CONCEPT OF WASTE PLASTIC BRICK

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BOOKS ARCADE

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Website: www.booksarcade.co.in

Year of Publication 2023

International Standard Book Number-13: 978-81-19199-36-5

CONTENTS

CHAPTER 1

INTRODUCTION TO INCORPORATION OF PLASTIC WASTE IN BRICKS

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Brick: A brick is a type of block that is used to build masonry features including walls, pavements, and other elements. Although a "brick" is a block composed of dried clay, it is now widely used in colloquial language to refer to a variety of construction blocks that have undergone chemical curing. Bricks can be joined together using interlock, cement, or adhesives. There are many different classes, types, metals, and sizes of bricks that vary by location and historical period and are produced in vast quantities. By a similar name, a rectangular construction unit composed of the same materials is known as a block; however, a block is often bigger than a brick**.** Lightweight bricks, commonly referred to as lightweight blocks, are made from expanded clay aggregate. Fired bricks, sometimes referred to as artificial stone and used as building materials since around 4000 BC, are some of the strongest and most resilient. The history of mud bricks, also known as air-dried bricks, is longer than that of burnt bricks, and they also contain a mechanical binder like straw. To keep the bricks together and build a durable construction, numerous types of mortar may be used to lay the bricks. Brickwork is the collective term for the placement of bricks in courses and other patterns known as bonding.

Clay: Clay is a perfectly good natural soil component that contains clay minerals. Clays become flexible when wet because of the molecular water layer that surrounds the clay particles, but after drying or being fired, they turn hard, brittle, and non-plastic. The majority of clay minerals are white or light in colour, however naturally occurring clays can have a range of colours due to impurities, such as a reddish or brownish tint brought on by minute amounts of iron oxide. Clay is the earliest material used in ceramics. The advantages of clay were recognised by early humans, who utilised it to make pottery. Around 14,000 BC is when the earliest ceramic artefacts were initially discovered, and the earliest known writing was on clay tablets. Many modern industrial processes use clay, including those that create paper, cement, and chemical filters. The majority of people in the world live or work in structures that use clay as a primary component of their load-bearing structure, frequently baked into brick. A relatively common material is clay. The most prevalent sedimentary rock is shale, which is mostly composed of clay. Despite the fact that silts and clays coexist in many naturally occurring deposits, clays are distinct from other fine-grained soils due to distinctions in size and mineralogy. The particle sizes of silts, which are fine-grained soils devoid of clay minerals, are typically bigger than those of clays. Loam is a term for mixtures that contain sand, silt, and less than 40% clay. One of the biggest challenges in civil engineering is dealing with soils that include a lot of swelling clays, or "expansive clay," which are clay minerals that easily expand in volume as they absorb water [1], [2].

Manufactured sand: Manufactured sand is a substitute for river sand. In most parts of the world, there is a significant dearth of sufficient river sand because of the fast growing construction industry. Due to a lack of high-quality river sand used in construction, the use of artificial sand has increased. Additional considerations are M-price Sand's and accessibility for transit. It is simple to find local manufactured sand because strong granite rocks can be shattered to produce it, which lowers the cost of shipping from far-off river sand deposits. As a result, utilising artificial sand as a substitute for natural sand can save construction expenses. Utilizing M-Sand also has the advantages of being dust-free and having easily manageable sizes so that it meets the required grade for the task at hand [3].

Plastic: Plastics, a broad category of synthetic or semi-synthetic materials, are mostly made of polymers. Due to their fluidity, plastics may be moulded, extruded, or pressed into solid objects with a variety of forms. Its extensive use is due to its adaptability as well as a number of other attributes including portability, strength, flexibility, and affordable production costs. Typically, industrial human systems are used to create plastics. However, more contemporary industrial methods employ versions made from renewable resources, such as corn- or cotton-derived products. Most contemporary plastics are created using chemicals derived from fossil fuels, such natural gas or petroleum.In an effort to ease environmental concerns, the plastics sector promoted recycling near the end of the 20th century while continuing to produce virgin plastic and placing the burden for plastic pollution on the consumer. The big plastics-producing companies at the time had concerns about the economic viability of recycling, and those concerns have never been allayed. Plastic collection and recycling are usually ineffective due to the shortcomings of the contemporary complexity required in cleaning and sorting post-consumer plastics for effective reuse. Most of the plastic produced hasn't been recycled; instead, it's either ended up in landfills or is still polluting the environment as plastic garbage. Plastic pollution harms terrestrial ecosystems and creates garbage patches in every ocean, affecting every significant body of water on the planet. 14% of the plastic that has been burnt and less than 10% of the plastic that has been thrown away so far have both been recycled [4].

Cement (OPC53): For the current exploratory study, ordinary Portland cement of grade 53 was used. To produce high performance concrete, it's crucial to use high strength cements. To produce concrete of high quality, the choice of cement brand and kind is crucial. The type of cement affected how quickly it hydrated. Assuring that the chemical and mineral admixtures are equivalent to cement is also crucial. Ordinary Portland Cement (OPC) 53 Grade, which exceeds IS12269-1987 Grade specifications. It is made by mixing high-grade clinker (with a high C_3S content) with appropriate-quality gypsum in certain ratios. It is widely used and appropriate for quick construction, durable concrete, and cost-effective concrete mix designs due to its optimal particle size distribution, superior crystalline structure, and balanced phase composition, which are recognised for their high early strength and excellent ultimate strength [5].

Advantages:

- Superior quality guarantees significant cement consumption reductions.
- Early de-shuttering is facilitated by the development of extremely high compressive strength, which is also enhanced resistance to sulphate attack owing to lower C_3A concentration. Durable concrete is also feasible for cost-effective concrete mix designs.
- An increase in the lifespan of concrete structures is caused by low percentages of alkalis, chlorides, magnesia, and free lime.

Applications:

- Suitable for high-rise buildings, commercial and industrial structures, bridges and dams, highways, and runways, among other things.
- For all forms of RCC structures, concrete blocks, electric poles, paving stones, etc., it is advised [6].

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CHAPTER 2

BASICS OF BRICKS

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A brick is a sort of block used to construct masonry structures such as walls, pavements, and other features [1]. The term "brick" technically refers to a block made of dried clay, but it is now frequently used colloquially to refer to various construction blocks that have undergone chemical curing [2]. Bricks can be attached to one another by mortar, adhesives, or by interlocking. Bricks are typically made in large quantities at brickworks and come in a variety of classes, types, materials, and sizes that vary by place and time period [3]. A rectangle building unit made of identical materials is referred to as a block by a similar name, but a block is typically larger than a brick. Expanded clay aggregate is used to create lightweight bricks, also known as lightweight blocks [4]. Fired bricks, sometimes known as artificial stone and utilised as construction materials since around 4000 BC, are among the most durable and powerful. Mud bricks, sometimes referred to as air-dried bricks, have a longer history than burnt bricks and also include a mechanical binder like straw [5]. Bricks may be set in different types of mortar to keep the bricks together to create a sturdy structure. Bricks are laid in courses and multiple patterns known as bonds, collectively known as brickwork [6].

- **Types of brick**

Bricks are frequently employed in industrial, residential, and industrial construction because they are strong, long-lasting, and largely fireproof building materials. However, even for little masonry tasks like setting up an outdoor grill station, creating the supports for a garden bench, or simply installing a straightforward brick mailbox stand, the quality of brick can make all the difference.It's crucial to educate yourself about which type of brick is appropriate for your present or future projects and how to discern the difference between these seven varieties of brick as there are seven different types of brick that are frequently used to complete building projects.

Burnt Clay Bricks: Because they are the most prevalent sort of brick used in contemporary construction, burned clay bricks are sometimes referred to as common bricks. These bricks serve a wide range of uses in columns, walls, foundations, and more. The burnt clay bricks must be plastered or rendered with mortar when used to build walls in order to increase its durability, water resistance, and insulating properties. Based on quality, these bricks are divided into four separate class levels. Fourth-class bricks are over burnt, shaped erratically, and frequently crushed for use as aggregate. Third-class bricks are subpar building materials that ought to only be utilised for ad hoc edifices. Second-class bricks are of average quality, although they may contain hair-thin cracks and an uneven shape. They can have a rough surface. The top tier of burnt clay brick classifications is first-class brick. These premium bricks are uniform in shape, have a smooth surface, and are stronger and more durable.

Sun-Dried Clay Bricks: Some do-it-yourself might prefer to create these straightforward sun-dried clay bricks, which were utilised as early as 7,000 BC in southern Turkey and the vicinity of the modern-day Palestinian city of Jericho. The bricks are made of loamy soil, water, and straw, with the possibility of adding manure, clay, or sand to increase their tensile strength and prevent cracking the bricks from cracking. The mixture must be poured into moulds, which must then be set in an area where it won't rain so they can dry. When the bricks are dry, take them out of the mould and use them for short-term building tasks. The weakest and least resilient brick varieties, these should never be used as load-bearing supports or foundations, so DIYers should keep that in mind.

Cement bricks: These bricks, which are composed of solid concrete, are typically employed in internal brickwork or to construct facades and fences. A diversity of sizes and forms can be produced by manufacturers by pouring the concrete into unique moulds. These bricks could be available at a nearby hardware store or masonry supply for many folks.These concrete bricks can be made on-site by professionals using a conventional mixture of one part cement, two parts sand, and four parts aggregates. If concrete bricks will be used as foundations, choose stronger concrete bricks with a modified formula of one part cement, three parts sand, and six parts aggregates.

