded significant instances of child labour and forced labour in the bricks manufacture sector and classified China as one of the 76 countries mentioned in its 2014 List of Goods Produced by Child Labour or Forced Labour.

EUROPE

Early civilizations around the Mediterranean adopted the use of fired bricks, including the Ancient Greeks and Romans. The Roman regions operated mobile kilns, and built large brick structures throughout the Roman Empire, stamping the bricks with the seal of the region.

During the Early Middle Ages the use of bricks in construction became popular in Northern Europe, after being introduced there from Northern-Western Italy. An independent style of brick architecture, known as brick Gothic (similar to Gothic architecture) flourished in places that lacked indigenous sources of rocks. Examples of this architectural style can be found in modern-day Denmark, Germany, Poland, and Russia.

This style evolved into Brick Renaissance as the stylistic changes associated with the Italian Renaissance spread to northern Europe, leading to the adoption of Renaissance elements into brick building. A clear distinction between the two styles only developed at the transition to Baroque architecture. In Lubeck, for example, Brick Renaissance is clearly recognizable in buildings equipped with terracotta reliefs by the artist Statius von Duren, who was also active at Schwerin and Wismar.

Long distance bulk transport of bricks and other construction equipment remained prohibitively expensive until the development of modern transportation infrastructure, with the construction of canal, roads and railways.

INDUSTRIAL ERA

Production of bricks increased massively with the onset of the Industrial Revolution and the rise in factory building in England. For reasons of speed and economy, bricks were increasingly preferred as building material to stone, even in areas where the stone was available. It was at this time in London, that bright red brick was chosen for construction to make the buildings more visible in the heavy fog and to prevent traffic accidents.

The transition from the traditional method of production known as 'hand-molding to a mechanised form of mass production slowly took place during the first half of the nineteenth century. Possibly the first successful brick-making machine was patented by a Mr. Henry Clayton, employed at the Atlas Works in Middlesex, England, in 1855, and was capable of producing up to 25,000 bricks daily with minimal supervision. His mechanical apparatus soon achieved widespread attention after it was adopted for use by the South Eastern Railway Company for brick-making at their factory near Folke stone. The Bradley & Craven Ltd 'Stiff-Plastic Brick making Machine' was patented in 1853, apparently predating Clayton. Bradley & Craven went on to be a dominant manufacturer of brick making machinery. Predating both Clayton and Bradley & Craven Ltd. However was the brick making machine patented by Richard A.Ver Valen of Haverstraw, New York in 1852.

The demand for high office building construction at the turn of the 20th century, led to a much greater use of cast and wrought iron and later steel and concrete. The use of brick for skyscraper construction severely limited the size of the building – the Monadnock Building, built in 1896 in Chicago required exceptionally thick walls to maintain the structural integrity of its 17 storeys.

Following pioneering work in the 1950s at the Swiss Federal Institute of Technology and the Building Research Establishment in Watford, UK, the use of improved masonry for the construction of tall structures up to 18 storeys high was made viable. However, the use of brick has largely remained restricted to small to medium-sized buildings, as steel and concrete remain superior materials for high-rise construction.

METHODS OF MANUFACTURE

The three basic types of brick are un-fired, fired, and chemically set bricks. Each type is manufactured differently.

FIRED BRICK

Fired bricks are burned in a kiln which makes them durable. Modern, fired, clay bricks are formed in one of three processes – soft mud, dry press, or extruded.

Normally, brick contains the following ingredients:

- Silica (sand) – 50% to 60% by weight
- Alumina (clay) – 20% to 30% by weight
- Lime – 2 to 5% by weight
- Iron oxide – ≤ 7% by weight
- Magnesia – less than 1% by weight

The soft mud method is the most common, as it is the most economical. It starts with the raw clay, preferably in a mix with 25–30% sand to reduce shrinkage. The clay is first ground and mixed with water to the desired consistency. The clay is then pressed into steel moulds with a hydraulic press. The shaped clay is then fired ("burned") at 900–1000°C to achieve strength.

TYPES OF FIRED CLAY BRICKS

There are thousands of types of bricks that are named for their use, size, forming method, origin, quality, texture, and/or materials.

- Face – A very common classification meaning they are suitable to be visible.
- Common or building – A less common type of brick not intended to be visible such as being underground or covered with render or plaster.
- Hollow – not solid, the holes are less than 25% of the brick volume.
- Perforated – holes greater than 25% of the brick volume.
- Keyed – indentations in at least one face and end to be used with rendering and plastering.
- Paving – brick intended to be in ground contact as a walkway or roadway.
- Ceramic glazed – face bricks with a decorative glazing.
- Engineering – a type of hard, dense, brick used where strength, low water porosity or acid (flue gas) resistance are needed. Further classified as type A and type B based on their compressive strength.
- Pressed – wire cut bricks which are then pressed to improve appearances.
- Molded – shaped in moulds rather than being extruded.
- Interior quality – lower quality brick not for exterior exposure.
- Special quality – High quality for use in wet and freezing conditions.

CHEMICALLY SET BRICKS

Chemically set bricks are not fired but may have the curing process accelerated by the application of heat and pressure in an autoclave.

UNFIRED BRICKS

Also known as earth masonry, unfired clay brickwork is constructed using earth materials (possibly with some additives). Earth masonry is not "fired" like conventional bricks, but the masonry units are air dried after manufacture to reduce shrinkage and improve strength. In some traditional forms of earth construction (e.g. cob or rammed earth), monolithic (solid) walls are constructed, but unfired clay bricks are similar to other masonry systems where there the units ("bricks") are bonded together with mortar and possibly covered with a finishing system (paint or render).

OPTIMAL DIMENSIONS, CHARACTERISTICS AND STRENGTH

For efficient handling and laying, bricks must be small enough and light enough to be picked up by the bricklayer using one hand (leaving the other hand free for the trowel). Bricks are usually laid flat and as a result the effective limit on the width of a brick is set by the distance which can conveniently be spanned between the thumb and fingers of one hand, normally about four inches (about 100 mm). In most cases, the length of a brick is about twice its width, about eight inches (about 200 mm) or slightly more. This allows bricks to be laid bonded in a structure which increases stability and strength. The wall is built using alternating courses of stretchers, bricks laid long ways, and headers, bricks laid crossways. The headers tie the wall together over its width. In fact, this wall is built in a variation of English bond called English cross bond where the successive layers of stretchers are displaced horizontally from each other by half a brick length. In true English bond, the perpendicular lines of the stretcher courses are in line with each other.

