RED MUD GEOPOLYMER APPLICATIONS

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CHAPTER 1

INTRODUCTION TO RED MUD BASED GEO POLYMER BRICKS

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Industrial wastes are being produced in large quantities as a result of the rapid industrialization and urbanisation. Fly ash (FA), Red mud (RM), and ground granulated blast furnace slag (GGBS) are only a few of the wastes produced in large numbers and carelessly dumped on open areas, which not only takes up space but also pollutes the soil and ground water. The usage of traditional building materials has also grown as a result of increasing construction activity. The manufacture of traditional building materials like cement carries significant environmental risks. Finding sustainable alternatives to current materials is thus necessary for a brighter future. During the Bayer's process, which produces alumina from bauxite, red mud becomes the primary waste product. Along with certain other minor components, it contains iron, titanium, aluminium, and silica oxides. This research project examines "Experimental Study on Red Mud [1]."

It is possible to create binders by using an alkaline liquid to react with the silicon (Si) and aluminium (Al) in a source material having a geological origin or in byproduct materials like fly ash and rice husk ash [2],[3]. He created the term "Geo-polymer" to describe these binders since the chemical reaction that occurs in this circumstance is a polymerization process [4],[5]. The Si-Al minerals undergo a relatively quick chemical reaction during the polymerization process, which produces a three-dimensional polymeric chain and ring structure made up of Si-O-Al-O links. The inorganic polymer family includes geo-polymers [6]. The geo-polymer material has a chemical makeup with natural zeolitic materials;however, its microstructure is amorphous. Fly ash, powdered blast furnace slag, and met kaolinite are examples of common alumino-silicate precursors. Aside from having an abundance of raw materials, geo-polymers also offer good qualities including cheap manufacturing costs, high early strength, quick setting, and minimal CO_2 emission. Due of these characteristics, geo-polymer has several uses in civil engineering. Low-calcium fly ash-based geo-polymer concrete that has been heat-cured has good resistance to sulphur attack, experiences minimal creep, and experiences almost little drying shrinkage. The inorganic polymer family includes geopolymers. Geopolymer materials have a chemical makeup with natural zeolitic materials, however their morphology is amorphous rather than crystalline. When Si-Al minerals are subjected to a relatively quick chemical reaction in an alkaline environment, a three-dimensional polymeric chain or ring structure made of Si-O-Al-O linkages develops.

The following step might be included in the chemical reaction:

- Hydroxide ions acting on the source material to dissolve the Si or Al atoms.
- Moving, orienting, or condensing precursor ions into monomers; setting, polymerizing, or condensing monomers into polymeric structures.

It might be difficult to separate and analyse each of these three processes independently since they can overlap and happen virtually simultaneously. Figure 1 illustrates the three fundamental shapes that a geopolymer may take.

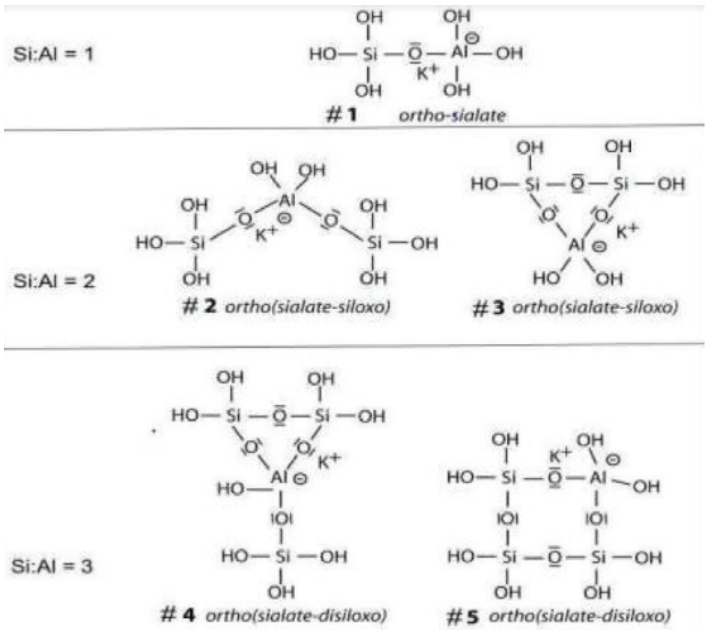

Figure 1. Illustrate the Schematic formation of geopolymer material.

The denser and, hence, stronger specimen is produced by ashes with smaller particle sizes. The best temperature for curing geo-polymeric specimens was discovered to be 80 ^{O}C in an oven. Alkaline solutions are supplemented with various sources of Silica and Alumina to facilitate their dissolution and subsequent polymerization. Characterization of materials is often done to determine how geo-polymer composites will behave. According to the literature, geo-polymer bricks may be made from lateritic soil and natural sand. The raw material for geo-polymer bricks and panels might alternatively be low-value clay. One such substance is dirt from tank beds. It is generally recognised that the manufacture of Ordinary Portland cement (OPC) has environmental consequences. Along with taking up enormous areas of precious cultivable land, the fast industrialization process results in the development of massive amounts of garbage. Concrete, the most popular man-made material worldwide, has to be used with industrial waste in order to solve these issues.

Red Mud is a byproduct that is produced when aluminium is extracted from bauxite ore using Bayer's technique. As a byproduct from 3 tonnes of bauxite ore, about 1.5 to 2.2 tonnes of red mud are produced for every 1 tonne of aluminium. Red mud is dumped over a larger region, producing ground water pollution via percolation. A solid, fine-grained byproduct of the burning of pulverised coal in power plant furnaces is called fly ash. Despite efforts made by the government, several nonprofit groups, and R&D institutions, only around 50% of Fly Ash is really used. Blast furnace slag from steel factories is ground to create ground granulated blast furnace slag (GGBS). In order to improve workability, increase ultimate durability and strength or improve resistance to chloride penetration, sulphate attack, or alkali-silica reaction, GGBS is generally recognised for usage in Portland cement concrete. Geopolymer is an inorganic alumino-silicate polymer that has the potential to be a significant component of a building that is ecologically friendly. Materials with a geological origin or byproducts that include both silica and alumina are used to create it. By releasing alumina and silica from the raw material and generating alumino-silicate structures, alkali activators play a significant part in the production of geopolymers. Red mud, GGBS, silica fume, and fly ashes are a few waste products that include alumina and silicate sources that might be utilised as a source material to create geopolymer.

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CHAPTER 2

RAW MATERIALS RED MUD

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A solid byproduct of the Bayer process, the main commercial method of refining bauxite, is red mud or red sludge. Red Mud is purchased for the research from a business in Salem, Tamil Nadu, close to Mettur Dam. The resultant solid mass is sun-dried until it is completely devoid of moisture. It is then thoroughly ground into powder and put through a 90 sieve. 1.67 is the specific gravity.

Ground Granulated Blast Furnace Slag (Ggbs)

When molten iron slag from a blast furnace is quenched in water or steam, it becomes a glassy, granular product that is subsequently dried and ground into a fine powder to create ground-granulated blast-furnace slag. The GGBS utilised in this research was produced by a firm in Bengaluru using slag that was acquired from a business in Bellary and Bhadravathi. 2.19 is the specific gravity [1],[2].

Scrap Copper

Copper slag is a substance leftover from the production of copper. The slag is a dark, glassy, granular substance with sand-like particle sizes. This study's source of copper slag is a business in Thoothukudi. It is thoroughly dried in the sunlight until the moisture is removed. Then it is put through a 4.75 mm sieve. The copper slag has an inelastic modulus of 7.14. The curvature coefficient is 1.053 as well as the uniformity coefficient is 2.37. 4.01 is the specific gravity.

Sandy River

It is taken from a nearby quarry and passed through a 4.75 mm filter. The river sand has an ineness modulus of 6.34. The curvature coefficient is 1.053, and the uniformity coefficient is 2.37. 2.54 is the specific gravity.

Granular Aggregate

20 mm and 10 mm coarse aggregates are to be employed in this investigation. The impact value of coarse aggregate is 13.20% for 20 mm and 17.720% for 10 mm.