Engineering Blocks: Because of its great compressive strength and density, which are perfect characteristics for use as load-bearing materials, engineering bricks are a favourite among structural engineers, as their name suggests. In order to prevent cracking, crumbling, and leakage, engineering bricks also have a low absorption capacity, which means they can't take in a lot of moisture.In addition, the reduced porosity of these bricks increases their resistance to pollutants that could otherwise seep into masonry materials and corrode them from the inside. These bricks are frequently used to construct basement foundations, sewers, manholes, and retaining walls due to their exceptional strength, density, chemical resistance, and water resistance.

Lime Sand Bricks: Sand lime bricks are typically used for load-bearing walls in homes and multi-story buildings because of its great compressive strength and ability to be coloured to change the brick's final appearance. This kind of brick requires less mortar plaster, which cuts down on project expenses and saves time.Sand lime bricks are produced using pressure and heat to hasten the chemical reaction, culminating in bricks with a consistent, smooth finish that are perfect for building projects. Due to the difficulty that sound has in travelling through the dense sand lime composition, these bricks are also frequently used as acoustic insulation.

Fly ash bricks: Byproducts from coal-fired power stations called fly ash can include poisonous elements like chromium, mercury, arsenic, and antimony. Fly ash bricks are made from quicklime, cement, aluminium powder, gypsum, class C or class F fly ash, and they also contain water. They assist in recycling and minimising the quantity of harmful metals released into the environment. They were cast in a machine mould, giving them a more consistent shape than certain bricks. These bricks are a great substitute for burned clay bricks because of their strong compressive strength and low water absorption rate. Fly ash slabs can crack and break because the durability of fly ash bricks reduces as the brick's size increases. Because of this, fly ash bricks often come in only in small sizes.

Firebricks: Firebricks are the ideal material if the aim of the masonry project is to build a wall, framework, or structure that is extremely heat- and fire-resistant. These bricks, which are also referred to as refractory bricks, are created from fireclay, a unique kind of clay that mostly comprises silica and alumina. Firebricks can therefore endure temperatures of more than 3,000 degrees.Not only can firebricks withstand flames, but they can also withstand low temperatures and abrupt temperature swings between hot and cold. These bricks are generally used to construct wood-fired ovens, brick grills, fireplaces, chimneys, furnaces, and other high-heat structures.

Brick construction benefits:

When bricks are utilised in construction, there are numerous benefits.

- **Aesthetic:** Bricks come in a range of beautiful, organic hues and textures.
- **Aesthetic:** Bricks come in a range of beautiful, organic hues and textures.
- **Strength:** Bricks have a strong compressive strength.
- **Porosity:** The capacity to both release and absorb moisture aids in controlling indoor humidity and temperature.
- **Protection from fire:** Brick has an eight-hour maximum protection rating against fire when properly constructed.
- **Sound attenuation:** A brick wall can attenuate a variety of sounds, but on average, it can block 60–70 decibels of noise. Brick walls can also be built to attenuate over 200 decibels of sound.
- **Insulation:** Bricks are a superior thermal insulator to other materials since they absorb heat slowly and release it slowly as well. Bricks can save 50% more fuel than wood by assisting in the regulation and maintenance of a structure's stable internal temperatures.
- **Wear resistance:** Strong construction prevents wear and tear that is typical of other materials.

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CHAPTER 3

CLASSIFICATION OF CLAY

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Phyllosilicates of hydrous aluminum, such as kaolin ($Al_2Si_2O_5(OH)_4$), are a form of fine-grained natural soil material known as clay [1]. Due to the molecular water film that surrounds the clay particles, clays become malleable when wet, but after drying or fire, they become hard, brittle, and non-plastic [2]. The majority of clay minerals are white or light in color, however natural clays come in a variety of hues due to impurities, like a reddish or brownish hue brought on by trace levels of iron oxide. The first ceramic substance is clay. Clay's beneficial qualities were discovered by prehistoric humans, who used it to create pottery [3]. The first documented ceramic artefacts date to roughly 14,000 BC, and clay tablets were the first known form of writing [4]. Clay is employed in numerous contemporary industrial processes, including those that produce paper, cement, and chemical filters [5]. The majority of people in the world live or work in structures that use clay as a primary component of their load-bearing structure, frequently baked into brick.

A relatively common material is clay. The most prevalent sedimentary rock is shale, which is mostly composed of clay. Despite the fact that silts and clays coexist in many naturally occurring deposits, clays are distinct from other fine-grained soils due to distinctions in size and mineralogy. The particle sizes of silts, which are fine-grained soils devoid of clay minerals, are typically bigger than those of clays. Loam is a term for mixtures that contain sand, silt, and less than 40% clay. High swelling clay content soils pose a significant problem to civil engineers because they easily expand in volume when they absorb water [6].

Various Clay Brick Types

First Class Bricks (Grade A): Bricks of the highest quality are attractive, well-burnt in kilns, table-molded, rectangular, and have sharp edges. These bricks are incredibly hard bricks, and their surface is clear, smooth, and free of fissures.First-class bricks are typically utilised for superior or face work structures.

Second Class Bricks (Grade B): Second-class bricks are shaped slightly irregularly but are burned in clamps and ground moulds.Despite having a rough and spotty surface, these bricks are sturdy.These bricks are utilised in common structures and locations where a plaster layer is applied to the brick surface.

Third Class Bricks (Grade C): The third-class clay bricks are burned in a clamp after being moulded to the ground.These bricks have a soft texture and warped edges on the surface.These bricks are employed in unimportant and transient 4.Fourth Class Bricks (Grade D): structures, particularly in locations with light rainfall.

Fourth Class Bricks (Grade D): Fourth class bricks (Grade D) are preferred to burn bricks.These bricks are extremely hard despite having an uneven surface and a dark colour.These bricks are utilised for roads, flooring, and other structures.

Advantages:

- Clay brick is slightly acidic at high temperatures, and the Al_2O_3 content increases and improves the erosion resistance of alkaline slag. Compared to refractory brick, magnesia brick also has greater thermal stability.
- After the blast of reasonable quality clay dried vacuum impregnation process, phosphoric acid impregnated low-temperature fire of secondary products, and phosphoric acid impregnated phosphoric acid impregnated products, it can be utilised for masonry lining blast furnace body section.
- Brick made from natural resources is affordable, long-lasting, and employed in a variety of engineering projects because it provides fire protection, thermal insulation, acoustic insulation, moisture absorption, etc. Concrete aggregate is able to be used to create waste and scrap refractory bricks.
- Fly ash mortar Fly ash can be used as the primary raw material, together with coal gangue cement or clay refractory materials, to produce, dry, and roast ingredients that fully utilise industrial waste while using less fuel.

Disadvantages:

- Self-important, clay brick masonry wall material by weight is substantially heavier than other weight, so the building needs to withstand more weight, increasing construction costs.
- Due to clay's low porosity, it has poor sound insulation and little ability to reduce noise levels compared to other masonry materials like the increasingly popular concrete aerated block, which has a much larger porosity.
- Large-scale environmental harm has been caused by clay soil extraction by sintering, which has also caused damage to the soil and plants, which has led to soil erosion.

Clay Soil Applications:

Farming: Since clay soil's particles are naturally compact, they frequently lack the essential air that many plants need to survive. Thus, clay soil cannot be used to cultivate all types of plants. However, several plants, including apples, elm, ash, willow, tamarack, and many more, can be cultivated on clay soil. Due to the moisture in the clay soil, these plants can grow on their own.By incorporating additional gypsum and compost, clay soil can be used for diverse plant species. The nutrients and moisture in clay can then be used by these plants.

Construction: Due to its unique qualities, clay soil has been utilised for construction from the dawn of time. Clay can be transformed into adobe bricks by being either sun-dried or burned in a fire. To construct a house, the bricks are then put together along with mortar, another component composed of clay. Clay is a component of the building material cob, which is combined with some sand and straw to create structures like as benches, ovens, and buildings. Buildings constructed with adobe and cob are affordable, sturdy, incredibly long-lasting, sustainable, and have the potential to last for hundreds of years.

Ceramics: When water is added to ceramic clay, it can be shaped into a variety of shapes and structures. Clay soil turns into a flexible substance after being moistened. Clay soil is used by ceramicists for ceramics because of this. Clay is a valuable material that may be used to create pots, tubes, and other useful home items. Ceramic tiles that can be used for countertops, floors, and walls are also made from clay.

Pottery: Since ancient times, making pottery out of clay has been a source of income. Clay is combined with water in a dimly lit atmosphere that is not only moist but also humid, resulting in the formation of a thick mass. The dense bulk is subsequently shaped into pots and other various pottery-related shapes. The moulded structures are then placed inside an oven and heated to remove all the moisture, causing the structure to harden. Clay-based pottery making is a labor-intensive procedure that takes many hours to finish since the clay needs to be heated carefully in order to prevent the moisture from being removed too rapidly. Rapid moisture evaporation will cause cracks to form in the structures.

Medicinal: Clay soil minerals have been employed in folk medicine disciplines. It has been shown that the mineral components of clay soil aid in treating wound infections and upset stomachs. According to a study, clay soil contains minerals with antibacterial characteristics that can effectively destroy pathogenic bacteria that are resistant to antibiotics. Additionally, studies have demonstrated that clay minerals can be used to make low-cost medications to treat human infections.

Sculpture making: Because it is simple to mould and shape, clay soil is excellent for making sculptures. Additionally, it has the strength to bear the sculpture's weight. Clay soil is a terrific resource for artists on a budget because it is very reasonably priced.The Venus of Willendorf is among the most well-known instances of a sculpture created from clay soil. This ancient sculpture, which was discovered in, is estimated to have been made approximately 25,000 BCE Austria. The Venus of Willendorf is a little, naked woman with enormous breasts, disproportionate thighs, and bulging buttocks.

