Reduction in Environment Load by Utilization of Alumina, Silica Wastes & Fly Ash in Geo-polymer Production

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ABSTRACT

Building Industry has been recognized to be the largest single consumer of finite natural resources. Rapid depletion of natural resources and consequential rise in their price has to be absorbed largely by the industry itself. High competition in the free market does not permit the transfer of resultant increase in the cost of production to consumers. Industry is, therefore, hard pressed to exploit all the engineering, technological and managerial skills to reduce manufacturing costs. Judicious selection of resources and their efficient utilization should surely help a lot in achieving the defined objective through mitigation or at least substantial reduction of wastages of all kinds. Waste is visualized as any unnecessary input to or any undesirable output from a system.

Waste can occur in variety of forms and at number of stages in an engineering industry. Besides the scrap produced and undesirable outcomes of the processes, there are other forms of waste such as using more expensive materials than required, consuming excessive energy, using old technology, keeping higher inventories, under-utilization of machinery and manpower and so on. Concerted and sustained efforts alone using appropriate technology at every stage of production activity can check waste generation. In the given situation, waste management program gains importance. For an effective management approach, it is prudent to deal with waste at a system level.

Despite the industry being alive to the prevailing dismal situation it is continuing with the old practices or have marginally improved. It is largely due to lack of awareness and familiarity on the part of the industry, with the tools and techniques of waste management and their application in the real life situations. Accordingly, industry is not in a position to precisely work out the amount of waste being generated and effectively mitigates it. This paper studies the utilization of alumina waste and silica waste for geopolymer production. The study makes the reuse of aluminum hydroxide waste (Al-waste) for geopolymers.

KEYWORDS: Alumina, Silica, Fly ash, Composite Materials etc.

INTRODUCTION

Metal composite materials have discovered application in numerous regions of everyday life for a long while in structural building. Aluminum is a concoction component in the boron assembly with both being of group 13. It is shiny white, and it is insoluble in water under typical conditions. Aluminum compounds are composites in which Aluminum (Al) is the most grounded metal. The commonplace alloying components are silicon and zinc. There are two divisions, to be specific, throwing combinations and creating compounds. Fly fiery debris is one of the buildups created in the burning of coal. It is a mechanical by-item recuperated from the vent gas of coal consuming electric power plants. In view of the source and cosmetics of the coal being singed, the fly fiery remains segments created changes significantly. When all is said and done, fly fiery debris contains Fe_2O_3 [Iron(III) Oxide], Al_2O_3[Aluminum Oxide], SiO_2[Silicon Dioxide] as significant extent and oxides of Ca[Calcium], Na[Sodium], Mg[Magnesium] and so on at a minor extent. Depending on the composition of the coal, these particulates can contain toxic elements and irritants such as Cd[Cadmium], SiO_2[silicon dioxide], As[Arsenic], and CaO_2 [Calcium Oxide]. Fly powder particles are for the most part round fit as a fiddle and range from under 1 µm to 100 µm with an upper zone, in the vicinity of 250 and 600 m^2/ kg. The specific gravity changes between 0.6-2.8 g/cc. Physical properties of fly fiery debris basically rely on upon the kind of coal consumed and the states of consuming. Class F sort fly fiery debris is created from consuming high rank (containing high carbon content) coals, for example, Anthracite and Bituminous coals, while, Class C fly slag is delivered from low rank coals such as Lignite and Sub-Bituminous Coals. Cement is the world's most used construction binder material. Cement production emits large amounts of CO_2 and consumes significant amount of energy. Production of one ton of Portland cement releases one ton of CO_2 into the atmosphere. The global cement industry contributes around 6% of all CO_2 emissions. It is a typical perspective that finding an option material to the Portland concrete is inescapable. A few analysts have expressed that CO_2 outflow could increment by half contrasted and the present degree. Therefore, the impact of cement production on the environment issues a significant challenge to concrete industries in the future. As a result, it is imperative to search a new concrete material that can replace traditional Portland cement concrete, which is environmentally viable, yet provides an effective building material. Promoting low-emission concretes is essential in order to face the crucial challenge to reduce the environmental impact of the construction sector and the concrete industry and to limit the impact of climate change. One method for diminishing these CO2 discharges is the utilization of mixed concretes in which a piece of the Portland bond clinker is supplanted with supplementary cementations materials (SCMs). The most well-known SCMs utilized as a part of high-volume applications are fly fiery debris (FA) and ground granulated impact heater slag (GGBFS). Fly-fiery remains based and GGBFS based mixed bonds are broadly utilized yet cutoff points are forced on the OPC substitution. By and large, mixed bonds still contain more OPC clinker than SCM.

