ALTERNATIVE CONCRETE

GEOPOLYMER CONCRETE

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BOOKS ARCADE

Alternative Concrete - Geopolymer Concrete

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CHAPTER 1

INTRODUCTION TO GEO POLYMER BRICKS

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The chance to reduce today's waste management issues may lie in substituting wastes for natural raw materials [1]. Red mud is a type of industrial waste that is created when alumina is extracted from bauxite using Bayer's technique. The annual global production of red mud is about 70 million tonnes [2]. Red mud is produced annually in India alone in amounts of over 4 million tonnes. Its high alkalinity makes it a dangerous substance. Red mud is typically disposed of by stockpiling; as a result, it is hazardous to adjacent residents, the local environment, local flora and animals, and nearby water sources. Although not frequently, red mud is used in the building sector. A few of its uses, including bases for roads and airfields, as an additive to cement, in the manufacture of bricks, blocks, and tiles, and in the field of ceramics. Since red mud has a significant amount of silica and alumina, it can also be used in geopolymerization technology. Geopolymer binders are an environmentally benign, sustainable replacement for OPC [3].

The Hindalco refinery in Belgaum, Karnataka, India, provided the red mud. Originally named as Indal, the Hindalco refinery began operations in 1969 with an annual capacity of 75,000 metric tonnes of alumina hydrate. 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. India has been warned by the World Bank that by 2015, 1000 square kilometres of land will be needed for the disposal of coal ash. 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 it requires a lot of land, water, and energy to dispose of because of its fine particles, if improperly controlled, may go airborne. India currently produces more than 120 million 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 [4].

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)
- Fired by a stoker
- Cyclone
- Boilers with fluidized-bed combustion (FBC)

The most common form of boiler is the PC boiler, especially when producing huge electric units. The other boilers are utilised in industrial or cogeneration facilities more frequently.

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 processes
- Coal as a fuel
- Particle form

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 bricks and blocks, which require materials 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. For these conventional materials, industrial wastes like fly ash, silica fume, GGBS, etc. are employed as substitutes. Red mud, micro silica, and fly ash are being employed as binders in the construction of bricks for the current experiment [5].

Recreation of a Geopolymer Chemically: 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 by-product materials like fly ash and rice husk ash. He created the term "Geo-polymer" to describe these binders because the chemical reaction that occurs in this circumstance is a polymerization process. 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. The geo-polymer material shares 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 alumina- silicate precursors. Geo-polymers offer great qualities including plentiful raw materials, minimal energy use, low production costs, high early strength, and quick setting. Due of these characteristics, geo-polymer has many useful applications in civil engineering. Little-calcium fly ash-based geo-polymer concrete that has been heat-cured exhibits high resistance to sulphur attack, low creep, and negligible drying shrinkage. The stronger the specimen, the finer the ashes' particle size produces. The best temperature for curing geo-polymeric specimens was discovered to be 80 C in an oven. Alkaline solutions are supplemented with various sources of Silica and Alumina for dissolution and subsequent polymerization. In general, material characterization is carried out to determine how geo-polymer composites would behave. According to the literature, geo-polymer bricks can be made from lateritic soil and natural sand. The raw material for geo-polymer bricks and panels might alternatively be low-value clay [6].

The inorganic polymer family includes geopolymers. Geopolymer materials share 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 and ring structure made of Si-O-Al-O linkages develops.

The following step could be included in the chemical reaction:

- Hydroxide ions cause the Si and Al atoms in the source material to dissolve.
- Condensation, transportation, orientation, or precursor ion conversion into monomers.
- Converting monomers into polymeric structures through condensation, polymerization, or setting.

It might be challenging to separate and analyse each of these three processes separately because they can overlap and happen virtually simultaneously. The three primary types of geopolymers are:

- Poly (sialate), whose repeating unit is [-Si-O-Al-O-].
- Poly (sialate-siloxo), whose repeating unit is [-Si-O-Al-O-Si-O-].
- Poly (sialate-disiloxo), whose repeating unit is [-Si-O-Al-O-Si-O-Si-O-],

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CHAPTER 2

BURNED CLAY BRICKS

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Bricks are among the oldest and most used forms of building materials and are typically used to make foundation covers, walls, pavements, and other structures [1]. The most important brick qualities are their physical and mechanical attributes [2]. The qualities of bricks include their strength, size, form, and hardness, among other things. Bricks are broadly acknowledged and utilised all over the world because of qualities including durability, affordability, strength, and hardness**.** Burnt clay building bricks can be divided generally into two groups. Those are

Common Burnt Clay Building Bricks: The term "common burnt clay building bricks" refers to a class of bricks used for common construction and housing applications where a lower level of structural strength is required than for heavy duty burnt clay building bricks [3].

Heavy Duty Burnt Clay Building Bricks: Because they are frequently used in heavy masonry and structural applications including bridges, constructions, industrial foundations, and multi-story buildings, they are also referred to as "engineering bricks." However, clay bricks can be further divided into two categories based on the method of production, which are

- **Country Bricks:** Hand-molded and kiln-dried clay bricks, country bricks are the most fundamental variety. It is a labour-intensive type, and depending on a number of variables, the bricks' quality may vary [4].
- **Wire cut Bricks:** Bricks that are "wire cut" are made by employing a wire cutter to slice or cut blocks of bulk clay into the appropriate brick dimensions. Compressive stresses are created in the bricks as a result of cutting caused by wires being pushed through the clay, resulting in tiny minute fractures. Contrary to popular opinion, because moisture and other gases can easily escape during baking, it actually makes bricks stronger. This distortion and enables correct particle bonding for increased strength and a more polished look [5].

Testing for Burnt Clay Bricks

Physical and chemical characteristics of brick exist. The most recent constructions employ bricks. It performs improvements everywhere [6]. Brick is a fire- and sound-resistant building material. Because it possesses these qualities, it is used to build partition walls in industries and use walls of various thicknesses for home additions. It is inexpensive, tough, long-lasting, and simple to handle and deal with. Brick is a top-tier building material as a result of these qualities. There are a few crucial tests to look for burned clay bricks. The brick testing was conducted as follows:

Compression power: Bricks are tested for their ability to support weight. This examination includes a compression testing apparatus.

Watching the water: This test is done on bricks to determine how much water is there. Bricks are laid out in courses in a variety of patterns called bonds. To hold the bricks together, many types of mortar are used in the construction and to construct a sturdy building. When bricks absorb water from mortar, the link between them becomes weaker. For these reasons, brick must have a lower water observing percentage. These water observing cannot make up more than 20% of its weight.

Dimension in the physical: Bricks come in a variety of shapes and sizes. It has simple rectangular faces with pointed corners or edges. And all of its faces are the same colour. Bricks come in two main categories:

Modular Bricks: When compared to Non-Modular Bricks, Standard Modular Bricks have different dimensions. Standard Modular Bricks have dimensions of 190 mm in length, 110 mm in width, and 90, 40 mm in height.

Non-Modular Standard Bricks: In comparison to modular bricks, normal non-modular bricks have different dimensions. Standard Non-Modular Bricks have dimensions of 230 mm in length, 110 mm in width, and 70, 30 mm in height. Standard Modular Bricks and Non-Modular Bricks are combined to create an even bond between bricks.

Brick must be free of defects and cracks in order to function properly. And without any inside-present alien materials.

Efflorescence: It is tested for efflorescence to see if it contains any foreign particles or other compounds. For this test, the brick is submerged in water for a day before drying in the shade. If there are patches of grey or white deposition, there are chemicals present.

Burned clay brick advantages

- Clay brick has a modest acidic reaction at high temperatures, while alkaline lava has a marginally weaker corrosion resistance.
- Greater thermal stability compared to magnesia or refractory brick.
- This low-temperature burning of secondary phosphoric acid products using dry masonry vacuum impregnation of acceptable quality soil is possible.
- This masonry blast furnace body section has been destroyed phosphoric acid.
- Brick offers many benefits, including affordability, durability, moisture absorption, thermal and sound insulation, and fire safety.