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CHAPTER 4

SPECIFICATIONS OF M SAND

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Artificial sand, also known as manufactured sand (M-Sand), is created by crushing hard stones into small, angular particles the size of sand, which are then cleaned and finely graded for use as construction aggregate [1]. It is a better option for construction than river sand [2].

Specifications of M Sand

- Because of its rough texture, cubicle and angular shape, and cubic shape, crushed sand is preferable for concrete.
- It does not contain silt because it is made by crushing aggregate, but occasionally it may contain some dust if screening is not done properly [3].
- There is no moisture present.
- When it is employed in concrete, concrete sets up somewhat more quickly.
- Concrete manufactured from M sand has greater compressive and flexural strengths than concrete made from natural sand [4].
- Because it is intentionally created, there are no large ingredients, and concrete has very little permeability when it is used in place of river sand.
- Crushed sand absorbs water between 2 and 4%.
- When compared to reverse sand, crushed sand has less slump.
- There are no marine products in it.
- Crushed sand has a bulk density of 1.75 gm/cm3.
- Depending on the parent rock, crushed sand has a specific gravity of 2.5 to 2.9.
- When employing crushed sand in concrete, bulkage adjustment during mix design is not necessary.
- Up to 10% of surface moisture can be removed from crushed sand.
- It is less contaminated than river sand.
- In comparison to natural sand, it has less of an adverse effect on the environment.
- It is produced in a controlled setting, giving it a higher quality than wild sand.
- Producing it nearby the construction site is an option. Lowering transportation costs and offering a guarantee of steady supply
- For RCC work, brickwork, and block work, it is strongly advised.
- More affordable than river sand. About 1000 cubic metres of crushed sand are produced each year.

Types of Manufactured Sand

- Concreting m sand, which is utilised in concrete
- M sand for plastering—used for wall and floor plastering [5].

- Masonry sand, often known as M sand, is used to lay bricks and blocks.

Manufactured Sand is used: An alternative to river sand is manufactured sand. Due to the rapidly expanding building sector, there is a severe lack of adequate river sand across the majority of the world. The usage of artificial sand has expanded as a result of the shortage of high-quality river sand used in building. The accessibility and expense of shipping M-Sand are other justifications for its use. Since manufactured sand can be made by crushing strong granite rocks, it can be easily found nearby, saving on transportation costs from distant river sand beds. As a result, using synthetic sand as an alternative building material can reduce construction costs. Another benefit of utilising M-Sand is that it may be used dust-free and that its sizes can be readily managed to ensure that it fits the necessary grading for the job at hand [6].

Advantages

- Greater flexural and compressive strength
- Greater flexural and compressive strength
- In comparison to natural sand and crusher dust, fineness modulus
- Has a denser particle packing and is free of contaminants including clay, dust, and silt.
- Can be produced close to construction sites, which lowers transportation costs and ensures a steady supply of the required quantity.
- It has the needed characteristics, such as the desired shape, smooth texture, consistency, and fineness gradation.
- M Sand has balanced physical and chemical characteristics and can tolerate any severe environmental conditions.
- It is able to fix concrete flaws such segregation, honeycombing, corrosion of the reinforcing steel, voids, capillary bleeding, and more.
- As it is shaped with a VSI shaping machine, it has a smooth surface texture and is devoid of elongated and flaky particles.
- The cubicle-shaped grains provide the concrete more toughness, strength, and longevity.
- The mortar has outstanding workability due to its cubical shape and correct gradation, which provides exceptional flexibility.
- M sand is used in concrete because it has an ideal initial and final setting time, eliminates voids, bleeding, and segregation.
- As it is easily accessible, the cost of transportation decreases.
- As environmental conservation becomes more important, M Sand is a good substitute for river sand.
- M Sand is more workable for concrete due to its higher Fineness Modulus Index.
- Free of clay and silt particles, which increase unit weight, decrease permeability, and improve abrasion resistance**.**

Disadvantages:

- The workability of concrete made using M sand is lower than that of naturally made concrete. But by utilising a water-reducing combination, this can be preserved (Superplastsizer).

- The river's sand has a flat texture and a rounded shape. In addition to being cubical and angular, M sand also has a rough texture from the cement paste used to patch gaps in concrete formed with river sand, which is less than M sand. Because of this, m sand requires more water and cement to achieve the desired workability, which raises the cost.
- M sand also has the disadvantage of producing more micro-fine particles during manufacture than natural sand does. Once more, this will reduce the concrete's strength and quality.
- River sand, which is readily available, contains moisture that is necessary for high-quality concrete. On the opposite side, moisture is only retained by M-Sand washed water.
- Due to its high demand, M-Sand has been known to be contaminated with unwanted substances such quarry muck.

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CHAPTER 5

CLASSIFICATION OF PLASTIC

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Through the polymerization or polycondensation process, natural resources including cellulose, natural gas, coal, crude oil and salt are utilised to create polymers. Natural, organic resources like cellulose, coal, natural gas, salt, and, of course, crude oil are used to make plastics. Crude oil must be treated in order to be utilised since it is a complicated combination made up of hundreds of distinct components. Before using crude oil to create polymers, it is first refined in an oil refinery. This divides the heavy oil into groups or lighter sections. Each percent is composed of several hydrocarbon chains, that are organic molecules made of carbon and hydrogen, but whose molecules vary in size and shape. One of them, naphtha, is essential for the creation of polymers fractions.

Polymerization and polycondensation, the two major methods for making plastics, both call for certain catalysts. Long polymer chains are created in a polymerization reactor by the fusion of monomers like ethylene or propylene. Depending on the many kinds of fundamental monomers utilised, each polymer has a unique structure, size, and set of properties [1], [2].

Types of Plastics:

Polyethylene Terephthalate (PET or PETE): One of the most popular polymers is PET, sometimes referred to as polyethylene terephthalate. It is frequently used in both textiles and food containers and is transparent, lightweight, and durable (polyester). Beverage bottles, food jars polyester clothing, and rope are among examples.

High-Density Polyethylene (HDPE): The three varieties of polyethylene—high-density, low-density, and linear low-density—are used to make the majority of plastics used across the world. Because of its resilience and resistance to moisture and chemicals, high-density polyethylene is perfect for use in pipes, boxes, and other building materials. Milk cartons, dolls, detergent bottles, buckets, park benches, and stiff pipes are a few examples.

Vinyl Chloride Polymer (PVC or Vinyl): This tough plastic is ideal for use in constructions since it can endure chemicals and the atmosphere. It is frequently utilised in high-tech applications like cables and cable since it doesn't carry electricity. Since it is pathogen-resistant, simple to sterilise, and offers single-use applications that prevent infections in healthcare, it is also often utilised in medical applications. As a result of its history of releasing poisons throughout the course of its whole existence, PVC is the material that presents the biggest damage to human health (eg: lead, dioxins, vinyl chloride). Examples include credit cards, breathing masks, IV fluid bags, animal and human toys, gutters, and plumbing lines.

Polyethylene Low Density (LDPE): An HDPE variant that is softer, clearer, and more malleable. Corrosion-resistant work surfaces, other items, and beverage carton liner frequently employ it. Other examples include bubble wrap, drinking cups, sandwich and bread bags, garbage bags, plastic wrap, and cling wrap.

Polypropylene (PP): One of the toughest plastics is this one. Given that it can withstand heat better than certain other materials, it is perfect for food packing and storage containers that are intended to trap or generate heat. Because of its flexibility, it may be slightly bent while still maintaining strength and shape over time. Examples include DVD/CD boxes, prescription bottles, hot meal container, packing tape, bottle caps, and prescription bottles.

Polystyrene (PS or Styrofoam): This stiff plastic, often known as Styrofoam, is widely utilised in the construction, food, and packaging sectors because of its low cost and excellent insulating properties. Polystyrene is regarded as a hazardous substance, much like PVC. The neurotoxic poison styrene, for example, may be released easily and eaten by humans. Styrene may then be easily absorbed by food. Examples include cups, takeout containers, packaging design for delivery and transportation, egg cartons, cutlery, and construction insulation [3].

The following processes are used to create the majority of plastic used today:

Extraction of raw materials: Materials that need to be processed after being extracted as raw materials include coal, crude oil, and natural gas, which are complex combinations of thousands of molecules [4].

Refining process: During the refining process, crude oil is transformed into a range of petroleum molecules, which are then processed to produce valuable chemicals like "monomers". When heated in a furnace, heavy petroleum in a distillation plant separates into lighter fractions as part of the purification process. A large volume of plastic can only be produced with one of them, naphtha. There are several approaches, such utilising gas.

Polymerisation: The conversion of lighter olefin gases (gasoline) like ethylene, propylene, and butylene (i.e., monomers) into heavier hydrocarbons is known as polymerization (polymers). This occurs as a result of the chemical linking of monomers to form chains.

There are two different ways that polymerization occurs:

Polymerization with addition: The reaction is known as addition polymerization when one monomer connects with the next to make a dimer, dimer unites with the next to produce a trimer, and so on. This is performed by including a catalyst, often a peroxide. Chain growth polymers are a method that adds monomer units one at a time. Polyethylene, Polystyrene, and Polyvinyl Chloride are common examples of addition polymers.

Polymerization by condensation: Condensation polymerization combines two or more different monomers by removing small molecules like water. A catalyst is also required for the reaction to occur between adjacent monomers. This is why step growth is called that when you, for instance, join one chain to another chain. Two well-known condensation polymer examples are polyester and nylon.