Alkaline Liquid

A mixture of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate (SiO_2) or potassium silicate is the most typical alkaline liquid used in geopolymerization. Since AlSi crystals are more soluble in sodium-based compounds, sodium hydroxide and sodium silicate are utilised in this application as an alkaline solution[3]. The chemical substance sodium meta-silicate, Na_2SiO_3, commonly referred to as water glass or liquid glass, is known by the common name sodium silicate. This investigation used a sodium silicate solution with the following mass ratios: SiO_2 –29.4%, Na_2O –14.73%, and H_2O –55.9%. Typically, lakes or pellets of sodium hydroxide are the only solid forms of this chemical. Here, a pellet-based sodium hydroxide solution with a 10M concentration is utilised[4].

Fibres

In order to prevent cracking in concrete brought on by drying shrinkage and plastic shrinkage, fibres are often employed. They change the fracture mechanism from brittle to ductile. The following ibres are used in this study:

- Steel fibre (corrugated type) of the metallic kind with a 50-aspect ratio.
- Polypropylene fibre (ibrillated type), non-metallic kind, 6 mm size
- Banana fibre with a 50-aspect ratio, natural kind.

Polypropylene fibres increase the cohesiveness of the mixture, its ability to be pumped over long distances, its resilience to freeze-thaw and explosive spalling in the event of a catastrophic blaze, and more. In addition to increasing structural strength, impact or abrasion resistance, ductility, freeze-thaw resistance, or crack widths, steel isbers also lower the need for steel reinforcement. Banana fibres have advantages including low density, effective sound absorption, low abrasiveness, and great biodegradability. Banana fibres are pretreated by soaking in 6% NaOH for two hours to prevent biodegradation of the natural fibres. Then, they get a thorough washing under running water. After that, it is iltered and dried for 24 hours at 80°C[5].

In many applications, including precast parts, geopolymer concrete has the potential to completely replace conventional Portland cement concrete since it is more environmentally friendly. It defends against global warming, efficiently uses waste materials to lower the danger of trash disposal, and conserves the earth's finite natural resources. Due of the higher binder concentration in Mix A, it performs better than Mix B and Mix C.

In terms of mechanical qualities, Mix D outperforms the other mixtures thanks to the addition of hybrid fibres (steel + polypropylene + banana) and the elimination of red mud. As may be shown, ibre-incorporated GPC has a lexural strength that is roughly 30% higher than OPC concrete. At a curing temperature of 40 to 50 ^{o}C, specimens acquired their characteristics. Consequently, solar curing is sufficient for the specified mix percentage, overcoming another drawback of GPC and enabling it to be used to on-site projects. In comparison to OPCC, GPC showed strength gains of 23% when exposed to 5% sulfuric acid and 17% when exposed to 5% sodium sulphate. The use of copper slag increases resilience to environmental effects and lowers the possibility of alkali-silica reaction damage[6].

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CHAPTER 3

GROUND GRANULATED BLAST-FURNACE SLAG

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One may make ground-granulated blast-furnace slag by quenching molten iron slag from a blast furnace in water or steam, which produces a glassy, granular product that is then dried and ground into a fine powder (GGBS or GGBFS). Granulated blast furnace slag functions as a latent hydraulic binder that creates calcium silicate hydrates when it comes into contact with water (C-S-H). It is a chemical that increases the durability and strength of concrete. It is a component of metallurgic cement (CEM III in the European norm EN 197). The capacity to pour concrete in the hot heat and prevent temperature increase in big concrete components and structures during cement setting and concrete curing are its main advantages [1].

Composition and Production

Depending on the chemical makeup of the raw materials used in the iron manufacturing process, slag composition varies greatly. In the blast furnace, silicate or aluminate impurities first from ore and coke are mixed with a flux to reduce the slag's viscosity[2]. Flux used in the manufacturing of pig iron is often a combination of limestone and forsterite, or dolomite in certain situations. The slag is decanted for separation in the blast furnace where it floats on top of the iron. Slag melts that have undergone slow cooling form an unreactive crystalline substance made up of a mixture of Ca, Al, and Mg silicates. The slag melt must be quickly cooled or quenched below 800 °C in order to avoid the crystallisation of merwinite and melilite and achieve high slag reactivity or hydraulicity. A granulation technique, in which molten slag is exposed to jet streams of water or air under pressure, may be used to cool and fracture the slag. As an alternative, the liquid slag is partly cooled with water and then launched into the air by a revolving drum during the pelletization process. The resulting fragments are ground to the same fineness as Portland cement in order to achieve an appropriate reactivity[3].

Blast furnace slag's primary constituents are SiO_2 (28–38%), CaO (30–50%), Al_2O_3 (8–24%), or MgO (1–18%). Slag basicity rises and compressive strength rises generally as the CaO component of the slag increases. Up to corresponding values of 10-12percentage points and 14%, the MgO and Al_2O_3 concentration exhibit the similar pattern, and beyond such values no further advancement is possible. Slag composition and hydraulic activity have been linked using a variety of compositional ratios, or so-called hydraulic indices; the latter is often stated as the compressive strength of the binder[4].

Slags that can be blended with Portland cement generally have a glass content of 90–100%, depending on the cooling technique and the temperature at which cooling is started. The proportions of network-forming components like Si and Al over network-modifiers like Ca, Mg, and to a lesser degree Al are key determinants of the glass structure of quenched glass. Network depolymerization and reactivity increase as network-modifier concentrations rise[5].

Merwinite and melilite are often found in blast-furnace slags as crystalline components. Belite, wollastonite, rankinite, monticellite, and forsterite are other small components that may emerge during progressive crystallisation. Oldhamite is a prevalent form of reduced sulphur in small levels[6].

Applications

In conjunction with regular Portland cement and/or other pozzolanic ingredients, GGBS is utilised to create long-lasting concrete buildings. Due to GGBS' better concrete durability, which increases a building's lifetime from fifty to one hundred years, it has been extensively utilised in Europe, and is being used more and more in the Americas and Asia (especially in Japan and Singapore).

The manufacturing of high-slag blast-furnace cement (HSBFC) and Portland blast-furnace cement (PBFC), both of which have GGBS contents that generally range from 30 to 70%, as well as the creation of ready-mixed or site-batched durable concrete, are two important applications of GGBS.

Depending on the percentage of GGBS in the cementitious material, GGBS cement causes concrete to set more slowly than regular Portland cement, but it also maintains its strength for a longer length of time under manufacturing settings. This helps minimise cold joints by lowering the heat of hydration and temperature spikes, but it may also have an impact on building timetables when rapid setting is necessary.The use of GGBS greatly lowers the possibility of alkali-silica reaction (ASR)-related damages, offers more protection against chloride intrusion, which lowers the possibility of reinforcing corrosion, and offers greater protection against sulphate and other chemical assaults.

How to Utilise GGBS Cement

In the batching plant of the concrete producer, GGBS cement may be added to concrete with Portland cement, aggregates, and water. The mix's typical proportions of water, cementitious material, or aggregate stay the same. On a weight-for-weight basis, GGBS is utilised in lieu of Portland cement in construction projects. For GGBS, replacement levels might range from 30% to 85%. The majority of the time, 40 to 50% is utilised.The concrete standard EN 206:2013 addresses the usage of GGBS in addition to Portland cement in concrete across Europe. Along with regular Portland cement, this standard provides two kinds of additives to concrete: Type I almost inert additions, and Type II pozzolanic or latent hydraulic additions (Type II). This last group includes GGBS cement. Concrete constructed using GGBS cement will cost around the same as concrete manufactured with regular Portland cement since it is somewhat less costly than Portland cement.

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CHAPTER 4

BASICS OF METAKAOLIN

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Metakaolin is the name for the calcined anhydrous kind of the clay mineral kaolinite. Porcelain has traditionally been made using kaolinite-rich materials called china clay or kaolin. The particles in metakaolin are smaller than those in cement but not as small as those in silica fume[1].