Burned clay brick drawbacks

Traditional bricks require a high fire temperature of between 900 and 1000oC and are often made from shale and soil. Quarrying is used in the activities to obtain the soil and shale. Quarrying is a practise that has a negative impact on the earth's landscape and can release significant amounts of garbage. In order to produce conventional bricks, topsoil is continuously removed, which causes environmental issues. Additionally, the typical bricks' high firing temperature uses a lot of energy and emits a lot of greenhouse gases.

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CHAPTER 3

ORDINARY PORTLAND CEMENT (OPC) BRICKS

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Processing a mixture of sandstone and additional raw ingredients such argillaceous, calcareous, and gypsum into a fine powder produces Ordinary Portland Cement (OPC) [1]. Three different grades of this cement are offered, including OPC 33, OPC 43, and OPC 53. The most widely used cement in the world is OPC [2]. This kind of cement is suitable where building is carried out quickly. However, the production of OPC has significantly decreased as a result of the benefits of blended cement, such as PPC, which includes fewer environmental pollution, energy consumption, and more economic efficiency.

- **Ingredients in Regular Portland Cement**

Ordinary Portland cement is primarily manufactured using the following primary basic materials:

- Clays and shales containing argillaceous or alumina silicates.
- Calcium carbonate, also known as calcareous material, is found in marl, which is a clay and calcium carbonate mixture, as well as limestone and chalk.

The mixture is then crushed and pulverised in ball mills in a dry condition or combined in a wet state, with around two parts of calcareous material to one component of argillaceous materials [3]. The dry powder or wet slurry is next burned at a temperature of 1400°C to 1500°C in a rotary kiln. The kiln-produced clinker is first allowed to cool before being transferred to ball mills, where gypsum is added and it is ground to the necessary fineness depending on the class of product.

- **Production of OPC cement**

In general, there are five phases in the production of OPC cement.

- **Raw material grinding and crushing:** The initial phase in the production of cement involves crushing and grinding the raw ingredients into particles of the proper size. There are three different cement manufacturing processes.
- Wet Process
- Semi-Wet Process
- Dry Process

Depending on the type of manufacturing operation, several crushing and grinding processes are used. The raw materials are dried before being crushed in a dry process.

Blending or mixing: This phase involves blending or mixing the ground raw material (lime stone) with clay in the correct ratio (limestone: 75%, clay: 25%) and thoroughly mixing with the use of compressed air to obtain a uniform combination [4]. These mixtures are kept in silos for the dry process; slurry tanks are utilised for the wet process. The resulting substance, which contains 35–40% water, is known as slurry [5].

Warming: This is the most crucial phase in producing OPC cement, and conveyor belts are used to transfer the finished product into the kiln. The mixture is first heated to 550C, when all the moisture is removed and the clay is broken down into silica, aluminium oxide, and iron oxide. Cement Clinkers, which are balls of greenish-black or grey hue, are the final product produced in the kiln and are cooled down to 200C in the final stage [6].

Grinding: In this phase, the required quantity of gypsum and cement clinkers are combined and ground into extremely fine particles that are then kept in silos before being placed in cement bags and dispersed. Ordinarily, OPC cement has a three-month expiration date.

Utilizations of Ordinary Portland cement:

- It is employed for conventional construction tasks where particular qualities are not necessary, such as in the construction of reinforced concrete structures, bridges, and pavements, and in areas with typical soil conditions.
- Most concrete masonry units are made with this.

Benefits of Ordinary Portland cement

- However, it is less resistant to chemical attacks and has a greater resilience to cracking and shrinkage.
- OPC's initial setting time is quicker than PPC's, hence it is advised for projects where props will be taken down early.
- OPC cures faster than PPC, which lowers the cost of cure. Therefore, where treatment is too expensive, it is advised.

Ordinary Portland Cement (OPC) bricks Services and Qualities:

- It is frequently utilised in R.C.C. construction for a variety of engineering projects.
- Although the OPC cement does not produce any defects, it has a moderately low heat of hydration and moderate strength.
- It is primarily utilised in sidewalks.
- This cement can also be referred to as normal forming cement because it sets normally and does not gain strength very soon.

OPC brick disadvantages include:

Bricks made from Ordinary Portland Cement (OPC) can also be produced in addition to bricks made from clay. OPC and aggregates are combined to create OPC bricks. Although OPC has been a staple of the cement industry for many years, it still releases greenhouse gases into the atmosphere, primarily carbon dioxide (CO_2). The production of 1 kg of OPC requires around 1.5 kWh of energy and releases 1 kg of CO_2 into the atmosphere. Additionally, about 7% of all CO_2 produced is attributable to the use of OPC in the building industry. The CO_2 emissions of the cement industry. The creation of geopolymer bricks can eliminate all the problems caused by clay and OPC bricks because they have the following benefits:

- Since bricks are regular in size and shape compared to burnt clay brick, less mortar is needed during construction, which saves cement.
- When compared to burned clay bricks, geopolymer brick offers better engineering qualities.
- Bricks respect the environment
- Burning in a kiln is not necessary as a result, less energy is used.

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CHAPTER 4

GEOPOLYMERS AND OTHER GEOSYNTHETICS

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Natural resources are in extremely high demand due to the ever-increasing demand for infrastructure, commercial space, and housing worldwide [1]. The decision to use considerable amounts of natural resources to construct a new structure or infrastructure is made [2]. Although they might be able to reduce such usage, designers and builders are powerless to alter the total commitment [3]. A synthetic inorganic substance called geopolymer is being utilised as an alternative binder in a variety of construction-related products and applications. In order to create binders, Davidovits suggested using an alkaline liquid to react with the silicon (Si) and aluminium (Al) in a source material having a geological origin or in a by-product material like fly ash. He created the word "Geopolymer" to describe these binders because the process of polymerization that occurs in this instance is a chemical reaction [4].

The source materials and the alkaline liquids are the two basic components of geopolymers. Ideally, silicon (Si) and aluminium should be abundant in the source materials for geopolymers (Al). These might be organic substances like kaolinite and natural clays [5]. Source materials can also include by-products such fly ash, ground granulated blast furnace slag (GGBS), silica fume, slag, rice-husk ash, and red mud. The soluble alkali metals that are used to make the alkaline liquids are typically sodium- or potassium-based. A mixture of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate ($SiO2$) or potassium silicate is the alkaline liquid used in geopolymerization. Construction items including geopolymer bricks, tiles, and concrete are made with geopolymers. In contrast to Ordinary Portland Cements (OPC), geopolymers do not produce C-S-H gel (calcium-silicate-hydrates), thus they must use polycondensation of silica and alumina and high alkali content to create the matrix and strength of geopolymer concrete [6].

Earth has been utilised by humans as a building material for thousands of years. Numerous earthen structures dating back more than 500 years can be found all over the world. These buildings are all still in good shape and have a lot of occupants. Despite the fact that earth is an old construction material, many nations have kept the earth building tradition alive, and the technology is continually being modified to meet the needs of modern society. Due to its minimal carbon footprint, durability, and limitless recyclability, unsterilized earth outperforms all other building materials in terms of sustainability, including lumber. The following are some benefits of earthen structures:

- A local, all-natural resource
- Has a small carbon footprint
- Favourable for the climate inside

- Low cost of ownership
- Cleansing effect
- Moisture management
- Fireproofing
- Noise management
- Affordable
- Waste less

The following are drawbacks of using earth as a building material:

- A collapsed structure as a result of low resistance to water entry
- When exposed to varying weather conditions, structural cracks are caused by high shrinkage and swelling.
- Change in resistance to abrasion necessitates frequent maintenance and repairs.