Manufacturing/Processing: Compounding is the technique of combining several component mixes to create plastic compositions. This is often accomplished using some sort of extruder, after which the mixture is pelletized. Then, using extrusion or another moulding method, these pellets are distorted into a completed or semi-finished product. The pellets are subsequently processed into plastic objects with distinctive patterns, forms, a range of sizes, and colours, as well as the proper quality in accordance with the predetermined processing parameters during compounding, which often takes place on a twin-screw extruder [5].

Using recycled plastic:

- Recycling plastic is very important. If they are not recycled when necessary, they combine with other chemicals or materials and become more difficult to recycle as well as a source of pollution.
- They cannot be broken down by microbial action and cannot be biodegraded.
- To stop this, it's essential to use biopolymers or naturally degradable polymers.

Plastic's characteristics:

- Easy to mould into a variety of sizes and shapes
- Reliable and ductile
- Poor heat and electricity conductors
- Prevent rust
- Chemically tough [6].

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CHAPTER 6

ROLE OF CEMENT IN CONSTRUCTION

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In construction, cement is a binder, or chemical ingredient, that binds other materials together by setting, hardening, and attaching to them. In most situations, rather than being used alone, cement is utilised to bind sand and gravel (aggregate). Concrete is formed from cement mixed with sand and gravel, while mortar for masonry is made from cement coupled with fine aggregate. Concrete, the most often used substance in existence, is the second most utilised resource in the world after water [1]. According to how effectively it sets in the presence of water, construction cement is normally inorganic, commonly made of lime or calcium silicate, and can be either hydraulic or non-hydraulic [2].

In hydraulic cements like Portland cement, the dry ingredients and water react chemically to set and become sticky. Although they are not highly water soluble and are created as a result of a chemical reaction, mineral hydrates are quite durable in water and resistant to chemical assault. As a result, the material is additionally protected against chemical assault and may be used to set in wet or submerged conditions. Ancient Romans used volcanic ash (pozzolana) and extra lime to create hydraulic cement via a chemical process (calcium oxide) [3].

Less commonly employed Cement that is not hydraulic does not set in moist or submerged conditions. Instead, it reacts with atmospheric carbon dioxide as it dries and sets. It is resistant to chemical assault after it has set. The word "cement" initially emerged in the term opus caementicium, which was used in ancient Rome to refer to a structure made of crushed rock and burnt lime that resembled contemporary concrete. The additives—volcanic ash and broken brick—that were combined with burnt lime to produce a hydraulic binder go by the names cementum, cementum, cement, and cement. Organic polymers are occasionally used as concrete cements in modern civilization.

Four billion tonnes are produced worldwide annually, with China producing roughly half of that total. With up to 2.8 billion tonnes of carbon dioxide emissions annually, the cement sector ranks third in the world behind only China and the United States. 4% of the world's CO_2 emissions are caused by the early calcination reaction in the manufacture of cement. Because the cement kiln in which the reaction takes place is normally fuelled by coal or petroleum coke because a brilliant flame is necessary to heat the kiln through radiant heat transfer, the total process is to blame for roughly 8% of global CO_2 emissions. Cement production is a significant cause of climate change as a result [4].

History of cements:

Since the beginning of human civilization, cement has been employed in many different ways, although being distinct from the refined product seen today. In the middle ages, the Romans developed the first hydraulic cement, which they manufactured from volcanic ashes, broken pottery, burned gypsum, and hydrated lime. Roman cement, which gained prominence but was finally supplanted by Portland cement in the 1850s, was the product of continuing cement research up to the 18thcentury, when James Parker obtained the patent for it. In the 19thcentury, Frenchman Louis Vicat laid the foundation for Portland cement's chemical composition, while Russian author EgorCheliev wrote essays on the manufacturing procedures, uses, and advantages of cement. The "new" Portland cement, developed by William Aspdin, was rapidly in very high demand. Portland cement was introduced to the English market by Joseph Aspdin. The actual creator of Portland cement is said to be Isaac Charles Johnson, who made a substantial contribution by outlining a process for producing meso-Portland cement in the kiln.

In the nineteenth century, Rosendale cement was discovered in New York. Despite the fact that it was initially rather popular because to its stiffness, due to its lengthy drying period, market demand rapidly declined, and Portland cement once again became the material of choice. However, a new combination of Rosendale-Portland cement was created by Catskill Aqueduct that is now often used to construct roads and bridges since it is incredibly durable and cures faster. The cement used today has undergone extensive research, experimentation, and development in order to produce strong concretes for roads and highways, hydraulic mortars that endure sea water, and stucco for humid environments. There are several different types of modern cement, most of which are classified as Portland cement or mixtures, including pozzolan cement, slag-lime cement, fly-ash cement, and cement from blast furnaces [5].

Uses of Cement:

Although cement can be used on its own, it is typically combined with neutral material known as aggregate in mortar and concrete. Mortar is made by combining cement with sand or crushed stone that must be smaller than 5 mm (0.2 inch). Cement, sand, or another fine aggregate are mixed with a coarse aggregate that is typically up to 19 to 25 mm (0.75 to 1 inch) in size. However, when concrete is deposited in massive masses, like dams, the coarse aggregate can be as large as 150 mm (6 inches). Mortars are used as surface treatments or to bind bricks, blocks, and stone together in constructions. Concrete is employed in a wide range of construction projects. Road bases are made of dirt and portland cement mixtures. Bricks, tiles, shingles, pipes, beams, railroad ties, and other extruded goods are all made with Portland cement. The goods are supplied ready for installation after being factory-prefabricated. Concrete is the most commonly used construction material in the world today, hence cement production is very common.

Specifications of Cement

Cement's fineness: The fineness of cement is determined by the cement's particle size. In the final phase of the cement production process, the clinker is ground to the requisite fineness for excellent cement. The fineness of cement is crucial because cement hydration rate and cement particle size are closely correlated.

Concrete soundness: The capacity of cement to resist shrinking after hardening is referred to as soundness. After setting, high-quality cement maintains its volume without experiencing delayed expansion brought on by too much free lime and magnesia.

Composition of Cement: Consistency is what allows cement paste to flow.Vicat Test is used to measure it. Vicat Test Cement Paste is taken in the Vicat Apparatus and has a typical consistency. The device' plunger is lowered until it makes contact with the cement's top surface. Depending on the consistency, the plunger will only go through the cement so far. When the plunger reaches a depth of 10 mm in cement, it is deemed to have a normal consistency.

Cement's Strength: Compressive, tensile, and flexural cement strengths are all measured. The ratio of fine aggregate to cement, curing circumstances, size and form of the specimen, moulding and mixing techniques, loading conditions, and age are only a few of the variables that determine strength.

Compression power: The most typical strength test is this one. It is necessary to apply a compressive load on a test specimen (50 mm) till failure. Between 20 and 80 seconds must pass throughout the loading process.

Cement setting time: When water is added, cement sets and becomes harder. The fineness of the cement, the cement-to-water ratio, the chemical composition, and the presence of admixtures may all affect how long it takes for the cement to set. The initial setting time and ultimate setting time of cement used in building shouldn't be too low or high.

Misfire in Ignition: Weight loss occurs when a cement sample is heated between 900 and 1000°C (i.e., until a constant weight is attained). This weight loss while heating is accounted for as ignition loss. Pre-hydration and carbonation may result through improper, extended storage or adulteration during transit or transfer; both of these conditions may be shown by an increase in the loss of ignition [6], [7].

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CHAPTER 7

INTRODUCTION TO GEOPOLYMER MASONRY BRICK PRODUCTION

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Today, finding recycling alternatives for various industrial wastes or by-products is a prevalent activity, driven in part by regulation but also in an effort to reduce disposal costs and prevent land and water pollution [1]. Geo-polymers are inorganic materials having a monocrystalline (amorphous) structure that are generally ceramic and made of covalently bonded aluminium silicate. Any substance that comprises amorphous silica and alumina oxides may be used as a binding agent in geo-polymer mortar [2]. The need for basic necessities is increased due to overpopulation, which leads to building activity and the development of industrial trash. Utilizing materials for a housing facility is a part of construction activity [3]. It results in the usage of building materials like bricks and blocks, which need resources like cement, clay, sand, etc. These conventional materials are being used, thus replacement methods that will ensure their availability in the future should be taken into consideration. Industrial wastes like fly ash, ggbs, and gbs are substituted for these conventional materials. Fly ash, red mud, and Solution (aqueous solution) are referred to as alkaline liquids for the sake of the current inquiry since they are the reaction products of raw materials containing alumina silicate. The wastes that include alumina and silicate and that easily react with alkaline solution are what give rise to geo polymerization, a novel environmentally friendly industrial process. India is the world's second-largest brick manufacturer. According to estimates, India has about 1, 45,000 brick kilns that produce more than 236 billion bricks annually. As a result, the manufacture of bricks uses a significant amount of rich soil, directly reducing the land's ability to support agriculture. The introduction of a clay substitute is thus necessary [4].