Aluminum

It is a silvery white element of the boron group of chemical elements in the periodic table. It has the symbol Al, having atomic number 13 and is in the 3RD Period and Group 13. It has a Neon core with a $3s^2\ 3p^1$ configuration i.e. it has 3 electrons in its valence shell. It is not soluble in water under normal conditions. Aluminum is the third most abundant element (after oxygen and silicon), and the most abundant metal, in the Earth's crust. It makes up about 8% by weight of the Earth's solid surface. Aluminum metal is so chemically reactive that native specimens are rare and limited to extreme reducing environments. Instead, it is found combined in over 270 different minerals. The chief ore of aluminum is bauxite. Bauxite is a rock formed from a reddish clay material called laterite soil and is primarily comprised of aluminum oxide compounds (alumina), silica, iron oxides and titanium dioxide.

Aluminum is remarkable for the metal's low density and for its ability to resist corrosion due to the phenomenon of passivation. Structural components made from aluminum and its alloys are vital to the aerospace industry and are important in other areas of transportation and structural materials. The most supportive compounds of aluminum, at least on a weight basis, are the oxides and sulphates. In keeping with its pervasiveness, aluminum is well tolerated by plants and animals. Owing to their prevalence, potential beneficial (or otherwise) biological roles of aluminum compounds are of continuing importance.
Aluminium also acts as a reducing agent in the Alumino-Thermite process. The reduction of ferrous oxide in presence of aluminium results in the formation of ferrous metal which is an exothermic reaction.

$$Fe_2O_3 + 2Al \rightarrow Al_2O_3 + 2Fe$$

Characteristics:

Physical:

Aluminum is a comparatively soft, durable, lightweight, ductile and malleable metal with appearance ranging from silvery to dull gray, depending on the surface roughness. It is nonmagnetic and does not easily ignite. A brand new film of aluminum film serves as a good reflector (approximately 92%) of visible light and an excellent reflector (as much as 98%) of medium and far infrared radiation. The yield strength of pure aluminium is 7–11 MPa, while aluminium alloys have yield strengths ranging from 200 MPa to 600 MPa. Aluminium has about one-third the density and stiffness of steel. It is easily machined, cast, drawn and extruded. Aluminum atoms are in order.

Chemical:

It has a remarkable Corrosion Resistance because of the thin layer of aluminum oxide that forms on the surface of the metal when it is exposed to air, effectively preventing further oxidation. This process is known as

Passivation For aluminum, this reaction is oxidation, known as Anodization. The strongest aluminum alloys are less corrosion resistant due to galvanic reactions with alloyed copper. This corrosion resistance is also often greatly reduced by aqueous salts, particularly in the presence of dissimilar metals.

Owing to its resistance to corrosion, aluminum is one of the few metals that retain their silvery reflectance in finely powdered form, making it an important component of silver-colored paints. Aluminum mirror finish has the highest reflectance of any metal in the 200–400 nm (UV) and the 3,000–10,000 nm (far IR) regions; in the 400–700 nm visible range it is slightly outperformed by tin and silver and in the 700–3000 (near IR) by silver, gold, and copper.

Aluminum is oxidized by water to give hydrogen and heat:

$$2\ Al + 3\ H_2O \rightarrow Al_2O_3 + 3\ H_2 + \Delta$$

Natural occurrence:

In the Earth's crust, aluminum is the largely abundant (8.3% by weight) metallic element and the third most abundant of all essentials (after oxygen and silicon). Because of its strong affinity to oxygen, it is almost never found in the elemental state; instead it is found in oxides or silicates. Feldspars, the most common group of minerals in the Earth's crust, are alumina silicates. Native aluminum metal can only be found as a minor phase in low oxygen fugacity environments, such as the interiors of certain volcanoes. Native aluminum has been reported in cold seeps in the north eastern continental slope of the South China Sea. It also resides in the minerals beryl, cryolite, garnet, spinel and turquoise.

Applications:

Aluminum is the most extensively used non-ferrous metal. Global production of aluminium in 2005 was 31.9 million tonnes. It exceeded that of any other metal except iron (837.5 million tonnes). Forecast for 2012 is 42–45 million tones, driven by rising Chinese output. Aluminium is almost always alloyed, which markedly improves its mechanical properties, especially when tempered. For example, the common aluminum foils and beverage cans are alloys of 92% to 99% aluminum. The main alloying agents are copper, zinc, magnesium, manganese, and silicon (e.g., duralumin) and the levels of these other metals are in the range of a few percent by heaviness.