One such substance that is extensively employed in the building sector is sand. After fresh water, sand is currently the most frequently used natural resource on the planet. The loss of sand along the shore and in streambeds causes widening of river mouths and coastal inlets as well as the deepening of estuaries and rivers. In light of this, the aim of sustainable construction is to utilise resources that are readily available locally without harming the environment or its inhabitants. Waste products from the iron smelting process include iron ore tailings (IOT). Iron ore tailings, which continue to be an overburden, were produced as a result of the surface mines' fast expansion. The safe disposal or use of this enormous mineral richness in the form of ultra-fine slime is still a very difficult and unresolved challenge. Utilizing iron ore tailings will aid in the discovery of novel building materials as well as the development of a suitable method for the disposal of tailings. Iron ore tailings, which are the by-products of the mining industry, are used in place of river sand in the production of concrete and bricks in order to lessen the negative effects of indiscriminately mining natural sand. An inorganic polymer known as geopolymer can be created at room temperature utilising industrial waste or by-products as source materials to create a solid binder that resembles and serves the same purpose as regular Portland cement (OPC). With better fire and chemical resistance as well as a reduction in CO2 emissions of between 80 and 90%, geopolymer binder can be used to completely or partially replace OPC in applications.

Earth and water are combined to create mud, which is then poured into moulds and dried outdoors. To help prevent cracking, straw or other fibres with a high tensile strength are frequently added to the bricks. Walls, vaults, and domes can be constructed with mud bricks and mud mortar. Geopolymer, an inorganic polymer, can be used as a binder with industrial waste/reject materials rich in silicon (Si) and aluminium (Al), such as fly ash, ground granulated blast furnace slag (GGBS), silica fume, slag, and rice-husk ash, to create geopolymers bricks and tiles that meet the standards of available commercially mud brick, are environmentally friendly, and can be recycled.

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CHAPTER 5

GEOPOLYMER CEMENTS

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The word "geopolymer" was coined in 1978 by a French academic by the name of Davidovits to designate a class of substances characterised by networks of inorganic molecules [1]. For silicon active sources (SI) and aluminium, the geopolymers will draw on thermally activated natural resources such Meta kaolinite or industrial wastes like fly ash or slag (Al) [2]. Water is evacuated after treatment and subsequent drying, not during the chemical reaction that occurs with the geopolymer concrete [3].

Geopolymer Concrete Types

Geopolymer concrete made of slag: Slag is a translucent by-product substance created during the melting and processing of iron ore. It is a mixture of silicon dioxide and steel oxide. Slag as an OPC replacement enhances performance, lowers lifespan costs, and boosts compressive strength. Core slag, steel slag, and iron blast furnace slag are a few examples [4].

Concrete made of rock-based geopolymers: This geopolymer is created by the MK-750 using natural rock-forming materials in place of slag. Quartz and feldspar are minerals that naturally create rocks [5].

Concrete made of Geopolymer and fly ash: Concrete made with fly ash-based geopolymer has better workability and greater compressive strength. With CO2 emissions, OPC costs are decreased and decreases drying shrinkage as well.

Concrete made of alkali-activated geopolymers: Heat curing for alkali activated geopolymers concrete is complete at 60 to 80 c. Fly-ash particles are encapsulated in alum inosilicate gel at a ratio of 1:2.

Slag-Based Geopolymer Concrete: This concrete contains silicates, fly ash, and blast furnace slag [6].

Ferro-silicate Geopolymer concrete: This ferro silicate geopolymers concrete has excessive iron oxide content and similar qualities to rock-based geopolymers. They are created by replacing some of the matrix's aluminium atoms.In place of conventional Portland concrete or cement in some constructions and offshore builds, geopolymer brick is regarded as a cutting-edge substance that offers a competitive alternative. It is particularly resistant to a number of the problems with durability that can lead to traditional concretes to crumble and crack. Utilizing unprocessed natural resources or industrial waste items allows for this. Portland concrete takes longer to cure than geopolymer concrete.

- **Use of Geopolymer Concrete: Its Importance**

Beginning to revolutionise concrete is this kind of concrete. Highway building projects and offshore applications are both using it more and more. Although contractors are starting to utilise it more and more in other construction projects, it is still a touch too expensive for the numerous do-it-yourself tasks.

- **Advantages:**

A more recent innovation is making conventional concrete appear less impressive. The top benefits of geopolymer concrete are listed below.

High Compressive Strength: Tests reveal that it has more compressive strength than normal concrete. It quickly increases strength and heals, making it a perfect option for rapid builds. The tensile strength of geopolymer-made concrete is high. It is less brittle and can withstand greater movement than Portland concrete. Although it is not completely earthquake proof, it is more resilient than conventional concrete.

Very Low Creep and Shrinkage: Concrete can shrink as a result of the cement drying and heating up or even as a result of moisture evaporating from the concrete, which can lead to significant and even deadly cracks in the concrete. Geopolymer-based concrete is less porous, shrinks considerably less, and does not hydrate. Very minimal creep is present in geopolymer concrete. The tendency of concrete to permanently deform as a consequence of the constant forces exerted upon it is known as creep in concrete terms.

Resistant to Heat and Cold: Even at temperatures of more than 2200 degrees Fahrenheit, it can remain stable. Cold and heat resistant. Concrete that is overheated may become unstable and may spall or have layers separate. It is resistant to freezing in cold weather. Despite the fact that cured concrete has very small holes, water can nevertheless enter. When it is below freezing, water freezes and expands, causing fissures to form. Geopolymer-made concrete won't freeze.

Chemical Resistance: It is extremely resistant to chemicals. Concrete made of geopolymer is immune to acids, harmful waste, and salt water. It is less likely for this concrete to corrode than traditional Portland concrete.

- **Problems with Geopolymer Concrete:**

Although geopolymer concrete seems to be the super concrete that will replace conventional Portland concrete, there are a few drawbacks, including:

Very Difficult to Produce: Geopolymer concrete requires special handling techniques and is incredibly difficult to produce. It asks for the use of chemicals, such as sodium hydroxide, that could be harmful to individuals.

Pre-Mix Only: Geopolymer concrete is only offered as a pre-cast or pre-mix product due to the hazards associated with its production.

Geopolymerization Process is Sensitive: Previous research has demonstrated that this field is very speculative and lacking in solid evidence. Lack of consistencyWhilegeopolymer concrete appears like the perfect solution and could be the best innovation since Portland cement, there are still too many instability problems that could result in significant hitches during the mixing and application of the concrete.

Geopolymer applications include:

Pavements:

- Using GPC, light pavement can be added.
- Water from bleeding does not surface.
- Sprays made of aliphatic alcohol are employed to prevent drying.

Reiterating Wall:

- The retaining wall was built using a 40MPa precast panel.
- The panels measure 2.4 metres in width by 6 metres in length.
- These panels were fixed in natural lighting.

Water Storage:

- Two water tanks were built, one using geopolymer concrete and the other 32MPa concrete mixed with cement.
- Deposition of calcium hydroxide caused OPCs to undergo autogenic therapy.
- There is not much calcium hydroxide in the GPC tank because of the gel swelling mechanism.
- Minor leak in the tank that heals quickly.

Boat Ramp:

- A geopolymer reinforced with GFRP was used to construct the ground slab for the ramp.
- Until activator chemicals are supplied, the entire component is inactive.

Concrete Beam:

- The formal three suspended floor level GCI building of GPC Beam and buildings has curved soffits.
- Water pipes were placed inside the top and bottom building sites to provide temperature-controlled hydronic heating.
- The GPC supported the three suspended floor levels of the GCI building with curved coffin beaming.
- Water pipes were installed into the top and bottom construction zones to provide regulated hydronic heating.
- The formal three suspend floor level GCI building of GPC Beam and buildings has curved soffits.
- They were equipped with water pipes to measure temperature.