A bigger brick makes for a thicker (and thus more insulating) wall. Historically, this meant that bigger bricks were necessary in colder climates, while a smaller brick was adequate, and more economical, in warmer regions. A notable illustration of this correlation is the Green Gatein Gdansk, built in 1571 of imported Dutch brick, too small for the colder climate of Gdansk, it was notorious for being a chilly and drafty residence. Nowadays this is no longer an issue, as modern walls typically incorporate specialised insulation materials.

The correct brick for a job can be selected from a choice of colour, surface texture, density, weight, absorption and pore structure, thermal characteristics, thermal and moisture movement, and fire resistance.

In England, the length and width of the common brick has remained fairly constant over the centuries, but the depth has varied from about two inches (about 51 mm) or smaller in earlier times to about two and a half inches (about 64 mm) more recently. In the United Kingdom, the usual size of a modern brick is 215×102.5×65 mm (about 8 ⅝ × 4 ⅛ × 2 ⅝ inches), which, with a nominal 10 mm mortar joint, forms a unit size of 225 × 112.5 × 75 mm (9 × 4 ½ × 3 inches), for a ratio of 6:3:2.

In the United States, modern standard bricks are (controlled by American Society for Testing and Materials ASTM) about 8 × 3 ⅝ × 2 ¼ inches (203 × 92 × 57 mm). The more commonly used is the modular brick 7 ⅝ × 3 ⅝ ×2 ¼ inches (194 × 92 × 57 mm). This modular brick of 7 ⅝ plus a ⅜ mortar joint eased the calculations of the number of bricks in a given run.

Some brick-makers create innovative sizes and shapes for bricks used for plastering (and therefore not visible) where their inherent mechanical properties are more important than their visual ones. These bricks are usually slightly larger, but not as large as blocks and offer the following advantages:

- A slightly larger brick requires less mortar and handling (fewer bricks), which reduces cost
- Their ribbed exterior aids plastering
- More complex interior cavities allow improved insulation, while maintaining strength.

Blocks have a much greater range of sizes. Standard coordinating sizes in length and height (in mm) include 400×200, 450×150, 450×200, 450×225, 450×300, 600×150, 600×200, and 600×225; depths (work size, mm) include 60, 75, 90, 100, 115, 140, 150, 190, 200, 225, and 250. They are usable across this range as they are lighter than clay bricks. The density of solid clay bricks is around 2,000 kg/m³, this is reduced by frogging, hollow bricks, and so on, but aerated autoclaved concrete, even as a solid brick, can have densities in the range of 450–850 kg/m³.

The term "frog" can refer to the indentation or the implement used to make it. Modern brick-makers usually use plastic frogs but in the past they were made of wood. It is best practice to lay bricks with the frog facing up to achieve a more full, compact bed.

CLASSIFICATION OF BRICKS

The **classification of bricks** is as follows:

(i) **Un-burnt or sun-dried bricks.**
(ii) **Burnt bricks.**

(i) Un-burnt or Sun-Dried Bricks

The un-burnt or sun-dried bricks are those bricks which are dried with the help of heat that is received from sun after the process of molding. The un-burnt bricks can only be used in the construction of simple temporary and cheap structures. Un-burnt bricks should not be used at places exposed to heavy rains.

(ii) Burnt Bricks

The bricks used in construction works are burnt bricks and they are classified into the following four categories:

- **First class bricks.**
- **Second class bricks.**
- **Third class bricks.**
- **Fourth class bricks.**

(1) First class bricks

These first class bricks are table molded and of uniform shape and they are burnt in kilns. The surfaces and edges of the bricks are sharp, square, smooth and straight. They comply with all the qualities of good bricks. These bricks are used for important work of permanent nature.

(2) Second class bricks

The second class bricks are ground molded and they are burnt in kilns. The surface of the second class bricks is slightly rough and shape is also slightly regular. These bricks may have hair cracks and their edges may not be sharp and uniform. These bricks are commonly used at places where brickwork is to be provided with a coat of plaster.

(3) Third class bricks

These bricks are ground-molded and they are burnt in clamps. These bricks are not very hard and they have rough surfaces with irregular and blunt edges. These bricks give dull sound when they are struck together. They are used for unimportant works, temporary structures and at places where rainfall is not heavy.

(4) Fourth class bricks

These are over-burnt bricks with irregular shape and dark colour. These bricks are used as aggregate for concrete in foundations, brick floors, surkhi, roads, etc. because of the fact that the over-burnt bricks have a compact structure and hence they are sometimes found to be stronger than even the first class bricks. It is thus seen that the above **classification of bricks** is based on the of manufacturing or preparing bricks.

TYPES OF BRICKS

- Common Burnt Clay Bricks.
- Sand Lime Bricks (Calcium Silicate Bricks).
- Engineering Bricks.
- Concrete Bricks.
- Fly ash Clay Bricks.

(i) Common Burnt Clay Bricks

Common burnt clay bricks are formed by pressing in molds. Then these bricks are dried and fired in a kiln. Common burnt clay bricks are used in general work with no special attractive appearances. When these bricks are used in walls, they require plastering or rendering.

(ii) Sand Lime Bricks

Sand lime bricks are made by mixing sand, fly ash and lime followed by a chemical process during wet mixing. The mix is then molded under pressure forming the brick. These bricks can offer advantages over clay bricks such as:

- Their color appearance is grey instead of the regular reddish color.
- Their shape is uniform and presents a smoother finish that doesn't require plastering.
- These bricks offer excellent strength as a load-bearing member.

(iii) Engineering Bricks

Engineering bricks are bricks manufactured at extremely high temperatures, forming a dense and strong brick, allowing the brick to limit strength and water absorption.

Engineering bricks offer excellent load bearing capacity damp-proof characteristics and chemical resisting properties.

(iv) Concrete Bricks

Concrete bricks are made from solid concrete. Concrete bricks are usually placed in facades, fences, and provide an excellent aesthetic presence. These bricks can be manufactured to provide different colors as pigmented during its production.