Kaolinite Sources

The quality and reactivity of metakaolin is strongly dependent of the characteristics of the raw material used. Metakaolin can be produced from a variety of primary and secondary sources containing kaolinite:

- High purity kaolin deposits
- Kaolinite deposits or tropical soils of lower purity
- Paper sludge waste (if containing kaolinite)
- Oil sand tailings (if containing kaolinite)

Creation of Metakaolin

There are no interlayer cations or water molecules in the T-O clay mineral kaolinite [2]. The stacking sequence of the structural layers affects the temperature of dehydroxylation. At temperatures between 570 and 630 °C, ordered kaolinite dehydroxylates, but disordered kaolinite does not. The pozzolanic activity of dehydroxylated disordered kaolinite is greater than that of organised. Because it takes a lot of energy to get rid of the hydroxyl ions that are chemically bound to the kaolin, the conversion of kaolin to metakaolin is an endothermic process [3]. The transformation of kaolinite into metakaolin, an intricate amorphous structure with considerable long-range order owing to layer stacking, occurs above the temperature range of dehydroxylation. A large portion of the octahedral layer's aluminium becomes tetra- or pentahedrally coordinated. It is necessary to achieve virtually full dehydroxylation without overheating in order to create pozzolan (supplementary cementitious material), which is to say that the material must be extensively roasted but not burned. In contrast to overheating, which may lead to sintering and create a dead burned, nonreactive refractory with mullite and a defective Al-Si spinel, this results in an amorphous, highly pozzolanic state. Although reported ideal activation temperatures range from 550 to 850 °C for varied times, the temperature range of 650 to 750 °C is most often mentioned [4]. With a wider temperature range between dehydroxylation and recrystallization than other clay minerals, kaolinite favours the synthesis of metakaolin but the use of thermally activated kaolin clays as pozzolans. Additionally, structural disorder is more readily acquired upon heating since the octahedral layer is immediately exposed to the interlayer (in contrast to, say, T-O-T clay minerals like smectites).

Reactivity-High Metakaolin

High-reactivity metakaolin (HRM) is a highly processed reactive aluminosilicate pozzolan, a highly split substance that combines with slaked lime to create a robust, slowly setting cement at room temperature and in the presence of moisture [5]. It is created by calcining purified kaolinite at temperatures usually between 650 and 700 °C in a rotating kiln that is heated externally. Additionally, it has been claimed that HRM accelerates the hydration of ordinary portland cement (OPC), with the majority of its effects being seen within 24 hours. Additionally, it slows down the Alkali Silica Reaction (ASR), which is beneficial when utilising recycled broken glass or glass fines as aggregate [6]. The modified Chapelle test is used to determine how much slaked lime can be bound by metakaolin.

Cement Additive

Metakaolin is a useful additive for concrete/cement applications since it is thought to have twice the reactivity of the majority of other pozzolans. A concrete mixture that substitutes 8–20 weight percent of metakaolin for portland cement demonstrates advantageous engineering characteristics, such as the filler effect, accelerated OPC hydration, or pozzolanic reaction. The impact of the filler is rapid, however the pozzolanic response effect takes between 3 and 14 days.

Advantages

- Increased flexural and compressive strengths
- Decrease in permeability (including chloride permeability)
- Reduction in the likelihood of efflorescence, which happens when calcium is carried by water to the surface where it mixes with atmospheric carbon dioxide to form calcium carbonate, which then precipitates as a white residue.
- Heightened defence against chemical assault
- Increased toughness
- Lessening of alkali-silica reactivity's consequences (ASR)
- Improved concrete workability or finishing
- Reduced shrinkage because concrete is denser as a result of "particle packing"
- Enhanced colour by making concrete's colour lighter, allowing for the tinting of intrinsic colour that is lighter.

Uses

- Concrete that performs well, is strong, and is lightweight
- Concrete poured into moulds and precast
- Products made of fibercement or ferrocement
- concrete with fibreglass reinforcement
- Sculptures or countertops (see for example the free-standing sculptures of Albert Vrana)
- stucco or mortar

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CHAPTER 5

ABSORPTION OF WATER

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According to IS: 2386 (Part III) - 1963, this test aids in determining the water absorption of coarse aggregates. A sample of at least 2000g should be used for this test [1]. The equipment used for this test includes a wire basket that is perforated, electroplated, as well as plastic coated and hangs on wire hangers [2]. a container that is watertight for hanging the basket, two dry, soft cloths measuring 75 cm by 45 cm each, a shallow tray with a minimum surface area of 650 cm, and a tight container with a capacity akin to the oven's and basket's [3].

A common technique for assessing how watertight concrete is is absorption testing [4]. The quantity of water that seeps into concrete samples while submerged is measured using a water absorption test, including the one described in BS 1881-122: 2011 Testing Concrete: Method for Determination of Water Absorption [5]. The higher the result, the lower the absorption; nonetheless, there are restrictions, like with many durability tests. The assumption that all weight growth is attributable to water, the fact that the submersion only lasts a brief time compared to what may occur under long-term circumstances, and any form of reactive mechanism that locks up water are not taken into consideration [6].

Furthermore, when it comes to the usage of concrete admixtures, absorption testing might provide false findings. Chemicals in products like Kryton'sKrystol Internal Membrane (KIM), a hydrophilic crystalline waterproofing additive, react with water and unhydrated cement to generate millions of needle-like crystals that stop water from passing through concrete. Unfortunately, absorption testing only evaluates the quantity of water that seeps into concrete samples while they are submerged; it ignores the water's essential role in crystallisation, particularly in the first phases of curing [7].

As the concrete becomes wet and the crystals continue to expand, the absorption tests will become better over time. Therefore, examining the absorption at later stages will provide more realistic findings when evaluating the durability of concrete that has a crystalline additive in the mix design. Test the concrete after 56 or 90 days rather than the early stage of 28 days to get the most reliable findings. In the end, you want the procedure to provide the clearest results possible. When attempting to construct a sustainable concrete construction that will survive for a very long time, the significance of concrete durability cannot be understated.

Plant Water Absorption Mechanisms

During numerous plant activities including respiration, transpiration, and osmosis, plants move capillary water from the soil to the root xylem through root hairs. This biological process is known as water absorption in plants. The availability of water has a significant impact on all plant processes, including photosynthesis, internal water balance, and others.

Leaf withering, stomatal closure, a decline in photosynthetic activity, and protoplasm disorganisation are all effects of water loss in plants. The two stages of absorbed water in plants are typically apoplastic water and symplastic water. While symplastic water is found in the cell protoplast, apoplastic water is found in the cell wall and xylem.

Kinds of Water Absorption in Plants

Typically, there are two ways that plants take water:

- Active water absorption
- Passive water absorption

Active Water Absorption

Because of this sort of water absorption, root cells must utilise metabolic energy to carry out metabolic processes like respiration. Plants may absorb water in two different ways: osmotically and non-osmotically. Water moves into the root xylem from across concentration gradient of the root cell during osmotic active water absorption, which takes place through osmosis. Osmotic mobility happens as a result of the high concentration of solute in the cell sap and the low concentration of solute in the surrounding soil.

Non-Osmotic Active Water Absorption

This calls for the usage of metabolic energy via breathing. As a consequence, the rate of water absorption will rise as the rate of respiration increases. Auxin, a growth hormone, causes plants to breathe more quickly, which speeds up how quickly they absorb water.

Passive Water Absorption

This method of water absorption does not need the utilisation of metabolic energy. As a consequence of metabolic processes like transpiration, absorption happens. The sort of water absorption that results from transpiration pull is called passive absorption. As a result, there is tension or force created, which facilitates the water's ascent into the xylem sap. The amount of water absorbed increases with transpiration rate.

Water Absorption Test on Bricks

To assess a brick's durability, including its degree of burning, quality, and weathering behaviour, a water absorption test is performed on the brick. A brick is more resistant to harm from freezing if its water absorption is less than 7%. A water absorption test may be used to determine how compact bricks are because brick pores absorb water. Bricks absorb more water as the number of pores increases.

Therefore, bricks that absorb less than 3% of water may be described as vitrified. This test determines how much water bricks will absorb, and the test's methodology is described below.