Industrial Waste

Around the globe, there are millions of factories, mills, industries, mining facilities, etc. These sectors manufacture finished commodities for customers using raw resources. But certain materials are rendered unusable throughout the production process.Metals, paints, sandblasting, slag, ash, radioactive wastes, and other materials are some examples of industrial wastes. We will go through various industrial wastes and how to dispose of them in this post a significant industrial waste from the refinement of alumina, as well as fly ash, another industrial waste from the burning of coal, using relatively little non-waste resources. To evaluate their effects on the mechanical characteristics of the final geo-polymer products, several synthesis parameters, such as the ratio of red mud to fly ash, the amount of sodium silicate solution throughout the solid combination (red mud and fly ash), and the kind of sodium silicate solution, were changed. Unconfined compression testing findings reveal that these variables have a big impact on the mechanical characteristics of the synthetic geo-polymers [5], [6]. The unconfined compressive strength varies from 3 to 13 MPa dependent on the synthesis conditions, and the high values are equivalent to certain forms of Portland cement. The structure of the final products, as determined by X-ray diffraction analysis, supported the geo-polymerization process. The results imply that the two main industrial wastes, red mud and fly ash, may be recycled to create geo-polymers that might take the place of Portland cement and so be employed in the building of civil infrastructure. In the 18^{th}century, the industrial revolution turned rural regions into industrialized and urban ones. But industrial waste, a significant issue and danger to our environment, came along with it. Industrial waste is the garbage created by industrial activity. Numerous sources, including businesses, mills, mines, power plants, etc., create a lot of garbage. It generates solid, liquid, and gaseous wastes of three different types, including chemicals, charcoal, industrial effluent, carbon dioxide, sulphur dioxide, and others. To protect both ourselves and our environment, it has to be effectively decomposed or controlled. Industrial waste is any trash produced by businesses or industrial activities. In addition to several dangerous gases, it also contains chemicals, garbage, oils, solvents, dirt, and stones. These aren't properly treated before being thrown in the ocean, rivers, or on land. So, it has grown to be a significant cause of environmental contamination.

Types of industrial wastes

Industrial waste can be divided into following two types-Biodegradable industrial waste Non-biodegradable industrial waste

Biodegradable Wastes

Biodegradable wastes are wastes that may break down into less toxic chemicals via the activity of microorganisms. Biodegradable industrial wastes are primarily produced by several industries, including those in the paper, food, sugar, and wool sectors, among others. These wastes could be readily and affordably managed.

Non-biodegradable Wastes

Waste that is not biodegradable cannot be further broken down by microorganisms. These materials are the main source of poisons in landfills. Non-biodegradable wastes include chemicals, aluminum, plastics, paints, rubber, and many more. Without causing any harm, these materials may be used as landfills for a very long time. Metal and plastic pollutants seep into the ground and contaminate the soil and the water supplies. Industries that manufacture cleaning products like detergent, phenols, etc., as well as those that produce coal or are in decline, among others, generate a lot of non-biodegradable industrial waste. These wastes are challenging to handle and very hazardous in nature.

Effects of Industrial Waste

Industrial waste is very hazardous to both the environment and humans. A few effects are listed, including the fact that the amount of liquid industrial waste that is dumped into the ocean is extremely unsafe for marine ecosystems. Industries generate a variety of air pollution-causing gases, including nitrogen oxides, carbon dioxide, and sulphur dioxide. Nitrates and phosphates are present in industrial effluent and often contribute to eutrophication. In general, the air near factories is extremely polluted and causes ailments of the skin, eyes, nose, throat, and lungs. Industries consume a lot of water, and they also discharge a lot of effluent that is filled with dangerous heavy metals and toxic chemicals. This pollution eventually contaminates our environment and health by contaminating natural water sources. It is a significant contributor to global warming. The beneficial bacteria and other organisms found in soil are destroyed by industrial effluent. Some industries may contribute to noise pollution. Industries and industrial wastes are ruining many species' natural habitats and are to blame for the extinction of animals. The only way to avoid the impacts of industrial wastes is through proper disposal and treatment. Local authorities or governments are not responsible for managing industrial solid waste. Industries that produce these solid wastes must handle them on their own. Additionally, they must get permission from the board that regulates pollution. In order to manage industrial waste, several techniques and strategies are used. Although all procedures follow some common fundamental stages.

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CHAPTER 8

INDUSTRIAL SOLID WASTE

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Industrial solid wastes may also include trash, the kind of rubbish that contains things like electrical equipment, abandoned cars, medical equipment, and more. They cause long-term environmental contamination problems. As a result, efforts must be taken to reduce pollution that results from trash disposal by turning these undesired wastes into raw materials that may be used for a variety of purposes [1]. There are still some plans in place for how big and medium-sized enterprises will get rid of their solid waste [2]. Small-scale enterprises, however, lack such planning. Such industrial wastes are mixed up with home garbage and dumped in various local bodies. Municipal organizations thus require a good plan for arranging the appropriate collection and disposal of commercial solid waste.

Industrial Waste Water Pollution

The majority of wastes, whether they are residential or industrial, degrade into water bodies, rendering them unsuitable for human consumption [3]. In addition to the oil, gas, mining, and chemical manufacturing sectors, other businesses that create industrial waste water include those that process food and beverages, chemicals, power stations, fabric, leather, and automobiles. The manufacturers dispose of both natural and inorganic waste, which should be appropriately handled before being released into the rivers, seas, etc. Many different sectors employ procedures like filter presses, together with filter plates and filter cloth, to treat municipal wastewater and effluent wastewater. These industrial filter press technologies may reduce environmental effect and aid in the reuse and conservation of our limited water supplies by stopping the flow of waste materials into water bodies, including plastics, metals, and other materials.

Industrial Waste Gases

Industrial waste gases are dangerous chemicals that are emitted into the environment by companies and include carbon monoxide, nitrogen, and sulphur oxides among many others [4]. Use of outmoded technology in enterprises to save expenses of manufacturing is one of the many reasons of such waste gases [5]. But a lot of waste gases are produced by these antiquated methods. A significant amount of hazardous fumes are produced when fuel is burned inefficiently. Another significant factor in the formation of waste gas is the unforeseen consumption of raw resources. Many of them include substances like sulphur, lead, and other things, and when they burn, they create dangerous fumes.

Reduce Industrial Waste Gases Pollution

The usage of fossil fuels like coal, oil and gas, etc. should be avoided in order to prevent industrial effluents gases since they release dangerous gases when burned. Renewable energy sources including solar energy, wind energy, and hydropower should be used by industries. The pollutants should be broken down into their component parts and then liberated as safe gases using catalytic oxidizers. Finally, businesses should make an effort to produce things from non-toxic raw materials and halt pollution solely at the source. Industrial wastes may or may not be dangerous. They are just the cause of a number of pollutions, including soil, water, and air contamination. Thus, it is crucial that they be properly disposed of. The main issue is with non-biodegradable wastes since they are more difficult to degrade than biodegradable wastes. To dispose of garbage properly and recycle it, we need better industrial wastewater treatment procedures. But above all else, reducing industry waste is the greatest way to solve this issue.

Characterization of Raw Material

The widespread use of cement-based composites is presently under fire for contributing significantly to the creation of carbon dioxide and the depletion of natural resources. Along with increasing health hazards for people, cement manufacturing poses environmental problems. Utilizing alkali-activated binders, also known as geopolymers, which represent a different kind of binder with desirable durability features and less detrimental environmental consequences, is one way to address the difficulties listed above. Recycling different trash or byproducts and using them into building materials is a chance for waste management and environmental impact reduction. As a result, several investigations on geopolymers were conducted for fly ash and blast furnace slag. The widespread use of cement-based composites is presently under fire for contributing significantly to the creation of carbon dioxide and the depletion of natural resources. Along with increasing health hazards for people, cement manufacturing poses environmental problems. Utilizing alkali-activated binders, also known as geopolymers, which represent a different kind of binder with desirable durability features and less detrimental environmental consequences, is one way to address the difficulties listed above. Recycling different trash or by-products and using them into building materials is a chance for waste management and environmental impact reduction. As a result, several investigations on geopolymers were conducted for fly granulated blast-furnace slag. Designing a geopolymer mix necessitates the use of adequate alkaline activators and curing conditions. Numerous investigations regarding the ideal silicate modulus of a activator came to the conclusion that this ratio, together with molar ratios in certain precursors, is needed to offer a thorough and useful output for individuals working [6].

The compressive strength may significantly increase as a result of the curing period's temperature and duration being adjusted. In-depth knowledge of a material's curing, the makeup of its precursors, or the quantity of activators used is crucial for more than just functional evaluation; it's also necessary for the assessment of environmental conditions. A paradigm on the unsuitability of low-amorphous predecessors for geo-polymerization was disproved by the thorough study on high-amorphous precursors, and the advantages of employing waste brickwork for geo-polymerization was made clear. This tendency supports the recommendation to focus on studying locally accessible materials despite their lesser responsiveness when compared to other resources. The relationship between the imposed silicate modulus, the impact of higher temperature crosslinking on reaction kinetics, the formation of chemical bonds, or the products of the reaction is not, however, well understood. These ideas were mirrored in a number of research that examined SiO2/Al2O3 molar proportions to explain the production of geopolymers and improve mechanical performance. Geopolymercentered on powdered bricks reaction kinetics, microstructure, and composition are examined while accounting for differences in the alkaline activator's silicate modulus but also curing conditions. The investigations make use of a broad range of characterization techniques, such as scanning electron microscopy, isothermal calorimetry, mercury intrusion porosimetry, X-ray diffraction, and thermogravimetric analysis, allowing for the identification of the effects of key mix design and curing specifications on the progression of chemical reactions during the solidification process as well as the associated increase of reaction products.