(v) Fly Ash Clay Bricks

Fly ash clay bricks are manufactured with clay and fly ash, at about 1,000 degrees C. Some studies have shown that these bricks tend to fail poor produce pop-outs, when bricks come into contact with moisture and water, causing the bricks to expand.

INFLUENCE ON FIRED COLOUR

The fired colour of clay bricks is influenced by the chemical and mineral content of the raw materials, the firing temperature, and the atmosphere in the kiln. For example, pink coloured bricks are the result of a high iron content, white or yellow bricks have a higher lime content. Most bricks burn to various red hues; as the temperature is increased the colour moves through dark red, purple and then to brown or grey at around 1,300 °C (2,372 °F). Calcium silicate bricks have a wider range of shades and colours, depending on the colourants used. The names of bricks may reflect their origin and colour, such as London stock brick and Cambridge-shire White.

"Bricks" formed from concrete are usually termed blocks, and are typically pale grey in colour. They are made from a dry, small aggregate concrete which is formed in steel moulds by vibration and compaction in either an "egg-layer" or static machine. The finished blocks are cured rather than fired using low-pressure steam. Concrete blocks are manufactured in a much wider range of shapes and sizes than clay bricks and are also available with a wider range of face treatments – a number of which simulate the appearance of clay bricks.

An impervious and ornamental surface may be laid on brick either by salt glazing, in which salt is added during the burning process, or by the use of a "slip," which is a glaze material into which the bricks are dipped. Subsequent reheating in the kiln fuses the slip into a glazed surface integral with the brick base.

Natural stone bricks are of limited modern utility due to their enormous comparative mass, the consequent foundation needs, and the time-consuming and skilled labour needed in their construction and laying. They are very durable and considered more handsome than clay bricks by some. Only a few stones are suitable for bricks. Common materials are granite, limestone and sandstone. Other stones may be used (for example, marble, slate, quartzite, and so on) but these tend to be limited to a particular locality.

USES OF BRICKS

Bricks are used for building, block paving and pavement. In the USA, brick pavement was found incapable of withstanding heavy traffic, but it is coming back into use as a method of traffic calming or as a decorative surface in pedestrian precincts. For example, in the early 1900s, most of the streets in the city of Grand Rapids, Michigan were paved with brick. Today, there are only about 20 blocks of brick paved streets remaining.

Bricks in the metallurgy and glass industries are often used for lining furnaces, in particular refractory bricks such as silica, magnesia, chamotte and neutral (chromomagnesite) refractory bricks. This type of brick must have good thermal shock resistance, refractoriness under load, high melting point, and satisfactory porosity. There is a large refractory brick industry, especially in the United Kingdom, Japan, the United States, Belgium and the Netherlands.

In Northwest Europe, bricks have been used in construction for centuries. Until recently, almost all houses were built almost entirely from bricks. Although many houses are now built using a mixture of concrete blocks and other materials, many houses are skinned with a layer of bricks on the outside for aesthetic appeal.

Engineering bricks are used where strength, low water porosity or acid (flue gas) resistance are needed.

In the UK a redbrick university is one founded and built in the Victorian era. The term is used to refer to such institutions collectively to distinguish them from the older Oxbridge institutions, the post-war 'plate glass' universities, and the 'new' universities of the 1990s.

Colombian architect Rogelio Salmona was noted for his extensive use of red brick in his buildings and for using natural shapes like spirals, radial geometry and curves in his designs. Most buildings in Colombia are

LIMITATIONS OF BRICKS

Starting in the 20th century, the use of brickwork declined in some areas due to concerns with earthquakes. Earthquakes such as the San Francisco earthquake of 1906 and the 1933 Long Beach earthquake revealed the weaknesses of brick masonry in earthquake-prone areas. During seismic events, the mortar cracks and crumbles, and the bricks are no longer held together. Brick masonry with steel reinforcement, which helps hold the masonry together during earthquakes, was used to replace many of the unreinforced masonry buildings. Retrofitting older unreinforced masonry structures has been mandated in many jurisdictions.

PROPERTIES OF BRICKS

The following are the required properties of good bricks, figure 1.2 shows the bricks kept in order.

- **Colour**: Colour should be uniform and bright.
- **Shape**: Bricks should have plane faces. They should have sharp and true right angled corners.
- **Size**: Bricks should be of standard sizes as prescribed by codes.
- **Texture**: They should possess fine, dense and uniform texture. They should not possess fissures, cavities, loose grit and un-burnt lime.

- **Soundness**: When struck with hammer or with another brick, it should produce metallic sound.
- **Hardness:** Finger scratching should not produce any impression on the brick.
- **Strength:** Crushing strength of brick should not be less than 3.5 N/mm^2. A field test for strength is that when dropped from a height of 0.9 m to 1.0 mm on a hard ground, the brick should not break into pieces.
- **Water Absorption**: After immersing the brick in water for 24 hours, water absorption should not be more than 20% by weight. For class-I works this limit is 15%.
- **Efflorescence**: Bricks should not show white patches when soaked in water for 24 hours and then allowed to dry in shade. White patches are due to the presence of sulphate of calcium, magnesium and potassium. They keep the masonry permanently in damp and wet conditions.
- **Thermal Conductivity**: Bricks should have low thermal conductivity, so that buildings built with them are cool in summer and warm in winter.
- **Sound Insulation**: Heavier bricks are poor insulators of sound while light weight and hollow bricks provide good sound insulation.
- **Fire Resistance**: Fire resistance of bricks is usually good. In fact bricks are used to encase steel columns to protect them from fire.

. **Figure 1.2 Bricks**

DESCRIPTION OF FIRED CLAY BRICKS

GENERAL DESCRIPTION

Fired bricks are burned in a kiln which makes them durable. Modern, fired, clay bricks are formed in one of three processes – soft mud, dry press, or extruded process. The fired clay bricks are baked in kilns. The bricks are fired to high temperature for about ten days. This process is done in many different ways according to the utility of the bricks. In this project the brick is manufactured with partial replacement of Waste Glass Powder (WGP). The brick consists of clay, fused silica waste glass powder.

CLAY

Clay is a fine-grained natural rock or soil material that combines one or more clay minerals with traces of metal oxides and organic matter. Clays are plastic due to their water content and become hard, brittle and non–plastic upon drying or firing. Geologic clay deposits are mostly composed of phyllosilicate minerals containing variable amounts of water trapped in the mineral structure. Depending on the content of the soil, clay can appear in various colors, from white to dull gray or brown to a deep orange-red.