Apparatus

A sensitive balance with an accuracy of 0.1% of the specimen's mass and a vented oven specimenfrom the samples gathered for testing, three numbers of entire bricks should be obtained.

Water Absorption Test Procedure

- Dry the sample until it reaches a basically constant mass in a vented oven at a temperature between 105 and 115 degrees Celsius.
- The specimen should be cooled to room temperature before weighing it (M1 specimens that are too warm to handle should not be utilised for this purpose).
- Immerse the fully dry specimen in clean water for 24 hours at a temperature of 27+2°C.
- When the sample has been taken from the water, wipe out any remaining water with a wet towel and weigh it (M2).

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CHAPTER 6

COMPRESSION TEST

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When a material or product is put through a mechanical test called a compression test, it is subjected to forces that push, compress, squash, crush, and flatten the test specimen [1]. Fundamental mechanical tests like tensile and bend tests are comparable in nature to compression tests [2]. Compression tests identify the stiffness and strength of a material or product under applied crushing stresses. In order to perform these tests, a testing equipment that generates compressive loads is often used in conjunction with platens or other specialized fixtures to impart compressive pressure to a test specimen [3].

A widely popular testing technique is compression testing, which determines a material's compressive force as well as crush resistance as well as its capacity to recover after being subjected to a certain compressive force and even maintained for a predetermined amount of time. To assess a material's response to a load, compression tests are employed [4]. A material's maximal stress tolerance under a constant or progressive load is calculated. Compression testing is often carried out to a rupture or a limit. Depending on the kind of material being tested, break detection may be specified when a test is run to a break. Whether it's a load limit or a deflection limit is utilised when the test is run to its limit.

Test of Compression

The material's characteristics, including sample stress and strain, are measured and numerous computations are conducted during a compression test [5]. A stress-strain diagram is used to plot the data. Compressive strength, proportional limit, elastic limit, yield strength, yield point, and modulus of elasticity are among the properties that may be determined using data. Numerous test samples are positioned between two plates or platens, which evenly distribute the applied force throughout the surface area of the test sample's two opposing sides. A test device with compression capabilities squeezes the plates together, flattening the sample. The machine, a deflectomer, or an extensometer measure the deflection or strain of the sample [6].

Compression Test Uses

Compression testing's objective is to ascertain a material's behaviour or reaction to a compressive load by measuring key parameters such strain, stress, and deformation. Compressive testing allows for the determination of a material's compressive strength, elastic limit, ultimate strength, yield strength, and elastic modulus among other properties.

If these various factors and the values associated with a particular material are understood, it is possible to assess whether or not the material is suitable for a certain application or if it will fail under the given stresses.

Measurements of the Highest Compressive Strength

The compressive load or stress that a material can withstand before breaking is measured by a compressive strength test. Usually a cube, prism, or cylinder, the test sample shape is squeezed between compression plates or a platen. The load cell measures the force, as well as the test controller collects the data. In these applications, the crosshead motion position encoder is used to measure machine platen to platen displacement. A deformation limit may be thought of as the limit for compressive load as certain materials deform permanently while others shatter at their compressive strength limit. The particular test procedure and measurement circumstances have an impact on compression strength readings.

Compressive Stress and Strain Properties

The characterization of the uniaxial stress strain characteristics, in addition to strength, is important for many applications. These parameters include compressive modulus of elasticity, yield point, proportional limit, yield and elastic limit, and yield strength. Numerous test procedures determine stiffness or hardness under compression force. The precision of the deflection, displacement, or strain sensors that assess sample deformation determines the accuracy of the strain readings. Test machine compliance may be removed by putting the sensor on the test sample or measuring platen to platen displacement directly. In contrast to crosshead movement encoder readings, compression tests often need sensors with short journey precision that are in close touch with the test material. In order to correctly detect axial deflection for many applications, platen to platen measurements need three evenly placed displacement sensors.

Applications for Compression Tests

A compression test is used to evaluate the quality of various materials according to their characteristics, including compressive strength, elastic modulus, yield strength, etc. Knowing whether a material can withstand actual usage is important when choosing it for a final product or prototype. Knowing your materials' strengths may let you realise if you're utilising something that won't hold up well under pressure since every material has a breaking point. A compression test may aid you in deciding whether composites, metals, rubber, as well as other raw materials are the strongest candidates for the task.

Tests of Compression Applications

In a variety of sectors, compression testing is used to ensure the quality of the components, raw materials, and completed goods. The following sections on: showcase typical compression testing applications:

- Automotive and Aerospace Industries
- The construction industry.
- The cosmetics industry.
- The electrical and electronics industry.
- The medical device industry.
- The packaging industry.
- The paper and board industry.
- The industry for plastics.
- Rubber, and elastomers.

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CHAPTER 7

INTRODUCTION TO RED MUD GEOPOLYMER PAVER BLOCKS

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Today, finding options for recycling a variety of industrial wastes or by-products is a popular endeavor, driven in part by legal requirements but also in an effort to reduce disposal costs and prevent pollution [1]. The most common type of building material used nowadays is concrete made of Portland cement. It is frequently stated that the production of cement involves very high temperatures (1400–1500 C), the destruction of natural quarries to extract raw materials, and the emission of greenhouse and polluting gases [2]. Each tonne of cement produced releases nearly the same amount of carbon dioxide into the atmosphere. Global warming is brought on by an increase in the airborne emissions of carbon dioxide. The protection of the environment can be accomplished through various means. Utilizing alternative cementing materials is an effective way to use less cement without sacrificing strength or durability [3]. There is a persistent interest in research being done to address this problem. The Hindalco refinery in Belgaum, Karnataka, India, provided the red mud. Indal refinery, formerly known as Hindalco, began operations in 1969 with a preliminary. 75,000 metric tonnes of alumina hydrate may be produced annually. Red mud is a solid by-product of Bayer's method, which extracts alumina from bauxite.

Depending on the raw material treated, 1.5 to 2.5 tonnes of red mud are produced for every tonne of alumina produced. According to estimates, India produces 4.71 million tonnes of red mud annually, or 6.7% of the approximately 70 million tonnes of red mud produced worldwide. The stock of red mud is growing consistently and quickly. Aluminium plants are still quite concerned about its disposal. The need for basic necessities is increased by overpopulation, which leads to construction activity and the development of industrial wastes. Utilizing materials for a housing facility is a part of construction activity. It results in the usage of building materials like paver blocks, bricks, and blocks, which make use of 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 and GGBS are substituted for these conventional materials. Fly ash, Red mud, and GGBS are being employed as binder materials in the construction of paver blocks for the current inquiry [4].

Fly ash: India has been warned by the World Bank that 1000 tonnes of coal ash will need to be disposed of by 2015. Land area, in sq. km. Since coal now generates 70% of the nation's electricity, there is a need for fresh, cutting-edge approaches to lessen environmental effect. The issue with fly ash is that, in addition to requiring significant amounts of land, water, and energy for disposal, its fine particles can go airborne if not handled properly.India currently produces more than 120 million metric tonnes of fly ash per year, and ash ponds take up 65000 acres of land. Such a large amount does present difficult issues, such as land utilisation, health risks, and environmental harm.

Coal-fired power and power producing plants release fly ash into the environment. Typically, coal is ground and air is forced into the combustion chamber of the boiler where it ignites instantly, producing heat and a molten mineral residue. The flue gas is cooled by the heat extracted from the boiler by the boiler tubes, which also causes the molten mineral residue to solidify into ash. The lighter, finer ash particles, known as fly ash, stay suspended in the flue gas while the heavier, coarser ash particles, known as bottom ash or slag, sink to the bottom of the combustion process. Fly ash is collected by particle emission control equipment, such as electrostatic precipitators or filter cloth baghouses, before the flue gas is exhausted.

Fly ash production: When pulverised coal is burned in commercial boilers or electric utility boilers, fly ash is created. Boilers that burn coal come in four varieties:

- Shredded coal (PC)
- Stoker-fired
- Cyclone
- Boilers with fluidized-bed combustion (FBC)

The most common form of boiler is the PC boiler, particularly when producing huge electric units. The other boilers are widely used in industrial or cogeneration facilities more frequently [5]. Electrostatic precipitators (ESP) or collectors made of filter cloth are used to remove fly ash from the flue gases. Fly ash's physical and chemical properties rely on

- Combustion techniques
- Combustion techniques
- Coal source
- Particle form are the first three.