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CHAPTER 9

GEOPOLYMER MASONRY BRICK PRODUCTION

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Cement consumption has grown as a result of increasing infrastructure development and building activity both domestically and abroad. Due to the large-scale cement manufacture that has resulted from this, CO_2 emissions have increased, severely polluting the environment. Thus, the hunt for substitute construction materials with a reduced carbon footprint is ongoing. Masonry bricks composed of geo-polymers could provide us a chance to do this. Geo-polymers are synthetic nonorganic polymer materials that are predominantly made of alumina or silicate, either naturally occurring or as a by-product from fly ash. These geo-polymers have excellent material characteristics, including resistance to sulphide, strong acid resistance, fire resistance in ceramics, and high compressive strength in structures. Being the second-largest brick manufacturer in the world, India runs over 2 lakh kilns annually, turning out about 300 billion masonry blocks. And a significant amount of clay is utilised in this masonry brick making process. Clay is created by scrubbing the topsoil, which has caused soil erosion [1], [2]. The supply of high-quality clay also seems to be an issue during monsoon and rainy seasons, which has a significant impact on the quality and output of masonry bricks. Therefore, it is crucial to provide alternatives to traditional masonry bricks now. Fly ash and phosphogypsum-based masonry bricks seem to be a promising substitute. Additionally, burning bricks in kilns, ovens, and other devices uses a lot of electrical and thermal energy. If we could also cut down on the use of this energy, it would be incredibly helpful. In order to achieve this, an effort has been made to create air-dried masonry bricks composed of phosphogypsum and fly ash that have strong structural and other characteristics comparable to those of traditional masonry brick.

Bricks have been utilised as building materials since 14,000 BC and are still often employed in modern construction. Clay bricks are the most common masonry units used in building because of their distinctive strength, durability, and bonding with mortar. Bricks are often manufactured from clay soil. Clay bricks must be heated inside a kiln to temperatures of roughly 1400 degrees Celsius in order to be manufactured. This necessitates burning a substantial quantity of fuel, such as wood, coal, biomass, etc., in the kiln, which has major negative effects on the air quality. Due to the release of harmful compounds into the environment, brick kilns offer substantial health risks to the neighboring population. For a sustainable development, bricks must be produced in a method that is energy efficient. Bricks may be made at lower temperatures, at 600 degrees Celsius, using river sand as a filling component. For continued growth, river sand's depletion must be managed since it is a non-renewable resource. The over use of this non-renewable resource will cause soil erosion, have an impact on the water's quality and environment, and degrade local livelihoods. Because of advancements in the building sector, the demand for river sand and gravel is likewise rising and spreading unchecked.

Currently, mining is the most important economic activity in the majority of developing nations. As a result, it is necessary to find a replacement material for river sand in a number of applications. On the other side, there have been several issues with how thermal power plants and steel industries' byproducts, flash and ground granulated blast furnace slag (GGBS), have been disposed of. Since these goods have an impact on the ecology, they cannot be dumped in water or on land. Therefore, it is necessary to handle their disposal by using them to create building blocks. Due to its eco-friendliness, geopolymer brick manufacturing has gained attention recently. Due to its assistance in lowering the emissions of carbon dioxide from the production of cement and solving the issue of fly ash but also GGBS disposal, geopolymer technology is seen as being environmentally beneficial. It has been discovered that the technical and mechanical qualities of geopolymer concrete are superior to those of cement concrete and are produced by the alkaline activation of aluminium silicate source material. The properties of Geopolymer bricks vary greatly depending on the percentages of raw materials, ratio of highly alkaline to be used, as well as the molarity of sodium hydroxide solution. Geopolymer is however discovered to possess fair properties even when under elevated temperatures, replacing cement concrete in all different aspects of the construction industry. This study proposes a number of experiments to improve the numerous variables that affect the strength, hardening, and durability characteristics of Geopolymer bricks. This innovation opens the door for creating eco-friendly, energy-efficient bricks.

Red Mud

Red mud, also known as bauxite residue, is a kind of industrial waste created during the Bayer process used to convert bauxite into alumina. Iron oxides, which give it its red colour, are among the many oxide compounds that make up this substance. The Bayer method accounts for over 95% of the world's alumina production; for every tonne that alumina produced, 1 to 1.5 tonnes of red mud also are created. In 2020, there were more than 133 million tonnes of alumina produced annually, producing more than 175 million tonnes produced red mud. Due to its quick rate of synthesis and high alkalinity, the substance poses a serious environmental risk if improperly kept. As a consequence, a lot of work is put into developing better strategies for handling trash, such as waste valorization, in order to produce components suitable for cement and concrete [3].

Production of red mud

Red mud is a by-product of the Haber-Bosch process, which is the main technique for processing bauxite to produce alumina. The resultant alumina is used as the primary raw material in the Hall-Héroult process, which produces aluminium. Red mud is often produced in bauxite plants one to two times more frequently than alumina. This ratio is influenced by the extraction circumstances and the kind of bauxite employed during the refining process. The Bayer method is used by more than 60 industrial facilities worldwide to create alumina from bauxite ore. Bauxite ore is extracted from the ground, often in open-pit mines, and then sent to an alumina refinery further processing. Under circumstances of high temperature and pressure, sodium hydroxide is used to extract the alumina [4]–[6]. A sodium aluminate solution is created by removing the insoluble portion of the bauxite (the residual), after which it is seeded with only an aluminium hydroxide crystals and allowed to cool, causing the remaining aluminium hydroxide to precipitated from the solution. Whereas the remaining aluminium hydroxide was calcined (heated) at over 1000 °C using rotary kilns or fluid flash calciners to generate aluminium oxide, a portion of it is utilised to seed the next batch (alumina). Bauxite is often utilised with an alumina percentage of between 42 and 50%, however ores with a broad range of alumina levels may be used as well. Gibbsite, boehmite, or diaspore are possible forms of the aluminium compound ($Al(OH)_3$). Iron oxide, which is always present in large concentrations in the residue and gives the finished product its distinctive red color. The residue contains a minor quantity of sodium hydroxide that was employed in the process, which causes the substance to have a high pH/alkalinity, often >12. To increase the efficiency of the Bayer Process and lower production costs, several phases throughout the solid/liquid divorce process are added to recycle quite so much sodium hydroxide has practicable from the residue returned into the Bayer Process. Additionally, by reducing the residue's ultimate alkalinity, this makes it simpler and safer to store and handle.

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CHAPTER 10

THE RED MUD PROBLEM IN ALUMINIUM PRODUCTION

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Bauxite is the name of the mineral that is used to create aluminium. It also includes several additional gangue (tramp) minerals, some of which are extremely rare and valuable and others of which are quite hazardous [1],[2]. It contains alumina minerals including alumino-silicate clays as well. The Bayer method exposes the bauxite ore to very hot caustic soda (chemically: sodium hydroxide) in order to dissolve the insoluble components of the bauxite [3]. The Bayer method yields red mud as an unwanted by-product in addition to the highly desired Al oxide from of the bauxite ore. Its high alkalinity and poisonous heavy metal content make it exceedingly caustic and harmful to soil and biological forms, making disposal of it extremely difficult. One of the main issues with aluminium production is the trash, which is both valuable and poisonous. More than 130 million tonnes of smelter and chemical grade alumina are produced annually, mostly using the Bayer process. Between 1 and 1.5 tonnes of bauxite residue are produced per tonne of aluminium globally. As a result, bauxite residue is generated in excess of 150 million tonnes annually, with more than 6 million tonnes produced in Europe alone [4], [5]. The bulk of this dangerous waste, which includes some valuable materials as well is dumped in landfills. More than 100 Bayer facilities are running across the world. More than 3500 million tonnes of the bauxite residue are now in storage. Red mud is produced as a by-product every year, and this annual increase in production poses an immediate danger to humans, plants, and the ecosystem as a whole.

Chemical composition of red mud

In essence, red mud comprises all the gangue components that were originally present in the bauxite ore, which is the source of competitive Al oxide. Iron, titanium, and different silicic acid compounds make up the majority of them. Iron (III) oxide, the primary ingredient in red mud that gives it its distinctive red color, may one day prove to be a highly lucrative resource for the production of green steel. The minor components included in bauxite ore in varying degrees depend on where the material was mined. The red mud and bauxite both contain a number of hazardous and heavy metals, including arsenic, lead, cadmium, molybdenum, vanadium, and mercury. Had red mud's dry mass may include 110 ppm of arsenic, 1.3 ppm of mercury, and 660 ppm of chromium. More precise tests reveal that the red mud may include more than 40 chemical components, some of which are present in small amounts (a few hundred parts per million), such as cadmium, nickel, arsenic, and antimony. The provenance of the ore has a considerable impact on composition.

Opportunities if red mud processing

In addition to the many risks related to the red mud's poisonous element concentration, this industry offers significant financial and sustainability prospects due to the red mud's abundance in precious minerals. Depending on where the bauxite ore was mined, red mud often includes up to 65-70% iron oxide (Fe_2O_3), 40-50% aluminium oxide (Al_2O_3), and 15-

25% titanium dioxide (TiO_2). The iron present in the forms of oxides and hydroxides, which gives the substance its vivid red colour, is of particular importance. It may be used to the manufacturing of iron, to the sintering of alumina, and to pigments. There are still a significant number of aluminium components in red mud after the Bayer process, where the aluminium oxide is produced, therefore attempts to extract the residual aluminium from red mud are an appealing target. The red mud contains titanium as titanium dioxide (TiO_2). Since it offers UV protection and is utilised as a pigment in many items, it is often found in sunscreen and cosmetics. As a pigment, it might also be employed in more commercial applications. The so-called elements of rare earths are of great importance because they are urgently required in a variety of applications, including magnets, alloys design, semiconductors, and they are heavily used in so-called high- and green-tech goods in which they are often irreplaceable. The red mud may also be used to extract the element scandium. Red mud additionally includes Silicon Dioxide (SiO_2), Calcium Oxide (CaO), Sodium Oxide (Na_2O), and Potassium Oxide in additional to these elements (K_2O). Three very significant resources are zirconium dioxide (ZrO_2), vanadium pentoxide (V_2O_5), and lithium oxide (Li_2O). Today, almost all oil is just thrown in hazardous landfills, leaving plenty of area for basic metallurgical study.