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CHAPTER 6

MATERIAL CHARACTERISATION

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The principal by-product of the Bayer process for extracting aluminium from bauxite ores is red mud (RM), often referred to as bauxite residue [1]. By 2011, there were a stunning 2.7 billion tonnes of Red mud in circulation, and that number is rising by 120 million tonnes annually [2]. The NaOH solution used in the Bayer process yields RM, which has a pH value of 11.3 1.0, with a high water content and high alkalinity. Additionally, Red mud is known to have significantly higher concentrations of a number of hazardous and trace metals that are naturally present in many bauxite ores, including iron, manganese, copper, zinc, cadmium, lead, chromium, and nickel [3]. Due to these qualities, Red mud treatment and disposal are challenging for alumina refineries [4]. Red mud is now dumped into site-based waste lakes for additional dewatering, consolidation, and storage, which is very expensive due to required environmental monitoring and ongoing maintenance. Red mud, on the other hand, makes a good raw material for geo-polymerization due to its high Si and Al levels. Red mud can replace conventional alkali hydroxide, one of the most expensive raw materials used in the synthesis of geo-polymers, because to its high alkalinity. Out of the 65 million tonnes worldwide, there are approximately 3 million tonnes of bauxite reserves. Worldwide, 5.8 million tonnes of aluminium are produced each year. Red mud is obtained from Hindalco in Belgaum for the purposes of the current inquiry [5].

Fly ash: A building material called fly ash brick (FAB), specifically masonry units, is made of water and class C or class F fly ash. The bricks can withstand more than 100 freeze-thaw cycles when compressed at 28 MPa (272 atm), cured for 24 hours in a 66 °C steam bath, and toughened with an air entrainment agent. The brick is referred to as "self-cementing" because class C fly ash contains a lot of calcium oxide. The production process uses less energy, emits less mercury into the atmosphere, and frequently costs 20% less than making clay bricks the old-fashioned way. The following are the main components of fly ash bricks: Fly ash Sources: Cement, Sand, and Water [6].

India has 72% coal-based power plants. Each year, these power plants produce around 40 million tonnes of fly ash. Thermal power plants and other businesses that use coal as a fuel release undesirable ash and smoke, which results in the production of fly ash, which contains carbon dioxide. Fly ash is separated from other materials in all power plants and businesses utilising cyclone converters. Then, this fly ash is utilised as a raw material in the production of bricks.

Manufacture of Fly Ash Bricks:

The pozzalona cement mixture that makes up a fly ash brick has a slow setting time. The procedure is the same as for creating cement in cement factories, except that gypsum and coal are burned along with the clay and limestone. It is then blended and processed to create cement. Fly ash, which consists of burnt clay oxides produced by burning coal that contains clay from mines, is also mixed with the fly ash. In a pan, hydrated lime powder and gypsum are combined and pulverised to create pozzalona cement, which sets slowly. In a hydraulic press that is specifically made to deliver high pressure loads of around 350 kg/square inch slowly, the mix is compressed at low pressure and low moisture content. Fly ash bricks are given their maximum strength at this rate of pressure and with the pressure held for the necessary amount of time.

Silica fume: Microsilica, commonly referred to as silica fume, is an amorphous (non-crystalline) polymorph of silicon dioxide, generally known as silica (CAS number 69012-64-2, EINECS number 273-761-1). It is an ultrafine powder with spherical particles and an average particle diameter of 150 nm that is gathered as a waste product from the manufacturing of silicon and ferrosilicon alloys. The primary use is as a pozzolanic component in high performance concrete. Sometimes people confuse it with fumed silica (also known as pyrogenic silica, CAS number 112945-52-5). However, compared to silica fume, fumed silica has a distinct production method, particle makeup, and application domains.

A by-product of making silicon metal or ferrosilicon alloys is silica fume. Concrete is one of silica fume's best applications. It is an extremely reactive pozzolan due to its chemical and physical characteristics. Concrete made with silica fume can be extremely strong and long-lasting. When specified, silica fume is readily available from providers of concrete admixtures and is merely added during the preparation of concrete. Concrete contractors must take extra care when placing, finishing, and curing silica-fume concrete. Wood chips, coal, and quartz make up the basic materials. Instead of being dumped, the smoke produced by running a furnace is collected and sold as silica fume. The usage of this substance as a mineral additive in maybe the most significant application is concrete.

Advantages:

- Fresh and hardened concrete's characteristics are improved by silica fume.
- Silica fume lessens bleeding and segregation.
- Heightened toughness
- Low bleeding makes the finishing process effective.
- Early compressive strength that is high
- High elastic modulus and flexural strength
- Increased bond strength
- Since it reduces thermally induced cracking, it is appropriate for bulk concreting.

Disadvantages

- Issue of availability
- High price

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CHAPTER 7

INTRODUCTION TO GEO POLYMER MORTAR

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Geopolymers are inorganic polymers made of aluminosilicate that are cured at room temperature from a needed due [1]. It is determined that the reason metakaolin-based geopolymer ceramics are formed from solution rather than through high temperature diffusion is the strained character of the 5-coordination aluminium cation polyhedra. Alkali-based geopolymers have a nanoporous and nanoparticulate microstructure. This enables the production of silicon carbide (SiC), silicon nitride (Si3N4), or silicon aluminate (SiAlON) nanoparticles from geopolymers through carbothermal reductions and carbothermal similar concept under flowing argon or nitrogen and in the presence of extra carbon [2]. There have been produced crystallized geopolymer composites with adjustable thermal expansion coefficients. For composites having both ceramic, polymeric, and biological reinforcements, intrinsic mechanical properties as well as those of geopolymer composites are compiled. Geopolymers are inorganic aluminosilicate polymers that solidify into materials resembling ceramics at temperatures close to ambient [3]. These materials exhibit acceptable mechanical properties, strong heat stability above 1000 °C, and the ceramic-specific brittle failure. Due to their low processing temperature, they can be fabricated using the same methods as thermosetting resins, which are often impractical for ceramic materials. This opens up new opportunities for the production of composite materials that resemble ceramics [4].

The geopolymerization process has created new opportunities for the use of industrial wastes. Any aluminosilicate source could serve as a geopolymerization raw material. Numerous investigations have been conducted on geopolymers that use fly ash as their foundation material. Previous research has shown that fly ash and alkaline activators react very slowly at room temperature. As a result, the majority of these studies used the thermal curing approach to create fly ash-based geopolymers. By treating naturally occurring aluminosilicates (clays) or alumino - silicate wastes (fly ash and blast furnace slag) with alkali metals or acids, geopolymers are ceramic-like materials created at low temperatures. Similar to ceramics, they break down in a brittle manner, although fibre reinforcement can cause elegant failure. Organic reinforcing fibres can be employed without experiencing thermal deterioration because geopolymers are produced at low temperatures.

Geopolymers are covalently bonded, non-crystalline (amorphous), inorganic materials that are generally ceramic and aluminum-silicate. Some geopolymer blends contain obsidian (volcanic glass) particles as a main ingredient. Commercially available geopolymers can be utilised for a variety of applications, including coatings and adhesives that withstand fire and heat, high-temperature ceramics, novel binders for fire-resistant fibre composites, the encapsulation of radioactive and hazardous waste, and new concrete cements. Numerous scientific and industrial fields, including current organometallic chemistry, material science, colloid chemistry, geology, geology, and other engineering process technologies, are investigating the characteristics and applications of geopolymers. One of the main subfields of materials science, polymer science, chemistry, and technology is the study of geopolymers

[5]. Polymers can either be made of organic material, such as carbon, or inorganic material, like silicon. Natural polymers (such as rubber and cellulose), synthetic organic polymers (such as textile fibers, plastics, films, and elastomers), and natural biopolymers are all types of organic polymers (biology, medicine, pharmacy). The primary raw materials utilized in the manufacture of silicon-based polymers are minerals that form rocks in the earth, therefore the name geopolymer [6].