Clays are distinguished from other fine-grained soils by differences in size and mineralogy. Silts, which are fine-grained soils that do not include clay minerals, tend to have larger particle sizes than clays. There is, however, some overlap in particle size and other physical properties, and many naturally occurring deposits include both silts and clay. The distinction between silt and clay varies by discipline. Geologists and soil scientists usually consider the separation to occur at a particle size of 2 µm (clays being finer than silts), sedimentologists often use 4-5 µm, and colloid chemists use 1 µm. Geotechnical engineers distinguish between silts and clays based on the plasticity properties of the soil, as measured by the soils' Atterberg limits. ISO 14688 grades clay particles as being smaller than 2 µm and silt particles as being large.

FORMATION OF CLAY

Clay minerals typically form over long periods of time from the gradual chemical weathering of rocks, usually silicate-bearing, by low concentrations of carbonic acid and other diluted solvents. These solvents, usually acidic, migrate through the weathering rock after leaching through upper weathered layers. In addition to the weathering process, some clay minerals are formed through hydrothermal activity. There are two types of clay deposits, primary and secondary. Primary clays form as residual deposits in soil and remain at the site of formation. Secondary clays are clays that have been transported from their original location by water erosion and deposited in a new sedimentary deposit. Clay deposits are typically associated with very low energy depositional environments such as large lakes and marine basins.

GROUPING OF CLAY MINERALS

Depending on the academic source, there are three or four main groups of clays: kaolinite, montmorillonite-smectite, illite, and chlorite. Chlorites are not always considered a clay, sometimes being classified as a separate group within the phyllosilicates. There are approximately 30 different types of "pure" clays in these categories, but most "natural" clays are mixtures of these different types, along with other weathered minerals.

AS A BUILDING MATERIAL

Clay is one of the oldest building materials on Earth, among other ancient, naturally-occurring geologic materials such as stone and organic materials like wood. Between one-half and two-thirds of the world's population, in traditional societies as well as developed countries, still live or work in a building made with clay as an essential part of its load-bearing structure. Also a primary ingredient in many natural building techniques, clay is used to create adobe, cob, cordwood, and rammed earth structures and building elements such as wattle and daub, clay plaster, clay render case, clay floors and clay paint sand ceramic building material. Clay was used as a mortar in brick chimneys and stone walls where protected from water.

PROPERTIES OF CLAY MINERALS

- Clay is a fine grained soil particles having size less than 2 µm.
- The colour of clay soil is brown to a deep orange-red.
- It is sticky in nature while wet and hard when dry.

GLASS

Glass is a solid material that is normally lustrous and transparent in appearance and that shows great durability under exposure to the natural elements. These three properties—luster, transparency, and durability make glass a favoured material for such household objects as windowpanes, bottles, and light bulbs. However, neither any of these properties alone nor all of them together are sufficient or even necessary for a complete description of glass.

COMPOSITION OF REPRESENTATIVE OXIDE GLASSES

Table 1.1 Properties Of Glasses

		OXIDE INGREDIENT (percent by weight)				
Glass family	glass application	silica (SiO_2)	soda (Na_2O)	lime (CaO)	alumina (Al_2O_3)	magnesia (MgO)
Vitreous silica	furnace tubes, silicon melting crucibles	100.0	—	—	—	—
Soda-lime silicate	Window	72.0	14.2	10.0	0.6	2.5
	Container	74.0	15.3	5.4	1.0	3.7
	bulb and tube	73.3	16.0	5.2	1.3	3.5
	Tableware	74.0	18.0	7.5	0.5	—
Sodium borosilicate	chemical glassware	81.0	4.5	—	2.0	—
Lead-alkali silicate	lead "crystal"	59.0	2.0	—	0.4	—
	television funnel	54.0	6.0	3.0	2.0	2.0
Aluminosilicate	glass halogen lamp	57.0	0.01	10.0	16.0	7.0
	fibreglass "E"	52.9	—	17.4	14.5	4.4
Optical	"crown"	68.9	8.8	—	—	—
		oxide ingredient (percent by weight)				
Glass family	glass application	boron oxide	barium oxide	lead oxide	potassium oxide	zinc oxide

		(B_2O_3)	(BaO)	(PbO)	(K_2O)	(ZnO)
Vitreous silica	furnace tubes, silicon melting crucibles	—	—	—	—	—
Soda-lime silicate	Window	—	—	—	—	—
	Container	—	trace	—	0.6	—
	bulb and tube	—	—	—	0.6	—
	Tableware	—	—	—	—	—
Sodium borosilicate	chemical glassware	12.0	—	—	—	—
Lead-alkali silicate	lead "crystal"	—	—	25.0	12.0	1.5
	television funnel	—	—	23.0	8.0	—
Almino-silicate	glass halogen lamp	4.0	6.0	—	Trace	—
	fiberglass "E"	9.2	—	—	1.0	—
Optical	"crown"	10.1	2.8	—	8.4	1.0

PHYSICAL PROPERTIES

DENSITY

In the random atomic order of a glassy solid, the atoms are packed less densely than in a corresponding crystal, leaving larger interstitial spaces, or holes between atoms. These interstitial spaces collectively make up what is known as free volume, and they are responsible for the lower density of a glass as opposed to a crystal. For example, the density of silica glass is about 2 percent lower than that of its closest crystalline counterpart, the silica mineral low-cristobalite. The addition of alkali and lime, however, would cause the density of the glass to increase steadily as the network-modifying sodium and calcium ions filled the interstitial spaces. Thus, commercial soda-lime-silica glasses have a density greater than that of low-cristobalite. Density follows additivity behaviour closely.

ELASTICITY AND PLASTICITY

Because of the isotropic nature of glass, only two independent elastic moduli are normally measured: Young's modulus, which measures the ability of a solid to recover its original dimensions after being subjected to lengthwise tension or compression; and shear modulus, which measures its ability to recover from transverse stress. In oxide glasses, both Young's modulus and shear modulus do not strongly depend upon the chemical composition.