Environmental advantages Utilizing fly ash offers important environmental advantages:

- By enhancing concrete durability, it lengthens the lifespan of concrete roads and structures.
- It aids in the net reduction of greenhouse gas emissions and energy use.
- It may be utilised in place of or in addition to produced cement.
- Less coal combustion byproducts because it is used for other things.
- Additional Natural Resources and Materials Conservation [6]

GGBS: High-strength concrete is made by mixing cement and granulated blast furnace slag, or GGBS. To help the red mud-based geopolymer in the current study set up quickly at room temperature, GGBS was added. It was possible to buy GGBS from the adjacent RMC plant. The GGBS has a specific gravity of 2.9 and a specific surface area of 326 m2/kg, respectively. Calcium oxide and silicon dioxide made up the majority of it. The amount of CaO, which typically ranged from 30% to 50%, was significant since it helped the binder's strength through hydraulic reactions.

Production of GGBS: Depending on the chemical make-up of the raw materials used in the iron-making process, a slag's chemical makeup varies greatly. In the blast furnace, silicate and aluminate impurities from the ore and coke are mixed with a flux to reduce the slag's viscosity. Flux used in the manufacturing of pig iron is typically a combination of limestone and forsterite, or dolomite in some situations. The slag is decanted for separation in the blast furnace where it floats on top of the iron. Slag melts that have undergone slow cooling form an unreactive crystalline substance made up of a mixture of Ca, Al, and Mg silicates. The slag melt must be quickly cooled or quenched below 800 °C in order to prevent the crystallisation of merwinite and melilite and achieve good slag reactivity or hydraulicity. A granulation technique, in which molten slag is exposed to jet streams of water or air under pressure, can be used to cool and fracture the slag. As an alternative, the liquid slag is partially cooled with water and then launched into the air by a revolving drum during the palletisation process. The resulting fragments are ground to the same fineness as Portland cement in order to achieve an appropriate reactivity. Blast furnace slag's primary constituents are CaO (30–50%), SiO2 (28–38%), Al2O3 (8–24%), and MgO (1–18%). In general, raising the slag's CaO level raises the basicity of the slag and increases its compressive strength [7].

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CHAPTER 8

APPLICATION OF RED MUD

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Red mud, also known as bauxite residue, is a type of industrial waste created during the Bayer process used to convert bauxite into alumina [1]. 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 of alumina produced, 1 to 1.5 tonnes of red mud are also created. In 2020, there were more than 133 million tonnes of alumina produced annually, producing more than 175 million tonnes of red mud. Due to its quick rate of synthesis and high alkalinity, the substance poses a serious environmental risk if improperly kept. . As a result, a lot of work is being put into developing better strategies for handling trash, such as waste valorisation, in order to produce components suitable for cement and concrete. This substance is also sometimes referred to as bauxite tailings, red sludge, or alumina refinery leftovers.

Production: Red mud is a by-product of the Bayer process, which is the main technique for processing bauxite to produce alumina. The resulting 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 conditions and the kind of bauxite used in the refining process [2].

The Bayer process is used by more than 60 manufacturing facilities worldwide to create alumina from bauxite ore. Bauxite ore is extracted from the ground, typically in open-pit mines, and then brought to an alumina refinery for processing [3]. Under conditions of high temperature and pressure, sodium hydroxide is used to extract the alumina. A sodium aluminate solution is created by removing the insoluble portion of the bauxite (the residual), which is then seeded with an aluminium hydroxide crystal and allowed to cool, causing the remaining aluminium hydroxide to precipitate from the solution [4].

While the remaining aluminium hydroxide is calcined (heated) at over 1000 °C in rotary kilns or fluid flash concentrated form to generate aluminium oxide, some of it is utilised to seed the following batch (alumina). Bauxite is often utilised with an alumina percentage of between 42 and 50%, however ores with a wide range of alumina levels can 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 colour. The residue contains a minor amount of sodium hydroxide that was employed in the process, which causes the substance to have a high ph/alkalinity, typically >12. To increase the efficiency of the Bayer Process and lower production costs, various phases in the solid/liquid separation process are added to recycle as much sodium hydroxide as feasible from the residual back into the Bayer Process. Additionally, by reducing the residue's final alkalinity, this makes it simpler and safer to handle and store [5].

In Red Mud, Precious Metals/Elements:

Red mud is a significant issue, but it also contains several metals that could be retrieved. Red mud has been estimated to include up to 64% iron oxide (Fe2O3), 43% aluminium oxide (Al2O3), and 24% titanium dioxide (tio2), however it's crucial to keep in mind that figures vary widely from source to source. The following are some of the most prevalent metals generally discovered in red mud that are being investigated for recovery applications:

IRON: The iconic red colour of red mud is a result of the abundance of iron (in the form of oxides and hydroxides).

Tio2 is a versatile substance that is widely utilised as a pigment in many items. It even provides UV protection, which has made it popular for usage in cosmetics and sunscreens. As a pigment, it can also be utilised in more commercial applications.

Rare Earths: The demand for rare earth elements (rees), whose special qualities make them indispensable in many applications, is growing as technology advances. Rees are employed in a wide range of applications, most notably electronics.Additionally, the European Commission defines rees (apart from scandium) as "essential" in reference to their economic significance and supply risk. Due to the difficulties in economically procuring rare earths and the rising demand for them, many are exploring various options for their recovery.

Advanced Materials:

Red mud contains a variety of less significant elements, in addition to the primary metals mentioned above, that may also be valuable:

- Silicon Dioxide (SiO_2)
- Vanadium Pentoxide (V_2O_5)
- Calcium Oxide (CaO)
- Lithium Oxide (Li_2O)
- Potassium Oxide (K_2O)
- Sodium Oxide (Na_2O)
- Zirconium Dioxide (ZrO_2)
- Extraction of scandium

Chemical make-up 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 colour, may one day prove to be a very lucrative resource for the production of green steel. Had red mud's dry mass may contain 110 ppm of arsenic, 1.3 ppm of mercury, and 660 ppm of chromium.More precise tests reveal that the red mud can contain more than 40 chemical elements, 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. 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, chromium, vanadium, and mercury [6].

Reconciling human activities with the fundamental principles of environmental stewardship, sustainability, and protecting living forms will be a significant problem in the future. This is true of all production sectors, and the problem of bauxite residue, sometimes known as red mud, is one from the worldwide aluminium industry. The majority of the world's bauxite resources are made up of closely correlated alumino-silicate clays and precious alumina minerals. In the Bayer process, the ore is digested using extremely hot caustic soda (sodium hydroxide) to remove the insoluble components of the bauxite. Red mud is a waste byproduct of the Bayer process used to manufacture aluminium oxide from bauxite ore. It contains hazardous heavy metals and is exceedingly caustic and harmful to soil and other life forms due to its high alkalinity, creating a significant disposal issue. One of the by-products produced by the calcination process used to extract aluminium dioxide from bauxite in the aluminium industry is red mud. The words "red" and "mud," which describe colour and waste respectively, are combined to form the term "red mud." Alumina is extracted from bauxite ore using a calcination process. In general, the bauxite industry produces 2.5–3 kilogramme of red mud for every kg of aluminium produced. A total of 160 million tonnes of red mud must be disposed of because the world produces 64 million tonnes of aluminium annually. Red mud is currently disposed of either being pumped into ponds or by being dried out using a specific liner.