Geopolymer synthesis

Polymers can either be made of organic material, such as carbon, or inorganic material, like silicon. Natural polymers (such as rubber and cellulose), synthetic organic polymer (such as textile fibres, plastics, films, and elastomers), and natural biopolymers are all types of organic polymers (biology, medicine, pharmacy). The primary raw materials utilised in the manufacture of silicon-based polymer are minerals that form rocks in the earth, therefore the name geopolymer.

The needs of geopolymer chemistry, which is controlled by covalent bonding mechanisms, are no longer met by this ionic coordination model. Covalent bonding and the ionic notion (coordination) differ greatly from one another. In contrast to the Si-O-Si-molecular structure, where Si and O co-share only one electron, the double tetrahedron structure (coordination) involves the sharing of one oxygen anion, O_2.

Oligomers

Oligomers are low molecular weight polymers with a limited number of repeat units whose physical characteristics are strongly influenced by the chain length. Material science uses oligomers, which are essentially polymerization process intermediates, extensively and directly. Along with light cure systems, common oligomer types employed in applications include epoxy ester, urethane, epoxy, acrylic, polyester, and polycaprolactone.

Geopolymerization starts with oligomers

The process of joining several tiny molecules, known as oligomers, into a covalently bound network is called geopolymerization. The oligomers (dimer, trimer, tetramer, and pentamer) used in the geo-chemical syntheses give the actual unit structures for the three-dimensional macromolecular structure. The existence of isolated soluble alumino-silicate molecules in solution at relatively high concentrations and high pH was demonstrated by T.W. Swaddle and his team in 2000. Their experiment was carried out at extremely low temperatures, as low as 9 °C, which was a significant advance over previous research. In fact, it was found that the time scale for the polymerization of oligo-sialates at room temperature was approximately 100 milliseconds, which is 100–1000 times faster than that of the polymerization of ortho-silicate, oligo–siloxo units. The ambient temperature.

Geopolymer 3D-frameworks

Eopolymerization creates aluminosilicate frameworks that resemble those of minerals that produce rocks. But there are significant variances. A theoretical architecture for K-poly(sialate-siloxo) (K)-(Si-O-Al-Si-O) that was in line with the NMR spectra was published by Davidovits in 1994. Because he only paid attention to the interactions between Si, Al, Na, and K atoms, it does not demonstrate the presence of water in the structure. While many geopolymer industrial and commercial application operate at temperature of 95 °C, up to 1400 °C, i.e. at degrees above dehydroxylation, water is only present at temperatures below 150 °C to 200 °C, primarily in the form of -OH groups. However, researchers focused on waste management and cements, low temperature applications. They attempted to identify cation hydration and hydrogen atoms. This model depicts an inadequately reacted composite material (left in the figure) that contains free Si-OH groups that will eventually polycondense with opposing Al-O-K, creating Si-O-Al-O sialate linkages, with time or with temperature. The water produced by this reaction can either escape and be eliminated, remain in the pores like zeolitic water, or be connected with the framework. The book "Geopolymer Chemistry and Applications" describes a number of 3D-frameworks. Geopolymers grow increasingly more crystalline after dehydroxylation (and dehydration), which typically occurs above 250 °C (right in the figure), and crystallize at temperatures between 500 and 1000 °C (depending on the type of alkali cation present).

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CHAPTER 8

GEOPOLYMER CONCEPT

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Joseph Davidovits first proposed the geopolymer idea for alkali aluminosilicate binders in 1976. Similar to how these materials are thermoset, kaolinite is converted into tridimensionaltecto-aluminosilicates that are employed for polycondensation of biological resins at low temperatures. The procedure produces a nanocomposite that resembles a synthetic rock. In nature, the process of geosynthesis occurs a lot. Only 12% of the Earth's crust is made up of pure silica or quartz, while the remaining 55% of its volume is made up of siloxo-sialates and isolates. The geosynthesis process is based on the aluminium ion's effects on the silica backbone's crystallography (6-fold or 4-fold coordination) and indeed the chemical alterations that the same aluminium ion causes. These substances have an amorphous structure, various characteristics, and a chemical makeup that is comparable to zeolites and includes a polymeric Si-O-Al framework. The Al-Si source, the activator, the aggregate source and also its grading, the supply of water, the mix amounts of each content, the hardening/curing time, the temperature, the size of the particles, the calcium concentration, and the heat treatment, if used, are all important factors that affect the properties of these materials [1].

Obtaining of geopolymers

Geopolymers are inorganic polymeric substances created by combining an aluminosilicate dry solid with an alkaline solution and additional components as needed [2]. The main component is the source material, which must be high in silicon (Si) and aluminium (Al) [3]. Source materials might be "waste" materials like red mud, flash, slags, etc. or natural minerals like clays, kaolinite, etc. The liquid typically contains soluble alkali metals such as sodium (hydroxide or silicate) or potassium (hydroxide or silicate). The hardening process takes just four hours to complete, during which time they reach 70% of the final compressive strength [4].

The three-dimensional silico-aluminate connections (sialate) of SiO_4 and AlO_4 tetrahedra with shared oxygen atoms make up the architecture of geopolymers.

$$(SiO_2)_x\text{-}AlO_2\text{-}v^{*}aH_2O\ M^+$$

Where: M^+ is an alkali cation, either K^+ or Na^+; v is the degree of polymerization; x is the Si/Al ratio; and is the amount of water, if needed (if the alkali activator is liquid, no additional water is required to produce the reaction environment). The qualities of the geopolymer are heavily dependent on the value of z (z = 1–15, up to 300), and geopolymers with high z values (z>3) have rubbery and sticky capabilities. The end product of the exothermic process known as geopolymerization, which is carried out by oligomers, is a polymer with a very long reticular network, as well as a specialised tetragonal network of aluminates (AlO_4) and groups of silicates (SiO_4). Alkali ions like K^+, Na^+, or Li^+ equilibrate the connection between these tetrahedrons. Geopolymerization may generally be broken down into three steps. The first of these is dissolution, during which the solid alumino-silicate material dissolves due to the presence of water and an alkali activator. The reorientation process begins once some water has been removed, and the group atoms are now positioned in the structure.

Geopolymer concrete

A geopolymer is a synthetic inorganic substance that has been utilizedr for the past 40 years in a variety of applications, including waste encapsulation, construction materials, and heat-resistant ceramics. In order to develop new varieties of geopolymer concrete, our geopolymer team at Queen's University Belfast is actively researching the usage of geopolymer materials. One of the most popular building materials utilised worldwide in the construction of structures including buildings, bridges, and infrastructure is concrete. Despite being a superior building material, concrete produces a lot of carbon dioxide (CO2) during production [5].

By volume, natural quarry stone or sand or coarse and fine aggregate are the main components of traditional concrete. Water and a binder, such ordinary Portland cement, are added to the particles, forming a concrete matrix (OPC). To accomplish various desirable qualities, such as high power, workability, and durability, the amounts of each ingredient can be changed. OPC binder manufacturing is known to cause between 5 and 8% of the world's anthropogenic CO2 emissions, which results in severe environmental harm. The Cement Sustainability Initiative Putting the Numbers Right, created by the World Business Council for Sustainable Development, has tracked global cement output and CO_2 emissions since 1990.

As the industry increases the number of low-carbon/carbon-neutral fuel sources used to power cement kilns and increases the efficiency of the production process, the amount of CO2 produced per tonne of cement in the UK has decreased. Even while these reductions are encouraging, there is a limit to how much more CO_2 can be reduced per tonne of cement. OPC is created by heating limestone, which causes calcium carbonate (CaCO3) to break down into quicklime (CaO) and carbon dioxide (CO_2). About half of the total CO2 produced during the making of cement is released during the heating process known as calcination [6].