The hardness of glass is measured by a diamond micro-indenter. Application of this instrument to a glassy surface leaves clear evidence of plastic deformation—or a permanent change in dimension. Otherwise, plastic deformation of glass, which is generally observed in strength tests as the necking of a specimen placed under tension, is not observed; instead, glass failure is brittle—that is, the glass object fractures suddenly and completely. This behaviour can be explained by the atomic structure of a glassy solid. Since the atoms in molten glass are essentially frozen in their amorphous order upon cooling, they do not orient themselves into the sheets or planes that are typical of growing crystalline grains. The absence of such a growth pattern means that no grain boundaries arise between planes of different orientation, and therefore there are no barriers that might prevent defects such as cracks from extending quickly through the material. The absence of dislocations causes glass not to display ductility, the property of yielding and bending like metal.

WASTE GLASS CONTAINERS

The waste glass containers are the product of different utility of human need as shown in figure 3.1. In the total waste produced, waste glasses are produced is at a rate of 5-6% . The waste produced are in the form of glass containers, window glasses, glass vessels, picture tube of TV's and computers, mirrors, etc. These glasses are first broken into pieces and then let for grinding into powder in the form of sand.

When these glasses are reused in this form there won't be any need of dumping these waste any places. This can be reused to form strong and reliable brick.

Figure 1.3 Waste Glass Containers

REUSE OF WASTE GLASSES

The waste glasses materials are reused in many forms. The waste glass containers are cleaned and then reused further. The broken glass materials are crushed to form powder and melted and casted into new containers.

Figure 1.4 Waste Glasses Being Broken Into Pieces

The broken pieces of the windows are again crushed into small pieces and then it is used in recasting as window glasses, replaced in concrete and in other building materials. The figure 3.2 shows the breaking of waste glasses into small pieces for further crushing.

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WASTE GLASS POWDER

Waste Glass Powder is obtained from the different glasses which is formed by grinding. Grinding is done by the machines which is meant for grinding. The different glass vessels, window glasses, cool-drinks bottles, etc. These materials are taken to the industries for breaking into small pieces by manual activities. These broken pieces are then taken to the grinding industries for grinding purpose.

The grinded waste glass powder is then taken to the kiln for mixing with the clay mineral to form bricks. Figure shows the glass powder which is crushed in the mill.

Figure 1.5 Waste Glass Powder (WGP)

KILN

A kiln is a thermally insulated chamber, a type of oven, that produces temperature sufficient to complete some process, such as hardening, drying or chemical changes. Various industries and trades use kilns to harden object made of clay into bricks, pottery, tiles, etc. Various industries use various other kilns for calcinating ores, producing cement and many other materials.

TYPES OF KILN

In the broadest terms, there are two types of kiln: intermittent and continuous, both sharing the same basic characteristics of being an insulated box with a controlled inner temperature and atmosphere.

CONTINUOUS KILN

It is also called a tunnel kiln, is a long structure in which only the central portion is directly heated. From the cool entrance, ware is slowly transported through the kiln, and its temperature is increased steadily as it approaches the central, hottest part of the kiln. From there, it continues down the kiln and the surrounding temperature is reduced until it exits the kiln at near room temperature. A continuous kiln is energy-efficient, because heat given off during cooling is recycled to pre-heat the incoming ware. In some designs, the ware is left in one place, while the heating zone moves across it. Kilns in this type include:

- **Hoffmann kiln:** The Hoffmann kiln is a series of batch process kilns. Hoffmann kilns are the most common kiln used in production of bricks and some other ceramic products. Patented by German Friedrich Hoffmann for

Figure 1.6 Hoffmann Kiln

brick-making in 1858, it was later used for lime-burning, and was known as the Hoffmann continuous kiln.

Bull's Trench kiln: It is a continuous kiln generally oval in plan. It is 50 to 100 m. long and 1.5 -2.5 m deep below ground level. It is divided into 8-12 sections.

The dried bricks are stacked in the kiln with spaces in between them for circulation of hot gases and forming fuel galleries over which vertical shafts at 60-90 cm interval are provided to provide fuel. Bricks are stacked in section of about 3.60 m length having 20-30 thousands bricks in a section.

Figure 4.2 shows the over view of a Bulls Trench Kiln. When one section is being burnt, the hot gases are allowed to pass through the next section before escaping through chimney. It takes about 24 hours to burn the bricks in one section with temperature variations of 800 -1000.So in the kiln when one section is being unloaded ,the next two sections are left for cooling, one section shall be under fire and one under pre-heating , other one in smoking while last two sections are under loading. But it is difficult for kiln to work in the monsoon season. Its output is about 30000 bricks a day.

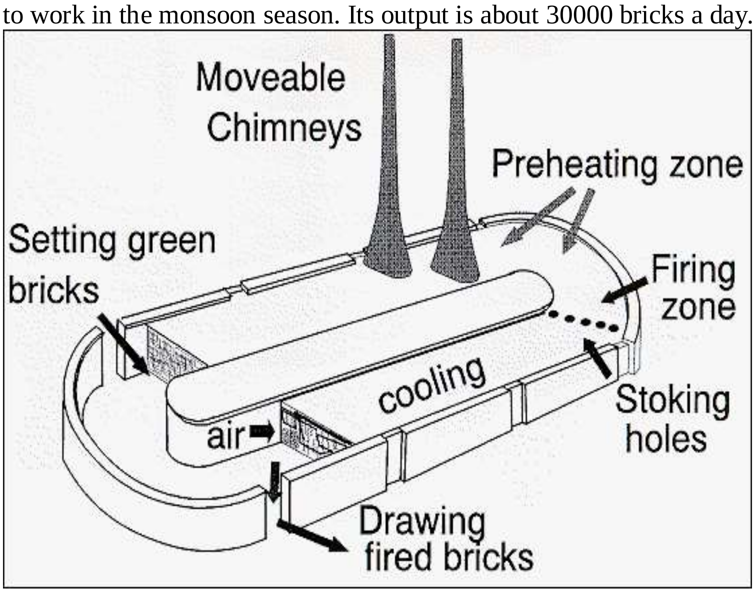

Figure 1.7 Bull's Trench Kiln

- **Roller kiln:** A special type of kiln, common in tableware and tile manufacture, is the roller-hearth kiln, in which ware placed on batts is carried through the kiln on rollers.