Ground Granulated Blast-furnace Slag

When added to concrete, the by-product of making iron called ground granulated blast furnace slag (GGBFS) gives it better workability, strength, and durability. Iron ore, limestone, and coke are heated at a temperature of roughly 1500 degrees Celsius to produce this substance. The operation takes place in some kind of a blast furnace. The origins of GGBFS are indirect. Slag and molten iron are the by-products of the production of iron. Alumina and silica, together with a certain number of oxides, make up the molten slag. Eventually, this slag is pulverised by cooling. It is permitted to do so by passing through a high-pressure water pump. This causes the particles to be quenched, resulting in granules with a diameter less than 5 mm. Blast furnace slag is mostly composed of CaO, SiO_2, Al_2O_3, and MgO. Most cementitious materials include these particular minerals. To create ground granulated blast furnace slag cement, the nanoparticles are even further dried and ground in a revolving ball mill. Now, many techniques may be used to carry out the primary quenching operation. It may be referred to as palletized waste, foamed or extended slag, GGBFS, or air-cooled slag from blast furnaces depending on the technique used (ACBFS). The fact that certain of the metals in GGBFS have not completely oxidized is another noteworthy distinction. Compared to Portland cement, this shift will be seen in the structural construction of concrete. The hydration reaction and the hydration products would alter as a result of the aforementioned two compositional variations when compared to Portland cement GGBFS.

Physical Properties of GGBFS

Blast furnace slag that has been ground into granules seems to be practically white in hue. To vividly illustrate the color difference between GGBFS and regular Portland cement, the figure below displays both types of cement. Therefore, unlike the dark grey hue of typical cement concrete constructions, concrete colored with GGBFS would be lighter and brighter. This gives GGBFS an additional visual benefit [6]. It has been noted that the GGBFS particle size changes according on the grinding methods used during production. Additionally, it has been noted that the product from a ball mill has broad particles while the one processed in an airflow mill has small particles. The vibro-mill-ground materials include spherical-shaped particles. The GGBFS may be included in the concrete making process, in addition to Portland cement, water, as well as aggregates. The mixture's typical ratio stays the same. The experiments indicate that between 30 and 85% of the cement weight may be replaced by GGBFS. In most cases, we replace 40 to 50 percent.

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CHAPTER 11

ADVANTAGES OF GGBFS IN CONCRETE

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The following benefits of using ground granulated blast furnace slag in concrete composition are discussed. GGBFS in concrete improves the structure's tensile strength and longevity. It reduces concrete voids, which lessens permeability [1]. GGBFS provides a usable mixture. It has strong compaction and pumping properties. The composition formed of GGBFS parts helps to improve sulphide attack resistance [2]. Reduced chloride intrusion is possible. In comparison to normal mixed hydration, the heat of hydration is reduced. Strong opposition exists to the alkali-silica reaction. These increase the chemical stability of concrete, give it a high surface polish and enhance its aesthetics, and lighten and uniformed the color[3]. The minimal likelihood of swelling lengthens the lifespan of concrete buildings by decreasing the expense of maintenance and repair. GGBFS doesn't emit carbon dioxide, sulphur dioxide, or nitrogen oxides, in contrast to cement. It has been discovered that using GGBFS is simple due to its better mobility features. This is as a result of its fineness and the GGBFS particles' form. These have a lower relative frequency as well. The very glassy nature of the GGBFS particles increases their workability. This may assist reduce the amount of water and Superplasticizers needed to achieve appropriate workability in everyday circumstances. Additionally, they are less likely to be separated during material handling and pumping. The blend held by GGBFS has a reduced relative density and better flow characteristics, which make pumping easier. Concrete built from GGBFS sets more slowly than concrete made from regular Portland cement mix, which is one of the distinctive characteristics that are provided by its use in concrete. The quantity of GGBFS will determine how long it takes to set. But strength develops with time. The development of cold joints would benefit from this gradual setup. However, this substitute cannot be used in circumstances when a quicker setup time is necessary. Because the GGBS composition maintains its plasticity for a longer time, the contractor may achieve a smoother finish. The features listed above demonstrate the GGBFS's sustainability. The actual product is really a by-product that serves as a vehicle for increased notoriety. They are more sustainable because of the lower carbon dioxide levels in the building. Since of their glassy smoothness, GGBFS are a better substitute because they need less water. The glassy surface of GGBFS particles prevents water from adhering to it. Due to the slow pace of strength increase, GGBFS is now encountering certain obstacles in its widespread application. Furthermore, it is quite sensitive to the circumstances of cure. Therefore, a better curing procedure assures that GGBFS will be used to its maximum potential.

Properties of Hardened Concrete with Blast Furnace Slag (GGBFS)

Concrete benefits from the physical characteristics of Ground Granulated Blast Furnace Slag (GGBFS) in both its fresh and hardened states. A concrete mix design that would result in a denser mass of concrete, or a solid devoid of cavities, is always advised. GGBS are crucial in removing voids from the concrete mass, which reduces the structure's permeability

Setting Time of GGBFS concrete

Less water is needed at the GGBFS, and there is a probability that the concrete may firm up more quickly [4], [5]. Setting time rises along with the quantity of cement being replaced by GGBFS. Al's investigation revealed that the quantity needed to replace the GGBFS by 40%, 50%, and 60% would nearly rise by an hour more than the OPC setup time (For both initial and final setting time).

Compressive strength of concrete containing slag

Compressive strength of slag concrete is primarily dependent on a variety of variables, including slag type, particles, activity index, and quantity used in concrete mixes, in addition to other variables like cement type as well as water to cementitious material proportion. Generally speaking, the strength of concrete of slag concrete progressively develops from 1 to 5 days and is lower compared to that of concrete without slag; nevertheless, from 7 to 28 days, the strength of slag concrete is comparable to controlled concrete. Additionally, after 28 days, the compressive strength of slag concrete is greater than that of concrete that contains no slag. Additionally, the use of silica fume may help slag concrete acquire its desired early strength. The quantity of used fume determines how early strength development improves. Last but not least, Figure 1 shows the evolution of compressive strength for controlled concrete and for concrete replacements with various slag percentages. Comparing controlled concrete as well as other replacement percentages, it can be shown that the 40% replacement had the optimum performance.

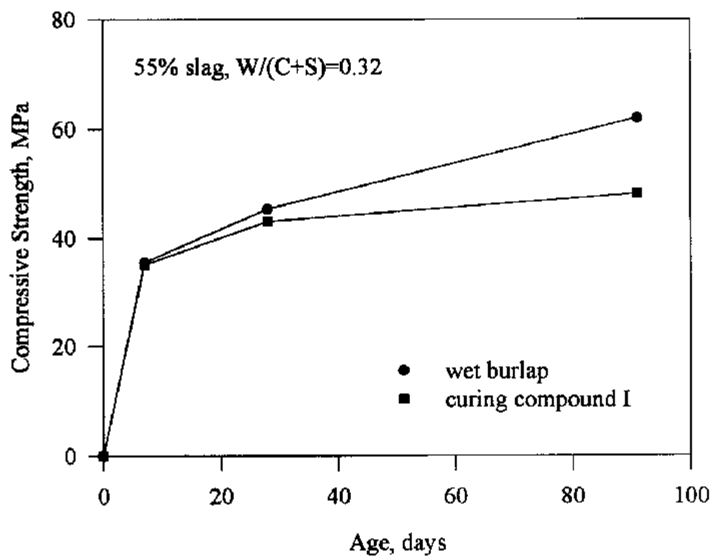

Figure 1: Illustrates the graphical representation of Compressive strength of concrete containing slag [6]**.**

Curing of blast furnace slag concrete

The degree and pace of hydration are significantly impacted by inadequate concrete curing, and as a result, the hydration that produces strength will develop slowly. In concrete that has a large proportion of slag, the negative effects of inadequate curing are more severe and obvious. Concrete that contains more than 30% slag is thus cured for a longer amount of time than concrete that contains no slag in order to eliminate ambiguity about strength and durability. Last but not least, the lengthening of slag concrete curing time depends on a variety of variables, including ambient temperature, cement quantity and type, cement temperature, as well as the proportion of cement replacement.

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CHAPTER 12

COLOR OF CONCRETE INCORPORATING SLAG

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Slag concrete has a lighter hue than regular concrete due to the pale colour of blast furnace slag. Additionally, slag concrete's interior has a strong blue-green tint, which is visible in shattered pieces, for instance after a compressive strength test [1]. After sufficient exposure to air, this hue would fade. The degree of the colour depends on the curing conditions, the amount of blast furnace slag used, and the degree of oxidation [2], [3].

Flexural strength of Blast furnace slag concrete

The flexural strength of slag concrete was equivalent to or greater than controlled concrete flexural strength at 7 days and even beyond. Because of the form and surface roughness of the slag nanoparticles, a stronger link between the cement, slag, and aggregate is produced, increasing the flexural strength with blast furnace slag concrete [4].

Permeability of concrete incorporating slag

Blaster furnace slag in cement paste is said to reduce the size of pores, which, in turn, lowers the permeability for slag concrete, making it perform better in terms overall permeability than controlled concrete. Additionally, it has been proved that concrete with up to 75% slag performed well in saltwater [5].

Young's modulus of elasticity of concrete incorporating slag

If the strength of both forms of concrete is the same, the modulus of elasticity of slag concrete as well as that of concrete without slag does not very much.