Some of the a lot of uses for aluminum metal are in:

- Transportation (automobiles, aircraft, trucks, railway cars, marine vessels, bicycles, etc.) as sheet, tube, castings, etc.
- Packaging (cans, foil, etc.)
- Construction (windows, doors, siding, building wire, etc.).
- A broad range of household items, from cooking utensils to baseball bats, watches.
- Street lighting pillars, sailing ship masts, walking poles, etc.
- A range of countries, including France, Italy, Poland, Finland, Romania, Israel, and the former Yugoslavia, have issued coins struck in aluminium or aluminium-copper alloys.

Silicon Carbide:-

Silicon carbide is composed of tetrahedra of carbon and silicon atoms with well-built bonds in the crystal lattice. This produces a very solid and strong material. Silicon carbide is not attacked by any acids or alkalis or molten salts up to 800°C. In air, SiC forms a protective silicon oxide coating at 1200°C and is able to be used up to 1600°C. The high thermal conductivity coupled with low thermal expansion and high strength gives this material exceptional thermal shock resistant qualities. Silicon carbide ceramics with little or no grain boundary impurities maintain their strength to very high temperatures, approaching 1600°C with no strength loss. Chemical purity, resistance to chemical attack at temperature, and strength retention at high temperatures has made this material very popular as wafer tray supports and paddles in semiconductor furnaces. The electrical conduction of the material has lead to its use in resistance heating elements for electric furnaces, and as a key component in thermistors (temperature variable resistors) and in varistors (voltage variable resistors).

Properties:

Silicon Carbide is the only chemical compound of carbon and silicon. It was originally produced by a high temperature electro-chemical reaction of sand and carbon. Silicon carbide is an excellent abrasive and has been produced and made into grinding wheels and other abrasive products for over one hundred years. Today the material has been developed into a high quality technical grade ceramic with very good mechanical properties. It is used in abrasives, refractory's, ceramics, and numerous high-performance applications. The material can also be made an electrical conductor and has applications in resistance heating, flame igniters and electronic components. Structural and wear applications are constantly developing.

Stir casting:-

Stir-casting techniques are currently the simplest and most commercial method of production of MMCs. This approach involves mechanical mixing of the reinforcement particulate into a molten metal bath and transferred the mixture directly to a shaped mould prior to complete solidification. In this process, the crucial thing is to create good wetting between the particulate reinforcement and the molten metal. Micro structural in homogeneities can cause notably particle agglomeration and sedimentation in the melt and subsequently during solidification. In homogeneity in reinforcement distribution in these cast composites could also be a problem as a result of interaction between suspended ceramic particles and moving solid-liquid interface during solidification. This process has main advantage that the production costs of MMCs are very low.

GEOPOLYMERS

Geopolymer is emerging as another development material which could be delivered by the substance activity of inorganic atoms, without utilizing any Portland cement. The geopolymer binder can be produced through chemical reaction between alumino-silicate materials such as fly ash or metakaolin that are rich in SiO_2 and Al_2O_3 and alkaline solutions such as NaOH[Sodium Hydroxide] or $(Na_2O)_x{\cdot}(SiO_2)_y$ [Sodium Silicate]. Geopolymer is a alumino-silicate material which can be applied for many applications due to the fact that geopolymers have several attractive properties of high strength, low permeability, high acid resistance, hazardous materials, and immobilization of toxic materials (Onutai, S). Generally, the geopolymer materials are activated in a high alkali solution (Davidovits, 2008) as alumino silicate geopolymers consist of tetrahedral AlO_4 and SiO_4 units that occur easily in a poly condensed polymer framework in high-alkali conditions (Davidovits, 1991). In geopolymer materials that are prepared at low temperatures with high alkali solutions, generally alumino-silicate materials such as slag metakaolin and fly ash (Ryu, Lee, Koh, & Chung, 2013) are mixed with alkaline solution. Fly ash is a suitable material for making geopolymeric binder because of its pertinent silica and alumina composition and low water demand. Low-calcium fly ash-based geoploymers concrete cured at high temperature are reported to have good mechanical properties in both short and long term tests. The structural behavior of heat-cured fly ash geopolymer concrete has been found to be similar or superior to that of OPC concrete when tested for reinforced columns and beams, bonding and bending properties.

The hardening mechanism for geopolymers essentially contains the polycondensation reaction of geopolymeric precursors, regularly aluminosilicate oxides, with alkali polysilicates yielding polymeric silicon –oxygen aluminum framework.