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CHAPTER 9

BASICS OF FLY ASH

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Fly ash is a by-product of coal-fired power plants and is a fine grey powder made up primarily of spherical, glassy particles [1]. Pozzolanic characteristics in fly ash allow it to interact with lime to produce cementitious compounds. It is frequently referred to as an additional cementitious substance. Fly ash is a byproduct of burning pulverised coal in power stations that produce electricity [2]. Clay, feldspar, quartz, and shale, mineral impurities in coal, fuse in suspension during combustion and float out of the combustion chamber with the exhaust gases. Fly ash, which are spherical glassy particles, are formed as the fused material cools and solidifies as it rises. With the use of bag filters or electrostatic precipitators, fly ash is removed from the exhaust gases [3]. Although the fine powder resembles portland cement, it differs chemically. In a chemical reaction, fly ash and calcium hydroxide, a result of the chemical reaction between cement and water, create additional cementitious products that enhance a number of concrete's desirable qualities [4]. Dependent on the chemical and physical characteristics of the fly ash as well as the cement, all fly ashes display cementitious qualities to varied degrees. Fly ash and calcium hydroxide often react chemically more slowly than cement and water, which delays the concrete's hardening. When installing steel-troweled floors, delayed concrete hardening and the variable fly ash characteristics might pose serious problems for the concrete manufacturer and finisher [5].

Quality of Fly Ash: Depending on the desired usage, different fly ash quality standards are needed. The characteristics of the fuel (coal), the co-firing of the fuels (bituminous and sub-bituminous coals), and other components of the combustion and flue gas cleaning/collection operations all have an impact on fly ash quality. The four most important properties of fly ash for concrete application are homogeneity, chemical composition, loss on ignition (LOI), and fineness. LOI, which measures the amount of unburned carbon (coal) still present in the ash, is an important property of fly ash, particularly for concrete applications. Significant air entrainment issues in fresh concrete can be caused by high carbon levels, the kind of carbon (activated), the interaction of soluble ions in fly ash, and the unpredictability of carbon content. These factors can also have a negative impact on concrete's longevity. Limits for LOI are specified by AASHTO and ASTM. Some state transportation agencies, however, will set a lesser level for LOI. Fly ash can also be cleaned of carbon.

Applications for Fly Ash: Many cement-based products, including poured concrete, concrete blocks, and brick, can employ fly ash as their primary ingredient. Portland cement concrete pavement, also known as PCC pavement, is one of the most popular uses of fly ash. The use of fly ash as a replacement for concrete in PCC road construction projects has substantial financial advantages. The Federal Highway Administration has come to accept fly ash as a filler in mines and for use in embankments. Fly ash is frequently substituted for Portland cement at a rate of 1 to 1 1/2 pounds of fly ash for 1 pound of cement. As a result, less fine aggregate needs to be added to the concrete mix to make room for the extra amount of fly ash [6].

Advantages:

- Decreases concrete's permeability and increases concrete's density. It could provide the building more strength.
- The very low heat of hydration produced by the fly ash-concrete combination inhibits thermal cracking.
- Able to withstand acid and sulphate attacks.
- Fly ash concrete does not shrink much.
- Concrete has good workability, durability, and finish because to the usage of fly ash.
- Conserves natural resources by lowering the amount of clay, sand, and limestone needed to make cement.
- Reduces the need for cement and the release of carbon dioxide during the manufacture of cement.
- Reduces the need for topsoil in land filling and brick production, saving agricultural land.
- The reliability of plastic material and the durability and strength of hardened concrete are both enhanced by the inclusion of fly ash in concrete.
- Less settlements occur when lightweight fill material (local soils) is employed more frequently.

Disadvantages

Fly ash products, which can have various qualities based on where and how it was obtained, may not be well known to smaller builders and house contractors. Traditional builders might also be reluctant to use fly ash because of the material's propensity to effloresce and problems with freeze/thaw performance. The following issues with employing fly ash in concrete also exist:

- Slow-growing strength
- Seasonal restrictions
- Heightened requirement for air-entraining additives
- Greater fly ash content results in more salt scaling.

Fly ash applications: Though not a new technique, the use of fly ash in the construction sector is increasing both the environment's quality and the construction industry's quality. Benefits of incorporating fly ash into concrete include financial, environmental, and technological advantages. Due to its similarity in SiO_2 and Al_2SiO_3 content to Portland cement, fly ash is currently utilised by the cement industry as a pozzolanic material for the production of Portland Pozzolana Cement. It chemically interacts with calcium hydroxide at room temperature and in the presence of moisture to produce compounds with cementitious characteristics. Here are some of the main applications for fly ash:

- Utilised when making Portland cement.
- Typically employed when building embankments.
- Used as a material for soil stabilisation.
- Additionally, fly ash is a component utilised in the creation of flowable fill.

- Used as a mineral filler to fill spaces in the asphalt road construction process.
- In geoploymers, fly ash is used as a component.
- Used in dams made of roller-compacted concrete.
- Utilised to create fly ash bricks
- Fly ash serves as a catalyst when it is handled with silicon hydroxide [7].

Two significant industrial wastes that are extremely attractive for bulk use are fly ash and red mud. When alumina is extracted using Bayer's technique from the bauxite ore, red muck is created. Depending on the quality of the bauxite, an average of 0.3 to 0.5 tonnes of red mud are produced for every tonne of alumina extracted. A total of 2.7 billion tonnes of red mud have accumulated worldwide due to the annual production of about 120 million tonnes of red mud. Because alkali is used in the Bayer's procedure to extract alumina, the red mud has a pH of about 11.3, which makes it a dangerous substance. The red mud poses a risk to human health because of its high alkalinity, prevalence of heavy metal ions, and small particle size. One of the greatest issues for the alumina refinery firms is the safe and affordable disposal of the red mud to reduce its unwanted effects. In-site waste lakes, such as marine disposal, sea disposal, or dry cake disposal, are now the most popular ways to handle this hazardous material. This method of disposing of the red mud is not cost-effective and necessitates ongoing environmental monitoring.

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CHAPTER 10

GROUND GRANULATED BLAST FURNACE SLAG

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By quenching molten iron slag from a blast furnace in water or steam, which results in a glassy, granular product that is subsequently dried and ground into a fine powder, one can create ground-granulated blast-furnace slag (GGBS or GGBFS) [1]. Blast furnace slag that has been ground into granules acts as a latent hydraulic binder that, when in contact with water, produces calcium silicate hydrates (C-S-H). It is a substance that gives concrete more strength and durability. It belongs to the metallurgic cement [2]. Its main benefit is the ability to reduce the temperature increase in large concrete structures and components during cement settling and concrete curing, or to pour concrete in the sweltering summer [3].

Benefits of GGBS: The ultimate strength of concrete built with GGBS cement is higher than that of Portland cement. Compared to Portland cement-only concrete, it contains more calcium silicate hydrates (CSH), which increase concrete strength, and less free lime, which has no such effect. Over time, concrete built with GGBS keeps getting stronger. Its benefits include;

- Increases the concrete structure's tensile strength and longevity
- Better flowability reduces the risk of thermal cracking in large pours and facilitates placement and compaction.
- Fissures due to less shrinking
- Concrete's permeability and voids are decreased.
- Offers a balanced mixture
- Stronger flexural capacity
- Possesses good compaction and pumpability properties.
- Increases resilience to sulphate attack
- High resistance to the entry of chloride
- When compared to traditional mix hydration, the heat of hydration is lower.
- Alkali-silica reaction is strongly resisted.
- Improves appearance and provides a superior surface polish.
- Significant sustainability advantages
- Gradual hydration of ggbs results in a reduction in peak and overall heat production.
- Does not release any nitrogen oxides, carbon dioxide, or sulphur dioxide [4]

GGBS applications: In conjunction with regular portland cement and/or other pozzolanic ingredients, GGBS is utilised to create long-lasting concrete buildings. It is combined with regular Portland cement and/or other pozzolanic ingredients to create sturdy concrete constructions. The manufacturing of durable ready-mixed concrete and quality-improved slag cement are two major applications of GGBS. In production settings, concrete manufactured with

GGBS cement continues to build strength over a longer length of time and sets more gradually than concrete made with regular Portland cement [5].

Ground granulated blast furnace slag: Uses and Advantages

GGBS is the best option for building projects where strong, long-lasting concrete is essential. The benefits of using this product in your construction process include:

Durability: GGBS increases concrete's resistance to damage from the alkali-silica reaction, sulphates, and chlorides, and also decreases the chance of thermal cracking in concrete. Use of GGBS as a partial cement replacement makes concrete substantially more resilient in hostile situations.