Benefits of geopolymer

Over traditional OPC concrete, geopolymer concretes have a variety of advantages, including:

- compared to OPC concretes, considerably reduced CO_2 emissions improved thermal insulating qualities by up to 90%
- increased temperature/fire resistance giving "waste" materials, which are frequently disposed of in landfills, a practical purpose.

Importance of geopolymer cement Concretes

About 2 tonnes of raw materials (shale and limestone) are needed to make one tonne of cement, which also produces 0.87 tonnes (less than 1 tonne) of CO2, about 3 kg of nitrogen oxide (NOx), an air pollutant that contributes to ground level smog, and 0.4 kg of PM10 (particulate matter of size 10 m), an airborne particulate that is harmful to the respiratory system when inhaled. The annual release of CO2 from all sources` is projected to be 23 billion tonnes, and the manufacturing of Portland cement produces around 7% of those emissions. The basic process of calcining limestone produces CO2, therefore further improvements are constrained. Nevertheless, the cement industry has been making great progress in decreasing CO_2 emissions through advancements in process technology and increases in process efficiency. The substantial environmental impact that the industry has is due in large part to the mining of limestone, which has an effect on local water regimes, air quality, and land use patterns. One of the major difficulties the industry is currently dealing with is dust emissions from the making of cement. Many thousands of tons of granular powder are handled by the sector. Even if only 0.1% of this is wasted to the environment.

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CHAPTER 9

INTRODUCTION TO 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 created, 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 metric tonnes of red mud [2]. 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 valorization, in order to produce components suitable for cement and concrete. This substance is also known by the less frequent names bauxite tailings, red slime, and alumina refinery leftovers [3].

Production of Red Mud

Red mud is a byproduct of the Haber - bosch 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 regularly than alumina. This ratio is influenced by the extraction conditions and the kind of sand used in the refining process [4]. The Bayer process is used by or more 60 manufacturing plants 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 preparation.

Under circumstances of high pressure 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. While the remaining aluminium hydroxide is calcined (heated) at over 1000 °C in rotary kilns or fluid flash calciners 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 broad 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 quantity of sodium hydroxide that was employed in the process, which causes the substance to exhibit a high pH/alkalinity, often >12. To increase the efficiency of the Bayer Process and lower production costs, several phases in the solid/liquid separation process are added to recycle as much sodium hydroxide as practicable from the waste back into the Bayer Process [5].

Composition of Red Mud

Solid and metallic oxides make up the majority of red mud's chemical makeup. Inorganic compounds, which can make up to 60% of the bulk, are what give the object its red colour. The mud has a pH between 10 and 13, and it is very basic. The titanium oxide, natural desires residual aluminium oxides, and silica are the other main constituents in addition to iron.

Insoluble metallic oxides make up the majority of the residue left over after the aluminium component has been extracted. The kind and grade of the bauxite ore, as well as the extraction procedures, will influence the amount of the oxides that a certain alumina refinery produces. The compositional ranges for typical chemical components are shown in the table below, however the values range greatly. With the exception of a small portion of the silicon component, the residue's composition generally reflects that of the non-aluminum components. While crystalline silica (quartz) will not react, reactive silica, which is a portion of the silicon present, will react under extraction conditions to produce sodium aluminium silicate and other related compounds [6].

The red mud problem in Aluminium production

Bauxite is the name of the mineral that is used to create aluminium. It also includes several additional gangue (tramp) elements, some of which are extremely uncommon and precious while others are exceedingly dangerous. It has alumina minerals and alumino-silicate clays as well. The Bayer method exposes the bauxite ore to extremely hot caustic soda (chemically: sodium hydroxide) in order to dissolve the insoluble components of the bauxite. The Bayer method yields red mud as an unwanted byproduct in addition to the extremely desirable Al oxide from 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.

More than 130 million tonnes of smelter plus chemical grade alumina are produced annually, mostly using the Bayer process. Between 1 and 1.5 tons of bauxite residue are produced each tonne of alumina globally. As a result, bauxite residue is generated in excess of 150 million tons annually, with even more than 6 million tones produced in Europe alone. The most 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 tons of this bauxite residue are now in storage. This yearly generation of red mud as a byproduct poses an immediate hazard to humans, animals, plants, and the ecosystem as a whole.

Bauxite residue

Iron oxide makes up up to 50% of the bauxite residue, while other materials including aluminium oxide, silica, titanium oxide, and others make up more than 10%. It is merely treated as garbage rather than being employed as a raw material in the manufacturing of iron, silicon, aluminium, plaster, building insulation, or other goods. Instead, the basic materials used to make all of these items come from mining operations, which have their own sustainability concerns and local environmental harm**.**

Because it includes significant amounts of lye, bauxite residue has a substantial alkali content (high pH values) (NaOH). It cannot, therefore, be simply released into the environment. NaOH is not particularly difficult to handle on its own, and it may be neutralized with chemicals like hydrochloric acid (HCl) to create fresh water and table salt. It is challenging to substitute unprocessed bauxite waste for iron ore in the steel sector due to the high salt level. It is challenging for the European alumina companies to develop sustainable solutions because they are engaged in international trade. Applications for bauxite residue outside of the aluminium industry are the subject of much research. The fact that there is so much bauxite residue is a pretty huge concern. Due to the massive amounts of mud that are created, there are also massive difficulties and issues with managing the area that it takes up. And even though we are surrounded by such a large number of books, we are completely aware that there are technology answers out there.

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CHAPTER 10

METAKAOLIN

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The most effective pozzolanic material for use in concrete is metakaolin, a type of pozzolan. It is created when china clay, a mineral called kaolin, is heated to a temperature between 600 and 800 oC, making it a manufactured good intended for use as opposed to a byproduct. Since its quality is monitored during production, it produces a material that is much less variable than industrial pozzolans, which are by-products. Metakaolin was successfully incorporated into the concrete when it was first used in the 1960s to build a number of significant dams in Brazil with the original goal of preventing any damage brought on by the alkali-silica reaction [1]. There are no interlayer cations or water molecules in the T-O clay mineral kaolinite. 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 [2]. 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 limestone powder is an exothermic reaction [3]. The transformation of kaolinite into metakaolin, an intricate amorphous structure with considerable long-range line due to layer stacking, occurs above the ambient temperature of dihydroxylation [4].

A large portion of the octahedral layer's aluminium becomes tetra- and 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 can 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 frequently mentioned. With a wider temperature range between dehydroxylation and recrystallization than other clay minerals, kaolinite favours the synthesis of metakaolin and the use of thermally activated kaolin clays as pozzolans [5].

Metakaolin is created by calcining pure or refined kaolinite clay at temperatures ranging from 650°C to 850°C, according to "P. Muralinathan, A. Joshua Daniel, and S. Sivakamasundari" (published in Published In journal of Applied and Pure Mathematics. After the burning process is finished, the material is suitably ground to the necessary fineness to enhance the strength and other property parameters of the concrete and cement mortar. The Metakaolin's primary raw material is kaolin clay. A material called kaolinite clay, which is fine and white in colour, is used to make porcelain. China clay or kaolinclay are other names for kaolinite clay.

In the same way as other mineral admixtures react with calcium hydroxide at room temperature to generate calcium silicate hydrate (C-S-H)-gel, metakaolin, which is composed of silica and alumina in an active state, raises the density of concrete and lowers its porosity.