Drying shrinkage of concrete containing slag

Concrete with slag has more drying shrinkage that concrete without slag. The volume of concrete paste is increased when slag substitutes some of the cement on either a weight basis because of the small specific gravity of slag.

Microstructure of GGBS Concrete

According to studies, GGBS helps make concrete denser by reducing the amount of holes it contains. The GGBS hydration reaction gets two more reactions. In the first process, GGBS particles are activated to get them ready for hydration. This is accomplished by the calcium hydroxide ($Ca(OH)_2$) alkali environment that is produced by the cement's first interaction with water. The pozzolanic reaction that the GGBS as well as the alkali carry out enhances the synthesis of the hydration product in this alkaline environment. This first results in C-S-H gel inside the paste. It takes time for strength to grow at this slower pace of production. The concrete mass becomes denser thanks to the hydration product C-S-H. More GGBS replacement leads to more C-S-H production, which results in denser concrete. Lower porosity and a denser microstructure are benefits of denser concrete. Low porosity is a characteristic that prevents water from penetrating, guaranteeing the lifetime of the concrete. The pace at which products are created in GGBFS concrete differs from the hydration products of Ordinary Portland Cement (OPC). The main reaction's $Ca(OH)_2$ hydration products will trigger the slag reaction, which will result in the formation of little CaO/SiO_2 ratio or C/S ratio. This lessens the AFm products as well, which are created when alumina and calcium hydroxide hydrate in cementitious materials. The unstable C-S-H and the Ca $(OH)_2$ are discovered to trigger the pozzolanic action to enhance the C/S ratio. GGBFS is used to minimize porosity and modify the pores' nature to smaller ones. This will assist in altering the cement's hydration's mineralogy. This encourages a decrease in chloride ion penetration.

Fresh Concrete Properties with Ground Granulated Blast Furnace Slag

Participants shall learn more about the function of ground granulated blast furnace slag (GGBFS) as it affects the qualities of new concrete. As a result, GGBFS would expand in its future potential. Some of the primary characteristics of new concrete after the addition of GGBFS.

Bleeding Characteristics of Fresh Concrete with GGBFS

The ability of water throughout the concrete mix to flow to the top layer of the mix is known as bleeding. Fresh concrete exhibits this behaviour, which is an undesirable element. The reality is that bleeding may happen to any concrete. Whenever the rate of bleeding outpaces the rate of evaporation, a problem occurs. After compaction, the bleeding rate would be constant for a brief amount of time. The creation of hydration products stops the bleeding. These products include solids that combine to form a blockage in the water's flow channel, which causes bleeding. Concrete mix characteristics alter as a result of bleeding. This happens because bleeding alters the amount of water in the mixture. According to tests, using GGBFS instead of regular Portland cement increased bleeding rates by 40 to 70 percent. A greater replacement with GGBFS causes more bleeding.

Workability Characteristics of Concrete with GGBFS

According to ACI, replacing GGBFS will enable us to utilise an acceptable quantity of coarse aggregates without affecting the concrete's workability. By using this technique, the mix's thickness may be decreased. Greater workability was seen when 30 to 50% of the cement was replaced with GGBFS. Value increases up to a certain point, beyond after which there is no further improvement in workability. It is concluded that slag concretes are more workable than regular fresh Portland cement concretes. The spherical and glassy texture of the surface of nanoparticles is the cause of the increased workability [6].

Glass Count of GGBFS

The glass or monocrystalline portion of the slag is referred to as the glass count. Due to its capacity for reactivity, the rate of reaction increases as glass content rises. The glass count throughout the GGBFS mix may be determined using the x-ray diffraction (XRD) technique. Having a glass count of more than 67 percent is advised. In comparison to Portland cement, the GGBFS reacts to water more slowly than it does. As a result, it takes longer for the GGBFS cement or concrete to become stiff. The replacement level is greater at this time, the increase in stiffening duration with replacement in accordance with BS 4550.

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CHAPTER 13

CHEMICAL REACTION OF GGBFS

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Because GGBFS respond to water extremely slowly, there is less hydraulic activity, which reduces the need for it in the production of concrete [1]. Because of their glassy structure, the GGBFS prevent the particle from interacting with water. The substance has latent hydraulicity, which has to be activated for it to become reactive [2]. The GGBFS reacts with activators like sulphates or alkalis, raising the pH of the entire mixture as a consequence. The glass structure of the GGBFS is disrupted when the pH levels approach a threshold level, which causes the particles to be activated. As a result, the GGBFS will react with the water and produce hydration products. The Portland cement is what causes the slag particles to activate for hydration when GGBFS is used as a substitute [3], [4]. As alkalis and sulphates make up Portland cement. Two processes combine to form the hydration mechanism [5]. As indicated in the equation below, a main reaction occurs when regular Portland cement is hydrated with water to produce calcium silicate hydrate, which may then be combined with specific alkalis like calcium hydroxide, sodium hydroxide, as well as potassium hydroxide. The following variables affect how quickly a concrete mix containing GGBFS reacts in the most significant way: Temperature: The response rate rises as the temperature rises and vice versa. The number of components: The reaction will intensify as the percentage of cement component increases. The attributes: The rate of reaction is influenced by the components' fineness and chemical makeup.

Durability Properties of Concrete with GGBFS

Concrete's durability is a crucial aspect in the design of constructions. In this article, the effect of GGBFS on the endurance characteristics of concrete is explored. Any structure's durability is a crucial component that must be taken into consideration if it is to fulfil the purpose for which it was designed. It has a time frame prerequisite. No matter what kind of material is used, every construction should acquire this quality. As a result, the durability characteristics of the material used for a structure must also be taken into consideration. It will go through how the longevity of concrete structures that have been replaced with GGBS has varied.

Durability Properties of Concrete with GGBFS

Following are the durability properties of Concrete with GGBFS:

Creep and Shrinkage of Concrete with GGBFS

Creep is the term used to describe the amount of concrete deformation over time under continuous load. Drying, chemical, or autogenous shrinkage are the three types of shrinkage. The most noticeable is drying shrinkage, which is mostly brought on by water evaporating from the gaps in the concrete structure (Figure 1). Considered to be significant time-dependent variables that primarily influence even the qualities of high-performance concrete are the two metrics creep and drying shrinkage (HPC). The graphs below demonstrate the variance in creep and shrinkage of the HPC specimen with GGBS replacement (Concrete B), silica fume replacement, and no replacement (Concrete A) (Concrete C). At 180 days old, a creep study was undertaken, and at 210 days old, a shrinkage research was conducted. According to Figure 2, the substituted samples had less creep than a sample made just of regular Portland cement. This may be explained by the fact that slag becomes stronger with age.

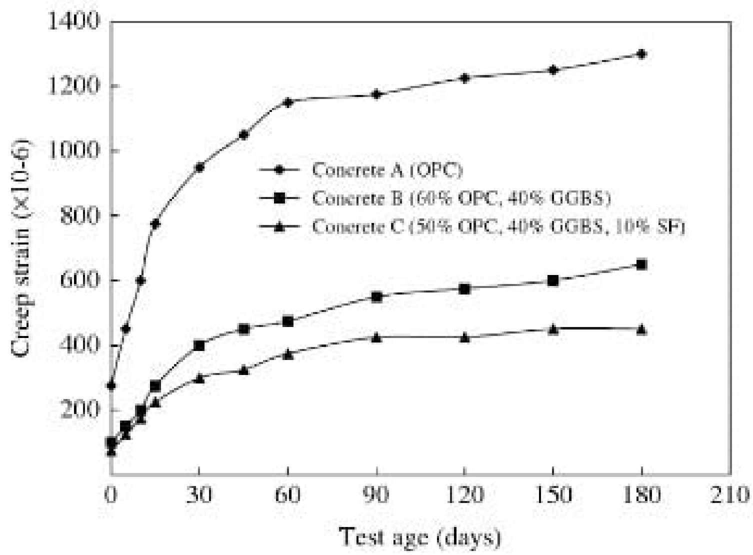

Figure 1: Illustrates the graphical representation of Creep Variation in Concrete A, B and C [6]**.**

According to the variance in Figure 2, drying shrinkage was also discovered to be smaller than the sample containing OPC alone. This could possibly be explained by the main issue, which is a dearth of voids. The concrete is effectively made denser and void-free using GGBS. This would aid in confining water within the crevices. This would make it easier to reduce water evaporation, which would prevent any shrinkage.

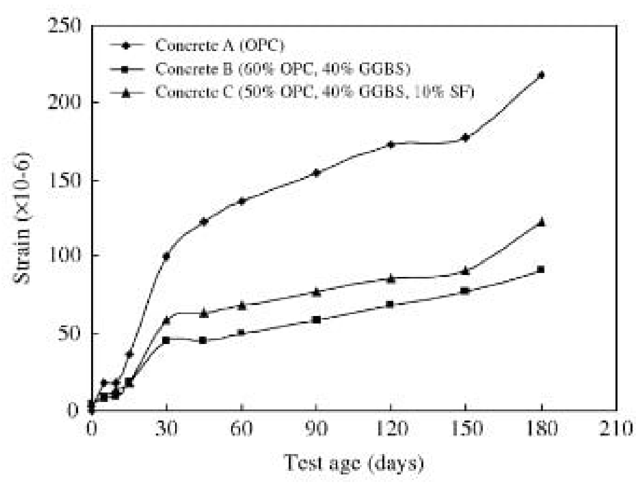

Figure 2: Illustrates the Variation of Drying Shrinkage in Concrete A, B and C.

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