Sustainability: Create concrete with low embodied CO_2 levels. Additionally, GGBS is actively reducing the quantity of waste produced by the industrial sector that is dumped in landfills. By lowering the embodied carbon, it aids in creating a greener cement. Comparing to Portland Cement-based concrete, an aesthetic finish can be produced with a much lighter coloured concrete. GGBS also contributes to the decrease of crystalline deposits on concrete surfaces and the enhancement of finished materials' reflectivity (increasing safety in low-light conditions) [6].

Effects of Slag Components on Cement: Slag produced by various steel mills has significantly varying chemical compositions, and occasionally even the same steel factory discharges slag at different times. Before using slag in the manufacturing of cement, each batch must first undergo chemical analysis. The following are the effects of slag oxides on cement quality:

Calcium Oxide (CaO): The majority (approximately 40%) of slag is composed of calcium oxide, an alkaline oxide. In slag, it is transformed into active minerals like di calcium silicate. The principal element affecting slag activity is calcium oxide. Therefore, the activity of slag increases with its content.

Alumina (Al_2O_3): An acidic oxide that works well as an active ingredient in slag is alumina. Slag develops minerals like aluminate or calcium alum inosilicate, and after being quenched in water while still hot, glass is created. Alumina level in slag ranges from 5% to 15% on average, with some samples reaching 30%; the higher the amount, the more active the slag is and the better it is suited to be added to cement.

Silicon Oxide (SiO_2): A type of mildly acidic oxide called silicon oxide has a high, usually between 30 and 40 percent, concentration in slag. Its composition is excessive when compared to calcium oxide and alumina, which leads to the creation of low activity and low calcium minerals as well as the presence of free silica, which lowers the activity of slag.

Oxide of Magnesium (MgO): Magnesium oxide has a lesser activity than calcium oxide. Its concentration in slag typically varies from 1% to 18%. It will not result in poor stability because it is a stable compound or glass in slag. Magnesium can make molten materials more fluid and enhance slag's granulation quality and activity. As a result, magnesium oxide is typically thought of as the active ingredient in slag.

Manganese Oxide (MnO): Although manganese oxide has little effect on the durability of cement, it does have some influence on slag's activity. Its composition should typically be kept to between 1% and 3%. The activity of the slag will drastically diminish if it is higher than 4% to

5%. Because there is a high concentration of alumina and a low concentration of silicon oxide in ferromanganese granulated blast furnace slag, the alumina content can be eased to 15%.

Sulphur (S): Loss of cement strength will be caused by the high sulphur level in slag. But calcium sulphide and water undergo a reaction to create calcium hydroxide, which has an alkaline excitation function. In addition to causing sulphide to transform into the hazardous manganese sulphide, the presence of manganese oxide also causes a corresponding decrease in the amount of calcium sulphide.

Titanium Dioxide (TiO_2): Ilmenite, which contains titanium in slag, will lessen the activity of slag. According to China's national requirements, no more than 10% of a slag's titanium dioxide content is allowed.

Ferrous Oxide and Ferric Oxide (Fe_2O_3) (FeO): Iron oxide and ferrous oxide make up a relatively small portion of slag—generally between 1% and 3%—and have little impact on the substance's activity [7].

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CHAPTER 11

FLY ASH BASED GEOPOLYMER CONCRETE PAVER BLOCKS

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The production of cement uses a lot of energy and produces a lot of greenhouse gases that are released into the environment [1]. According to statistics information, the cement industry accounts for around 7% of all carbon dioxide emissions [2]. Therefore, careful efforts are being made by a number of researchers to create substitute cementing materials for Portland cement. One such substitute for cement that is made by combining alum inosilicate material with very alkaline solutions is geopolymer binder. It uses pozzolanic substances like fly ash, GGBS, met kaolin, etc. as a source of alum inosilicate to react with high alkali solutions that are sodium- or potassium-based. Numerous benefits of geopolymers include their long-term durability, strong compressive strength, and tolerance to harsh environments [3].

When disposed of, fly ash and bottom ash from the combustion of coal in thermal power plants severely pollute the environment. Fortunately, coal fly ash is widely used in the building industry for many purposes due to its advantageous characteristics. There are many options for using fly ash as an additional material in geopolymer and cement concrete. While bottom ash is used sparingly, fly ash is a by-product that is widely employed in the construction industry.

Fly ash and bottom ash have nearly identical chemical compositions, with silica and alumina levels being particularly high in bottom ash. However, bottom ash is a porous, glassy, dark grey substance with sand-like grains. Bottom ash cannot be utilised directly as an original source in geopolymer concrete because it is coarser. In comparison to medium and coarse bottom ash, fine bottom ash produces good strength. With the addition of a little amount of flue gas desulfurization gypsum, bottom ash geopolymer mortar gains strength. Because bottom ash dissolves more slowly in activator solution at larger particle sizes, it cannot participate in the process [4].

The dissolving of the alum inosilicate material is directly impacted by the NaOH solution concentration, which in turn determines how the geopolymer framework is formed. A higher concentration of NaOH solution is needed to improve the dissolving ability in alum inosilicate particles. A higher sodium hydroxide concentration appears to favour the corrosion of the glassy membrane and increase compressive strength. The strength of the geopolymer concrete is increased by a longer cure time and higher temperature. A small number of researchers, however, have noted that the desired compressive strength can also be achieved by curing geopolymer concrete at room temperature. Geopolymer precast concrete products are currently being commercialised, including culverts, sewer pipes, railroad sleepers, and wall panels. In addition, there aren't many studies on geopolymer concrete paver blocks. Paver blocks are a common building material. They are primarily examined for traffic volumes ranging from light to heavy. Compressive strength was attained for M30 and M35 grade using a mix of bottom ash - GGBS geopolymer paver blocks mode curing at 3 days.

Geopolymer: Joseph Davidovits first created geopolymers in 1978 under the moniker "soil cement." They are created at a temperature that is lower than that needed to make cement. A new class of construction materials called geopolymers has the potential to revolutionise the building products sector. Davidovits asserts that geopolymer was cast on site to construct the Egyptian Pyramids. Additionally, he noted that despite being highly alkaline, this material has great mechanical characteristics, does not dissolve in acidic conditions, and does not undergo any harmful alkali-aggregate reactions. An alkali and an aluminosilicate source react to generate geopolymers, a group of inorganic polymers. These materials' amorphous three-dimensional structure gives geopolymers features that make them the perfect OPC replacement. Alkali to silicon and silicon to silicon ratio variations result in geopolymers with various mechanical and physical characteristics. It is a new type of cementitious material that makes use of "fly ash," one of the planet's most prevalent industrial wastes. Geo polymer binders have drawn a lot of interest from chemists and engineers ever since they were first developed. It has become one of the potential cement binder's alternatives in recent decades.

For this experiment, geopolymer concrete paver blocks made from the inorganic polymerization of fly ash and alkali activated solution are used. Geopolymers are modern materials with a wide range of applications. Numerous factors influence the geopolymerization. Following are some findings from research on how curing conditions and molarity affect the compressive strength of geopolymer concrete paver blocks: Compressive strength has been observed to rise as molarity increases. Greater source material dissolution is the cause of this. According to the compressive strength values, the curing conditions had an impact on the physical characteristics of the samples of fly ash-based geopolymer concrete paver blocks. The compressive strengths increased together with the length of curing. This might be explained by a higher level of geopolymerization. Using common tools comparable to those used to create traditional cement, the geopolymer concrete paver block mixtures were simply produced. Blocks for concrete pavers. The geopolymer binder may be considered a more cost-effective and environmentally friendly alternative to Portland cement in the future. Consequently, the geopolymer binders made from Class F fly ash can be utilised instead of regular Portland cement [5].