As a result, the concrete becomes more durable and its permeability is reduced. As a filler, it will now penetrate the spaces (voids) between cement particles when employed in concrete, making the concrete more impermeable. It is said that the beginning and ultimate setting times of controlled concrete, which contains around 10% highly reactive metakaolin, are comparable. Due to its remarkably large specific surface area, which is close to 20m2/g, bleeding of concrete containing metakaolin may be disregarded. According to Zhang and Malhotra, metakaolin-infused concrete has a greater autogenous temperature rise than concrete that contains no metakaolin. compares the heat generating characteristics of concrete with and without metakaolin. Metakaolin increases water consumption, hence adding it to concrete may require superplasticizer to provide the required workability. According to the National Ready Mix Mortar Association, pozzolans are currently employed in more than half of the portland cement produced in the United States. The most popular pozzolans, fly ashes and silica fume, are difficult for ornamental concrete since they are frequently dark in colour and, as they are industrial wastes, their colour is not constant. Silica fume is indeed a reactive pozzolan that may produce concrete that is extremely strong and durable, but it also produces "sticky" mixes that are challenging to put and finish and call for specialised curing methods [6].

Contrarily, high-reactivity metakaolin (HRM), a white powder, brightens concrete. It is made specifically to be used with concrete and to provide uniform look. It is extremely reactive and performs on par with or better than silica fume. However, in contrast to silica fume, it yields a creamy cement that is simpler to pump, trowels "like butter," and can be dried using standard drying methods. High-reactivity metakaolin (HRM) is a processed foods reacting aluminosilicate pozzolan, a finely split substance that combines with slaked lime to create a robust, slowly setting cement at room temperature and at the presence of moisture. It is created by calcining refined kaolinite at temperatures usually between 650 and 700 °C in a rotating kiln that is heated externally. It is also stated that HRM is responsible for acceleratthe ion in the dehydration of ordinary portland cement (OPC), and its significant influence is observed within 24 hours. It also prevents the degradation of coAlkali-Silicaby – Silica Reaction (ASR), remarkably efficient during using recycled crushed glassware or glass fines as aggregate. The modified Chapelle test is used to determine how much slaked lime can be bound by mettakaolin.

Kaolinite, a mineral included in kaolin clay, is used to create metakaolin (also known as china clay). The substance is cleaned to get rid of substances that might stain concrete, and it is then heated under control to generate an amorphous aluminosilicate that reacts with concrete. Metakaolin, which is often used to replace 5 percent to 20 percent of the Portland cement in a combination, also lowers greenhouse gas emissions related to the production of Portland cement. Metakaolin is now available from a rising number of concrete makers, and it is also sold by wholesalers that provide plastering supplies to swimming pool constructors. White Portland Cement Concrete may safely employ metakaolin without sacrificing the shine. It provides the concrete the lighter value when mixed into regular grey Portland cement, opening up additional aesthetic possibilities. Additionally, it may be used to brighten and enhance color in integrally coloured concrete, and because of its homogeneity and whiteness, it is simpler to match colors.

One of the most often utilised building materials worldwide is concrete. Around 12 billion tonnes of concrete are produced and 1.6 billion tonnes of Portland cement (PC) are used worldwide each year by the concrete industry. In reality, 0.8 tonnes of CO_2 are released into the environment during the production of one tonne of cement. Five to eight percent of the world's CO_2 emissions come from the cement sector. Cement manufacturing produces not just CO2 emissions, but also SO3 and NOx, which can contribute to acid rain and the greenhouse effect.

MK enhances the workability, mechanical qualities, and durability of concrete in addition to having a good environmental impact. The phrase "MKA pozzolan" describes a silecioussubstance that, when finely separated from calcium hydroxide in the presence of water, chemically interacts to generate cementitious compounds. Alkali-activated MK (future cement) or MK geopolymers are being employed recently in a similar effort to lessen the environmental damage caused by the cement industry. The author of this study reviewed the literature with an emphasis on the history of kaolin, MK sources, various calcination temperatures, various calcination times, and the physical and chemical characteristics of MK. The MK employed as cementitious material was the primary goal of both the calcination temperatures and times.

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CHAPTER 11

GGBS (Ground Granulated Blast-furnace Slag)

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GGBS (Ground Granulated Blast-furnace Slag) is a cement that is mostly utilized in concrete. About 1,500 °C is the operating temperature of blast furnaces, which are supplied with a precisely regulated combination of limestone, coke, and iron ore [1]. The leftover components create a slag that floats on the iron's surface once the iron ore is converted to iron. The research being done to alter the characteristics of concrete has improved along with concrete technology. The term "concrete admixtures" refers to a variety of extra components that have been discovered by several studies to alter the characteristics of concrete [2]. Different concrete admixtures affect the concrete mix differently and improve different concrete qualities in different ways [3]. Some concrete admixtures are used in place of Portland cement because they also possess cementitious qualities. These substances are also referred as aspozzolanic admixtures, mineral admixtures, or extra cementing ingredients. Here, we've covered ground granulated blast furnace slag as an example of one such cementitious material. As a pozzolanic admixture and mineral admixture, GGBS is essentially a waste product from blast furnaces [4].

Slag

A non-metallic residue of the blast furnaces used to manufacture iron is called ground granulated blast furnace slag (GGBS). Silicates and aluminosilicate of calcium and other bases make up the bulk of blast furnace slag that has been ground into granules. Its particles are less than 45 microns in size and have a specific surface area of 400 to 600 m2/kg. To put it simply, ground granulated blast slag is a waste material used to make pig iron. For every tonne of pig iron produced, around 300kg of slag are created. Chemically speaking, it is a combination of lime, silica, and alumina, which are also present in the majority of cementitious materials. Depending on how the slag is cooled, the chemical and physical structure of the slag might vary[5].

A non-metallic residue of the blast furnaces used to manufacture iron is called ground granulated blast furnace slag (GGBS). Silicates and alum inosilicate of calcium and other bases make up the bulk of blast furnace slag that has been ground into granules. Its particles are less than 45 microns in size and have a specific surface area of 400 to 600 m2/kg. To put it simply, ground granulated blast slag is a waste material used to make pig iron. For every tonne of pig iron produced, around 300kg of slag are created.

Chemically speaking, it is a combination of lime, silica, and alumina, which are also present in the majority of cementitious materials. Depending on how the slag is cooled, the chemical and physical structure of the slag might vary. Granulated blast furnace slag is produced by quickly cooling molten ash or liquid with water. The slag is broken down and turned into amorphous granules throughout this process (glass). The final step in creating ground granular blast furnace slag is grinding granulated slag to the appropriate fineness. The amount of GGBS in the cementitious material determines how long it takes for concrete manufactured with GGBS cement to set compared to conventional concrete and how quickly it gains strength.

- Utilizing GGBFS results in less hydration heat and less temperature increase.
- Using GGBS makes it extremely simple to prevent cold joints.
- Concrete from a furnace has improved workability and is simpler to place and compress.
- Due to the modest early age temperature increase, using ground granulated blast furnace ash decreases the danger of thermal cracking in big pours.
- Corrosion of the reinforcement is less likely when using furnace concrete. Because of its great resistance to chloride infiltration and increased resistance to attack from sulphates and other chemicals, enhanced slag cement exhibits these qualities. Furnace concrete guarantees a better level of structural durability as a result.
- The resistance to internal reactions, such as a chloride reaction, is provided by GGBS concrete.
- Blast furnace slag that has been ground into small granules is used for in-situ stabilisation of soil in addition to concrete and other uses.

Disadvantages of GGBS

The usage of ground granulated blast furnace slag may have an impact on building timelines when rapid setting is necessary due to the setting time delay and may not be the best option in such locations. Early age strength development is slower if GGBFS replacement with cement is higher. Since GGBS is often provided in bulk and is only cost-effective if the building site is close to such sources, it is not available or preferred for smaller-scale concrete production [6].

Permeability and Chemical Stability of GGBS

When GGBFS is used in concrete, the microstructure of the matrix is denser than it would be with regular concrete. With less permeability and more stability against chemical assaults such chloride, sulphate attack, alkali-aggregate reaction, etc., this improves the durability qualities. the partition coefficient of the concrete exposed to chloride ions is at least 10 times smaller than that of the concrete in which the cementitious material is entirely composed of Portland cement when the GGBS content is at least 60% by mass of the cementitious material and the w/c ratio is 0.50.