THE INTERMITTENT KILN

The ware to be fired is placed into the kiln. The kiln is closed, and the internal temperature increased according to a schedule. After the firing is completed, both the kiln and the ware are cooled . The ware is removed, the kiln is cleaned and the next cycle begins. Kilns in this type include:

Fig 1.8 Intermittent Kiln

- **Scove Kiln:** A kiln in which green bricks are stacked, enclosed with burned bricks that are then daubed with clay to reduce the loss of heat, and burned.
- **Clamp Kiln:** The clamp kiln is an improvement over the scove kiln in that the exterior walls are permanent, with openings at the bottom to permit firing of the tunnels.
- **Shuttle Kilns:** this is a car-bottom kiln with a door on one or both ends. Burners are positioned top and bottom on each side, creating a turbulent circular air flow. This type of kiln is generally a multi-car design and is used for processing white wares, technical ceramics and refractories in batches. Depending upon size and mass of ware, shuttle kilns may be equipped with car moving devices to transfer fired and unfired ware in and out of the kiln. Shuttle kilns can be either updraft or downdraft in design. A Shuttle Kiln derives its name from the fact that kiln cars can enter a shuttle kiln from either end of the kiln for processing, whereas a tunnel kiln has flow in only one direction.

USES OF KILNS

The earliest known kiln dates to around 6000 BC, and was found at the Yarim Tepe site in modern Iraq. Neolithic kilns were able to produce temperatures greater than 900 °C. Uses include:

- Annealing, fusing and deforming glass, or fusing metallic oxide paints to the surface of glass.
- Smelting ore to extract metal.
- Heating limestone with clay in the manufacture of Portland cement, the Cement kiln.
- Heating limestone to make quicklime or calcium oxide, the Lime kiln.
- Heating gypsum to make plaster of Paris.
- Formation of clay bricks.

TESTS CONDUCTED FOR FIRED CLAY BRICKS

GENERAL

It is necessary to check the quality of brick before using it in any construction activities. There are some field tests that we can conduct in the field in order to check the quality of bricks. These tests are as follows.

- Water Absorption
- Visual Inspection
- Efflorescence
- Dimension
- Hardness
- Soundness
- Structure

WATER ABSORPTION

5 bricks are taken and the bricks are weighed dry and the average dry weight of 5 bricks is calculated. Bricks are then immersed in water for a period of 24 hours. After 24 hours of immersion, bricks are weighed again and average of 5 bricks is calculated. The difference of the final average weight and initial average weight indicates the amount of water absorbed by the bricks. It should not in any case exceed 20percent of average weight of dry bricks.

VISUAL INSPECTION

In this test bricks are closely inspected for its shape. The bricks of good quality should be uniform in shape and should have truly rectangular shape with sharp edges.

EFFLORESCENCE

This test should be conducted in a well ventilated room. The brick is placed vertically in a dish 30 cm x 20 cm approximately in size with 2.5 cm immersed in distilled water. The whole water is allowed to be absorbed by the brick and evaporated through it. After the bricks appear dry, a similar quantity of water is placed in the dish, and the water is allowed to evaporate as before. The brick is to be examined after the second evaporation and reported as follows:

- Nil: When there is no perceptible deposit of salt
- Slight: When not more than 10% of the area of brick is covered with salt
- Moderate: When there is heavy deposit covering 50% of the area of the brick but unaccompanied by powdering or flaking of the surface.
- Heavy: When there is heavy deposit covering more than 50% of the area of the brick accompanied by powdering or flaking of the surface.
- Serious: When there is heavy deposit of salts accompanied by powdering and/or flaking of the surface and this deposition tends to increase in the repeated wetting of the specimen.

Bricks for general construction should not have more than slight to moderate efflorescence.

DIMENSIONAL TOLERANCE

Twenty bricks are selected at random to check measurement of length, width and height. These dimensions are to be measured in one or two lots of ten each as shown in figure. Variation in dimensions are allowed only within narrow limits, ±3% for class one and ±8% for other classes. Figure 5.1 portrays the dimension test on bricks.

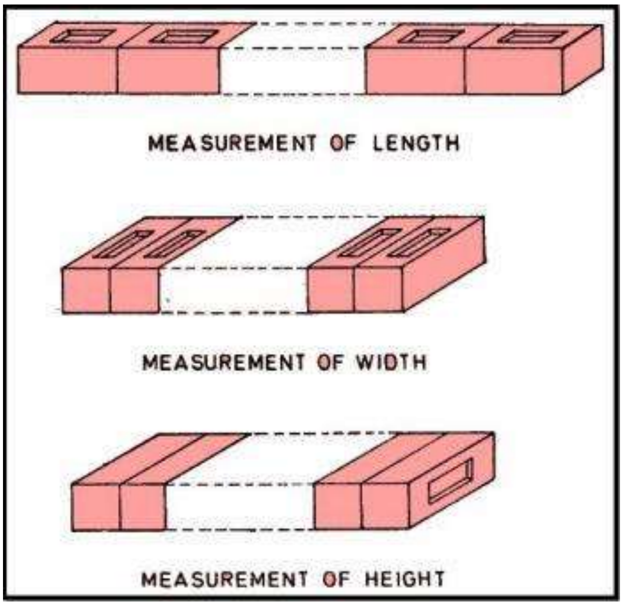

Figure 1.9 Dimension Test On Bricks

HARDNESS

In this test, a scratch is made on brick surface with the help of a finger nail. If no impression is left on the surface, brick is treated as to be sufficiently hard.

SOUNDNESS

Two bricks are taken, one in each hand, and they are struck with each other lightly. A brick of good quality should not break and a clear ringing sound should be produced.

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STRUCTURE

A brick is broken and its structure is examined. It should be homogeneous, compact and free from any defects such as holes, lumps etc.

COMPRESSION TEST

Compression stress induced in a body, when subjected to two equal and opposite pushes as a result of which there is a decrease in length of the body, is known as compressive stress. And the ratio of decrease in length to the original length is known as compressive strain. The compressive stress acts normal to the area and it pushes on the area. There are two types of compression testing machines, CTM manually operated , CTM single gauge and CTM with three gauge.

COMPRESSION TESTING MACHINE - MANUALLY OPERATED

In this type of machine the load is given manually to the surface of the specimen. These specimen can be a concrete block or brick. The load is applied manually and the applied load is noted. The CTM has a hydraulic means of applying load. The load is applied hydraulically and then the total load acting on the surface of the specimen increases till the specimen fails. The load is noted for further calculations. Figure 5.2 shows a typical CTM.