The idea of interlocking paver blocks is a very old one. The Minoans built the first road that used paver blocks about 5000 B.C. Romans originally built paved roads about 2000 years ago with the aid of labourers and a military force. Most likely, the Second World War was what sparked the development of concrete blocks as a pavement medium. Early in the 1950s, baked clay brick roads were replaced in The Netherlands by concrete block pavement (CBP). Green paver blocks are made using an environmentally friendly process and have nothing to do with colour. Different types of paver blocks have been used for thousands of years. Due to the accelerated construction of infrastructure, Portland cement concrete is currently the second most utilised material on the planet. Carbon dioxide (CO_2) is produced in huge quantities during the production of regular Portland cement and is then released into the atmosphere. For every tonne of OPC produced, approximately 900 kg of CO_2 are released. A significant greenhouse gas that contributes to global warming is CO_2. OPC production peaked in 2010 at 3300 million tonnes, approximately 5% of all carbon emissions from human activity. It has started looking into environmentally friendly and sustainable approaches for building infrastructure. Solid waste disposal is today's other major issue. Fly ash and pond ash are two types of solid waste produced by coal-fired thermal power plants. With stricter environmental regulations, disposing of these pollutants is a significant engineering challenge. Today's research has blended environmental responsibility with waste management, creating the magnificent Geopolymer concrete.

A binder known as Geopolymer was created in 1978 by Joseph Davidovits, a French chemist, by polymerizing silicon- and aluminium-rich raw materials with alkaline solutions. Fly ash and slag from blast furnaces are the two most often used source materials. In comparison to OPC, geopolymer derived from waste materials like fly ash has a lower carbon footprint. Davidovits claims that the Egyptians employed geopolymer technology to create the pyramids. The majority of modern geopolymers are manufactured from low calcium fly ash that has been activated by alkaline solutions (NaOH or KOH) to release silicon and aluminium, together with a second source of silica (usually sodium silicate or potassium silicate). For geopolymer concrete, they are thermally activated alongside aggregates. While typical Portland cement concrete requires water for hydration, water is not involved in the chemical process of geopolymer concrete and is evacuated during curing [6].

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CHAPTER 12

PRODUCTION OF GEOPOLYMER PAVER BLOCKS

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Supplies utilized in the experiment include:

PERFECT AGGREGATE: When the granular material's particles are so small that they can fit through a 4.75mm screen, it is referred to as fine aggregate. Aggregate is the granular material used to make concrete or mortar [1].

M- SAND: River sand is replaced by manufactured sand (M-Sand) for making concrete. Hard granite stone is crushed to create manufactured sand. The crushed sand is graded, rinsed, and shaped into a cubical shape with grounded edges for use in construction. M-Sand is manufactured sand with a particle size of less than 4.75mm [2].

Coarse Aggregate [10 mm]: Any particle larger than 0.19 inches is considered a coarse aggregate, which typically has a diameter between 3/8 and 1.5 inches. The majority of the coarse aggregate used in concrete is made up of gravel, while the majority of the remaining material is crushed stone [3].

Detergent Water: Use of clean, potable water for mixing and curing ensures that no harmful levels of oils, acids, alkalis, salts, sugar, organic material, or other chemicals that could harm concrete are present. Concrete is mixed with portable water. Water's pH value, which ranges from 6 to 8, indicates that there are no organic materials present [4].

In contrast to the manufacturing of traditional concrete materials, where the water cement ratio is based on both the water needed for hydration and workability, the water content for geopolymer materials shall be based only on the needs for workability. The flow test is typically thought of as a standard process to determine the water content. Consequently, early research through trial flow experiments is crucial to the creation of geopolymers. It should be emphasised that this also impacts molarity. The first step was to construct several trial mixes of red mud-alkali based composites and create test specimens in the shape of 50 mm cubes.

Combinations of geopolymers utilized: The investigation of strength growth and water absorption by the polymerization of various combinations of red mud, fly ash, and GGBS is the main goal of this work, as was already mentioned.Strength and water absorption must be completed in order to determine whether the method for making paver blocks may be used in practice.An initial batch of red mud-alkali composite experimental mixes was made.

Mixing: The test mixtures were blended by hand. For about three minutes, the Red mud-GGBS and Red mud-Fly ash-GGBS solid components of the polymer nanocomposites were dry mixed together. The sodium silicate solutions and sodium hydroxide, which make up the mixture's liquid component, were first premixed before being added to the solids. Four more minutes of wet mixing are often required for the mixtures to come together. A dry or low slump GPC mix is adequate for a pre-cast paver block. Extra water may be added if necessary or desired. Prior to adding the alkaline solution, it is preferable to thoroughly combine all dry solid components. Given the importance of water in GPC mix, care should be exercised when adding water to prevent bleeding or segregation. It is advised to blend the dry ingredients in the mixer for at least three minutes. After enough alkaline solution has been added, mix for an additional 4 minutes [5].

Casting: The correctly prepared geopolymer composite was instantly poured into 5 cm cubes.Three layers of the geopolymer composite are used, and each layer is compressed with 25 blows to create a fully compacted geopolymer cube that is then maintained for drying. In 24 hours, it is demolded. Clean, dry castings moulds must be sufficiently lubricated to make demolishing simple. To achieve the desired strength, GPC mix must be placed in layers with adequate compaction between each layer.

Curing: There were two ways to cure things. The prepared samples of geopolymer cubes were left in ambient settings and cured for a period of 7 days before being demoulded after 24 hours. Samples were held in water for 24 hours following the curing process before being tested for water absorption and wet compressive strength. For each mix proportion, the aforementioned process was repeated. That several methods can be used to treat GPC samples. Specimens can be exposed to a variety of curing processes, including ambient curing, oven curing, steam curing, membrane curing, hot gunny curing, and water curing [6]. Oven curing, however, is the most efficient curing technique. Demoulded GPC specimens need to be covered in order to prevent excessive evaporation at high temperatures [6]. The exposure times ranged from 4 hours to 96 hours, and the curing temperatures ranged from 40°C to 85°C for nearly complete geo-polymerization, although there was no discernible strength gain after 24 hours. Among the aforementioned techniques, specimens that were oven cured at 60 °C for 24 hr demonstrated exceptional strength results.

Application of GPC: In the prefabricated industries, GPC can be used as recyclable binders to create a variety of products, including hollow block units, pipes, roofing tiles, pavers, slabs, hollow bricks, and more. Additionally, GPC can serve as binders for producing lightweight components for the cement and concrete industries. Since geopolymer has strong endurance properties and may be utilised in harsh environmental applications such bridges, composite materials, sealant for commercial ceramics, foundry components, etc., the combining of Silicon-Oxo-Aluminate is known as "Sialate." GPC is used in mining and sewage systems because it has a high level of acid and alkali resistance. By turning waste materials into valuable and useful goods and by lowering greenhouse gas emissions, notably in the cement industry, the use of geopolymer technology creates the possibility for sustainable growth. Manufacturing of geopolymer pastes, coating materials, and aggregates is another aspect of its application. Applications for GPC are almost identical to those for regular Portland cement concrete [6].

Geopolymer paver blocks are mostly employed in pre-cast applications and can be used in a variety of settings depending on the situation and desired purpose. The installation and upkeep of GPC pavers are straightforward, easy, and affordable. Specific Indian standards are used to offer solid blocks in order to guarantee the appropriate quality of finished paver goods. In order to meet client requests while also utilising environmentally friendly pavers in a variety of applications, an effort is made while taking into account some inherent limitations. It presents a problem in handling carefully because it contains delicate chemicals like alkaline solution and a regulated heat curing regime. When using minor structural elements that do not require cast-in-situ, this GPC can be advised.

Recycled Asphalt Pavement is produced when an existing bituminous road surface is milled or dug up. Aggregate and old asphalt are present. If properly handled, it might be helpful for the construction sector. Unfortunately, a significant amount of this waste is still sitting in landfills in India, taking up valuable space. Lessening the rate of consumption is the long-term solution to reducing the damaging effects of construction materials on the environment. However, because of the rapid speed of infrastructure development, it is difficult for developing nations to limit the rate of consumption. Therefore, industrial ecology can be used to make short-term efforts. This approach entails using recycled waste from one business to replace raw materials from another [7].

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