GGBS is a by-product of another business; it doesn't call for the extraction of any new minerals and doesn't generate any waste streams. In comparison to conventional cement, it is predicted that its manufacture consumes less than 20% less energy and emits less than 10% less CO2. Additionally, it guarantees that fewer industrial byproducts wind up in landfills and has low amounts of embodied carbon. GGBS typically replaces between 30% and 70% of the cement in the concrete, although that percentage can increase to 85%. Typically, it substitutes cement in a precise 1:1 ratio, thus one tonne of Cementitious materials in the mix would be swapped out for one tonne of GGBS. Typically, it is introduced at the mixing step.

A brand-new type of concrete that has emerged in recent decades is high performance concrete (HPC). HPC has a low water content, and by combining ideal granular packing with the inclusion of excessive-range water reducing admixtures, it may achieve the necessary rheological qualities. The virtual removal of cavities within the concrete matrix that cause degradation is one of the key high-quality benefits in the production of HPC.

As a result, HPC tends to display exceptional properties such enhanced energy, endurance, and long-term balance. The concrete systems' long-term endurance must constantly be taken into account in competitive settings. Regarding buildings that come into constant touch with water.

Kaolin

The primary source of MK is kaolin following proper processing. In tetrahedral and octahedral coordination, respectively, silica and alumina alternately layer to form the phyllosilicate known as kaolin. This typical feature of clay minerals, electrically neutral crystalline layer structure, results in tiny particle size and plate-like morphology and permits the particles to glide easily over one another, giving rise to physical qualities including softness, soapy sensation, and facile cleavage.

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CHAPTER 12

CLASSIFICATION OF MORTAR

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When cement mortar dries, it hardens, creating a solid aggregate structure. However, because mortar can be repaired more cheaply and easily than building blocks, it acts as the sacrificial element in masonry and is therefore a weaker component than the blocks [1]. Sand, an adhesive, and water are the main ingredients used by bricklayers to create mortar. Since the early 20th century, Portland cement has been the most used binder, however some specialised new building still uses the antiquated binder lime mortar. Particularly inside the repair and repointing of historic buildings and structures, lime, lime mortar, plus gypsum in the form of plaster of Paris are used so that the repair materials will be comparable in performance and appearance [2]. To bond construction blocks like stones, bricks, and concrete, to fill and seal the crooked spaces between them, to distribute the weight of them uniformly, and occasionally to add beautiful colours or patterns to masonry walls, mortar is a workable paste that hardens. In its widest definition, mortar encompasses cement mortar as well as pitch, asphalt, and loose mud or clay, such as the ones used between mud bricks. Old French mortier, meaning "builder's mortar, plaster; mixing basin," is where the term "mortar" originates [3].

The second instance of concrete and mortar construction in history was in Greece. Megara's subterranean aqueduct excavations uncovered a reservoir that was covered in a 12 mm layer of pozzolanic mortar. This waterway was built in 500 BCE. Pozzolanic mortar, often known as hydraulic cement, is a lime-based mortar that is created with a volcanic ash component that enables it to solidify underwater. Greek colony of Dicaearchia (Pozzuoli) in Naples, Italy, or the Greek islands of Thira and Nisiros were the sources of the volcanic ash used by the Greeks. The use and production of what is now known as pozzolanic mortars and cement were later enhanced by the Romans [4].

Ancient China did not have hydraulic mortar, presumably because there was not enough volcanic ash available. Sticky rice soup and slaked lime were combined in the year 500 CE to create an inorganic-organic compound sticky rice mortar that was stronger and more water-resistant than lime mortar. It is unclear how the skill of creating hydraulic mortar and cement, which the Greeks and Romans developed and used so extensively, was lost for about two thousand years. The sole active component in the mortar throughout the Middle Ages, when the Gothic cathedrals were also being constructed, was lime. Many constructions over the years have been harmed by wind-blown rain because cured lime mortar may be damaged by contact with water [5].

Joseph Aspdin created it in 1794, and it was patented on December 18, 1824, primarily as a consequence of efforts to create a stronger mortar. It gained popularity in the late nineteenth century and surpassed lime mortar in popularity as a building material by 1930. The advantages of Portland cement is that it sets hard and quickly, allowing a faster pace of construction. Furthermore, fewer skilled workers are required in building a structure with

Portland cement [6]. However, it is generally advised against using Portland cement for repairing or repointing older buildings constructed with lime mortar, as these structures need the flexibility, softness, and breathability of lime to function well [7].

Lime mortar

By adding impure limestone in the kiln to create a hydraulic lime that will set on presence of water, the setting process may be sped up. Such lime must be kept as a dry powder in storage. As an alternative, pozzolanic components like brick dust or calcined clay can be included in the mortar mixture. By reacting with the water, the addition of a cement ingredient causes the mortar to set very rapidly. Using Portland cement mortars to restore ancient structures that were first built using lime mortar would be troublesome. Because lime mortar is weaker than cement mortar, brickwork may adapt to shifting earth or other changing conditions to a certain extent. Mortar made of cement is stiffer and offers limited flexibility. This type of lime mortar, sometimes referred to as non-hydraulic sets very slowly as a result of air carbon dioxide reaction. It might take millennia for a really thick wall composed of lime mortar to fully set and harden. Using unclean limestones in the kiln to create a hydraulic lime that will set when it comes into contact with water might speed up the setting process. Such lime must be kept as a powder in storage. As an alternative, pozzolanic components like brick dust or calcined clay can be included in the mortar mixture. This will produce a consistent findings, causing the mortar to set quite rapidly due to a reaction with the mortar's water

Pozzolanic mortar

A fine, sandy volcanic ash is called pozzolana. It was initially found and unearthed in Pozzuoli, Italy, a town close to Mount Vesuvius, and was afterwards mined there as well. The Romans discovered that adding pozzolana to lime mortar made the lime build up quite rapidly and even in the presence of water. The Roman architect Vitruvius mentioned four different kinds of pozzolana. It may be found in several shades, including black, white, grey, and red, throughout all of Italy's volcanic regions. Since then, the term "pozzolana" has evolved to refer to any siliceous or aluminous ingredient added to slaked calcium to form hydraulic cement.

Mortar is a binding agent that is often created by combining fine aggregate (sand, surki, sawdust, etc.) with rainwater and binding or cementing materials (lime or cement). Bricks, stones, and other construction materials are joined together by mortar. In masonry made of brick or stone, it can also provide a beautiful pattern. The use of mortar dates back to the start of civilization. The Egyptians made use of lime mortars 2000 years ago**.** Today, rather than being mixed on-site, more than 80% of mortars used in the UK are sourced from factory-produced sources. Their use is a reflection of the growing need for high-quality building materials in the construction of our built environment. Factory-made mortars provide:

- Precise cement composition.
- Consistent strength, quality, and color.
- Decreased labour and mixing expenses.
- Decreased waste.
- conformity to specifications
- Upon request, technical assistance and test results.

As a binder material, red mud, GGBS, and Metakaolin are employed. Process employed an alkaline solution of sodium hydroxide and sodium silicate. Red mud may replace clay by up to 50%. Strength was increased by using metakaolin. Compressive strength reaches a range of 38.1 N/mm2 with red mud content of 40 to 60% and activator content, and water absorption reaches a range of 18.9% to 8.77%. Later, a chosen mixture of mixes was employed to create a brick masonry prism. According to the experiments, geopolymer cubes may be made with compressive strengths ranging from 14.1 MPa to 38.1 MPa. Conclusion: Geopolymerizationof red mud, GGBS, M sand, and Metakaolin can be utilised as a sustainable substitute for traditional mortar.

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