Figure 2.0 CTM-Manually Operated

COMPRESSION TESTING MACHINE- SINGLE GAUGE

This particular series of models have loading unit, pumping unit and load gauge with safety valve.

The pumping unit is placed at the right side of the machine. This unit has a powerful motor fixed with it and oil placed in it. The oil is pushed by motor powered by electricity.

Figure 2.1 CTM - Single Gauge

COMPRESSION TESTING MACHINE - THREE GAUGE

These machines are similar to the earlier series except that these systems have three gauges instead of a single gauge Other essential elements like power pack and loading unit remains the same as described earlier.

Figure2.2 CTM - Three Gauge

EXPERIMENTAL INVESTIGATION

PREPARATION OF SAMPLE

The sample to be tested is prepared according to the proportions. The samples of 25%, 30%, 35%, 40%, 45% and 50% replacement of waste glass powder is measured according to the proportions and mixed with the clay. The mixture is cured for twenty-four hours. After curing the mixture is then mixed with water to get the proper consistency. The bricks are molded and sun dried. After a seven days of sun drying the brick is fired in the continuous kiln.

Table1.2 Mix Design

S.No	Percentage of Replacement (%)	Weight of Clay (kg)	Weight of WGP (kg)	INITIALS ASSIGNED
1	25	15	5	1
2	30	14	6	2
3	35	13	7	3
4	40	12	8	4
5	45	11	9	5
6	50	10	10	6

The bricks are fired for seven days in the kiln. After this the fired clay-WGP bricks are taken for testing of the compressive stress and other brick properties. the mixing of materials and molding of bricks.

Figure 2.3 Mixing Of Materials

Figure 2.4 Brick Being Molded

COMPRESSION TEST

The compression test is done with the help of compression testing machine single gauge is used. The brick of size 190x90x90 mm is tested for compression stress.

TEST PROCEDURE

the testing of specimen for the failure load with CTM.

STEP 1: The specimen is placed on the platform by the face 190 x 90 mm.

STEP 2: After placing the specimen on the platform the oil pumping unit is closed and then the motor is started for loading on the brick.

STEP 3: The load is applied on the brick specimen. The reading on the dial gauge is noted for further calculations.

Figure 2.4 compressive strength

TESTS FOR THE PROPERTIES OF FIRED BRICK

WATER ABSORPTION

The brick samples are taken and then soaked in fresh portable water for a time period of 24 hours.

TABLE 1.4 WATER ABSORPTION OF FIRED BRICKS

Sl. No.	% Replacement	Dry Weight Of Sample Kg	Wet Weight Of Sample Kg	Water Absorption In %	Cumulative %	Specimen Name
1	0	3.012	3.330	9.5	9.1	N.B
		3.124	3.422	8.7		
2	25	3.066	3.43	10.6	10.55	1
		3.159	3.53	10.5		
3	30	3.067	3.43	10.58	10.59	2
		3.153	3.53	10.6		
4	35	3.154	3.5	9.8	10.91	3
		3.079	3.5	12.02		
5	40	3.091	3.5	11.6	11.55	4
		3.157	3.57	11.5		
6	45	3.15	3.54	11.01	11.51	5
		3.123	3.57	12.02		
7	50	3.128	3.6	13.11	12.29	6
		3.16	3.57	11.48		

VISUAL INSPECTION

The manufactured brick is visually inspected for the shape, size and colour.

Shape **-** The shape of the brick was found that it had sharp edges with fine finishing.

Size **-** The size of the brick is optimum.

colour **-** The colour of the brick is brown.

EFFLORESCENCE

STEP 1: A container of size 30x20 cm is taken.

STEP 2: The brick is placed vertically in the container.

STEP 3: Distilled water is taken in the container for a depth of 2.5 cm of brick. The container is kept in open space at 30^0C.

STEP 4: The water gets absorbed and evaporated. again the depth of 2.5 cm water is poured to evaporate the same way and inspected.

Inference

There is a Slight efflorescence (When not more than 10% of the area of brick is covered with salt).

HARDNESS

The brick sample is taken and scratched with the finger nail as shown in the figure 6.4.

Figure 2.5 Hardness test

Inference

The brick sample was scratched with the finger nail, there was no scratch mark on the brick.

SOUNDNESS

Two bricks was taken in the hand and it was stricken against each other.

Figure 2.6 Soundness test

Inference

After striking the bricks did not break and a clinging sound was obtained.

STRUCTURE TEST

A brick was taken randomly and broken into two pieces to check its structure for any flaws

Figure 2.7 Structure Test

Inference

There was no structural defect in the brick.

DIMENSIONAL TEST

Twenty bricks was taken in random and measured for its dimensional flaws.

Inference

There was only 3cm difference.

All the tests was conducted according to the IS codes. And few inferences were made.

RESULT AND DISCUISSIONS

The following are the results obtained from the compression test and the properties of the manufactured brick.

COMPRESSION TEST

Table1.5 Loads And Calculation:

Sl. No.	% replacement	Loads obtained KN						Cumulative Load KN	S. Name	Compressive Strength N/mm^2
1	0%	60	50	60	60	60	50	56	N.B	3.27
2	25%	80	110	110	100	110	80	98	1	5.7
3	30%	80	60	80	90	70	80	76	2	4.4
4	35%	50	70	70	80	70	70	68	3	3.9
5	40%	70	70	70	70	70	70	70	4	4.1
6	45%	60	50	50	60	40	40	52	5	3
7	50%	50	60	60	40	40	50	50	6	2.9

After the recording of the readings the stress due to the loading is calculated according to the formula;
Compressive stress = (Failure Load / Cross Sectional Area)(N/mm^2)

FIGURE FOR LOAD VS COMPRESSIVE STRENGTH

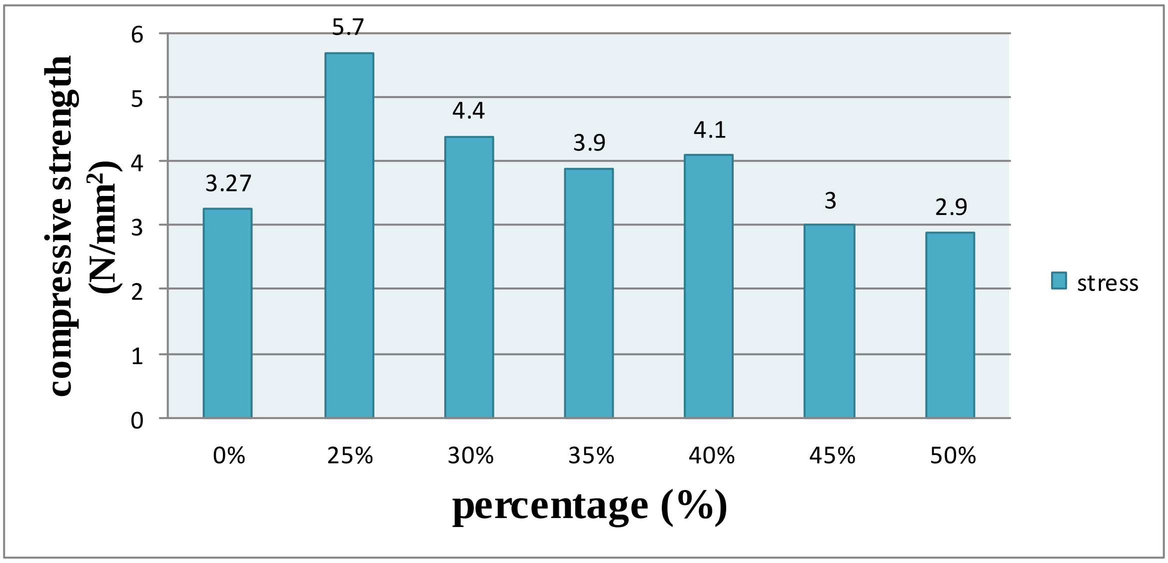

Figure 2.8 Load Vs Compressive Strength

FIGURE FOR LOAD VS PERCENTAGE REPLACEMENT

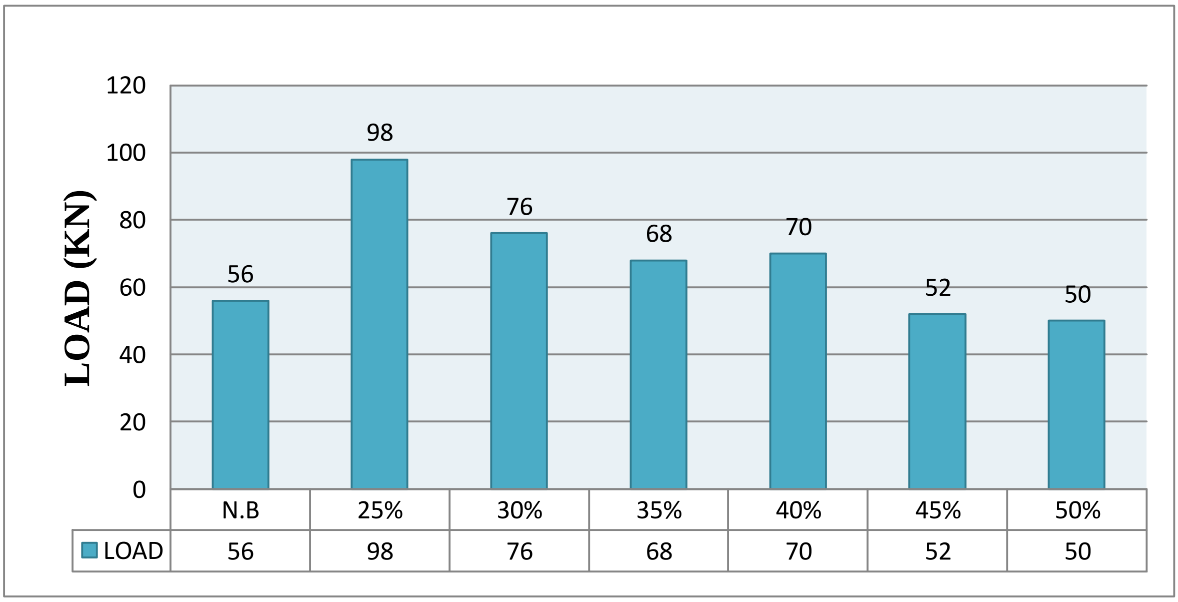

Figure 2.9 Load Vs Percentage Replacement

The compression testing was carried out for the manufactured brick with a compression testing machine with single gauge. A maximum load was obtained at a replacement of 40% with an increase compressive strength of 20.24% than the conventional clay brick. A constant loading was obtained in the replacement of 40% waste glass powder and the load obtained was 70 KN. The compressive strength obtained is 4.1 N/mm^2. For the conventional brick the load obtained was 56 KN and compressive strength was 3.27 N/mm^2.

The figures 7.1 and 7.2 shows the typical diagrams for load vs compressive strength and load vs percentage replacement.

RESULTS OF PHYSICAL PROPERTIES

The brick properties tested and found that there was low efflorescence and the soundness was upto the range and the hardness of the brick was high.

The visual inspection proved that there is sharp edges and the finishing is good. The water absorption is in the limit (i.e) 11.55. The limit of water absorption for the clay brick is 5%-20% of total weight of dried brick. The water absorption of the manufactured brick is 11.55% which is 21.21% greater than that of the normal brick.

The structure of the brick was tested and there was no defect in the brick such as packing of the materials were good, no holes were seen.

CONCLUSION

The following are the conclusion which is made from the experimental investigations done.

COMPRESSION TEST

The compression strength obtained by the brick which was manufactured by the replacement of 25% to 45% of waste glass powder gives load higher than that of the normal brick . But when the replacement is higher the compression strength gets decreased. This is concluded that at 40% replacement the compressive strength is constant (i.e) 4.1 N/mm^2 and the load obtained is 70 KN and the compression strength of specimen no 4 is 20.24% higher than the normal brick.

PHYSICAL PROPERTIES OF BRICK

Here the physical properties of the brick manufactured are all good.

- The water absorption test was conducted and the result obtained for the 40% replacement is 11.55%, this is 21.21% higher than that of the normal brick.
- The hardness of the brick is normal.
- The visual inspection shows that the brick has constant shape and size.
- The efflorescence of the brick is low and there is no change in its properties
- The dimension and the structure test has shown that the brick is hard and there is no defect in the brick.
- The soundness of the brick is also good.

Thus the replacement of the clay with the waste glass powder of 40% is considered optimum and it can be used in the construction works.

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