Consistently, aluminum utilization is expanding for some applications, for example, anodizing forms for delivering enriching and defensive films on aluminum and amalgams. The initial step of anodizing procedures is pre-treatment of the metal. The second step is scratching the surface of the aluminum metal in pre-treatment before fixing and shading. This step, which most often uses NaOH in warm solution, gives the metal surface a light grey sati finish. After etching, Al-waste in gibbsite phase ($Al(OH)_3$) is wasted: typically about 360 tons/year from various industries are discarded in landfills. Utilization of non-renewable energy sources in power plants for vitality creation is expanding, leaving fly ashes waste. Around 3 million tons/year of such modern waste are delivered by substantial and little power plants. For fly ash, pozzolanic materials are normally reused in cement and concrete industries. Subsequently, these fly ashes ought to be recovered to create novel materials. A pozzolan is a siliceous and aluminous material which, in itself, possesses little or no cementitious value but which when finely divided in the presence of water, reacts chemically with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties. On the off chance that individuals can do this, then such materials can end up noticeably reasonable items that give natural, social, and monetary advantages. Particularly, as sustainable assets of both aluminum hydroxide waste and fly ashes remains, these appear to be pertinent for reuse in solid materials. The study would also analysis the effect of degree of heating on compressive strength after specified period of heat curing of fly ash- aluminum based geopolymer mortar.

AIM

The present study has the following objective:

> To get the maximum use of the industrial wastes like aluminum, silica and fly ash material in order to make sustainable concrete materials and enhance the quality of environment.

Geopolymerization

The geopolymerization procedure includes three separate procedures and during initial mixing, the alkaline solution dissolves silicon and aluminum ions in the raw material (slag, fly ash, bentonite, silica fume, etc.). It is additionally comprehended that the silicon or aluminum hydroxide atoms experience a condensation reaction where nearby hydroxyl particles from these close neighbors gather to frame an oxygen bond connecting the water atom, and it is seen that every oxygen bond is shaped subsequently of a condensation reaction and in this way bonds the neighboring Si or Al tetrahedra.

Polymers are sensitive towards heat and can shape a more strong chain because of polycondensation. It is noted from the essential chemical reaction when subjected to heat causes silicon and aluminum hydroxide atoms to polycondense or polymerize, to shape unbending chains or nets of oxygen bonded tetrahedra. Likewise, at higher raised temperatures it produces more strong geopolymers. Aluminum particles require metallic Na+ particles for charge balance. Davidovits and Davidovics detailed that geopolymers can solidify quickly at room temperature and can pick up the compressive strength up to 21 MPa in 1 day. Comrie et al. led tests on geopolymer mortars and revealed that the vast majority of the 28-day strength was picked up in the initial 3 days of curing. Geopolymer concrete is discovered to be corrosive safe, in light of the fact that, not at all like the Portland cement, geopolymer concretes don't rely on upon lime and acid resistant. Most of the studies presumed that the NaOH solution plays the vital role on the strength of the fly ash-based geopolymers. The expansion of calcium oxide alongside sodium hydroxide quickens the geopolymerisation in fly powder. Guo et al. led trial considers in class C fly ash based geopolymers utilizing a blended alkali activator of sodium hydroxide and sodium silicate solution. Geopolymers are like zeolites in chemical composition, yet they present an amorphous microstructure. They form by the co-polymerisation of individual alumino and silicate species, which originates from the disintegration of silicon and aluminum containing source materials at a high pH in the presence of soluble alkali metal silicates. It has been proved before that geopolymerisation can change an extensive variety of waste alumino-silicate materials into building and mining materials with brilliant chemical and physical properties, for example, fire and acid resistance. All Al–Si minerals are to some degree solvent in concentrated basic solutions, with all in higher degree of dissolution in NaOH than in KOH medium. Factual examination has uncovered that framework silicates demonstrate a higher degree of dissolution in alkaline solution than the chain, sheet and ring structures. In general, minerals with a higher degree of disintegration show better compressive quality after geopolymerisation. The utilization of KOH rather than NaOH favors the geopolymerisation. The stream outline of geopolymerisation has been appeared in Figure 1.

These alumino-silicate materials displays excellent physical and chemical properties and a diverse scope of potential applications, including precast structures and non-structural elements, containment and immobilization of toxic, advanced structural tooling and refractory ceramics, hazardous and radioactive wastes, concrete pavements and products, and fire resistant composites used in buildings, racing cars, aero planes, shipbuilding, and the nuclear power industry.

Geopolymerization has been conducted for Al-waste and FA, where the wastes were mixed with aqueous NaOH solutions of 5, 10, and 15 M concentrations. Sodium silicate solutions containing 10.25% Na_2O, 31.37% SiO_2, and 58.64% H_2O were used as alkaline activators.

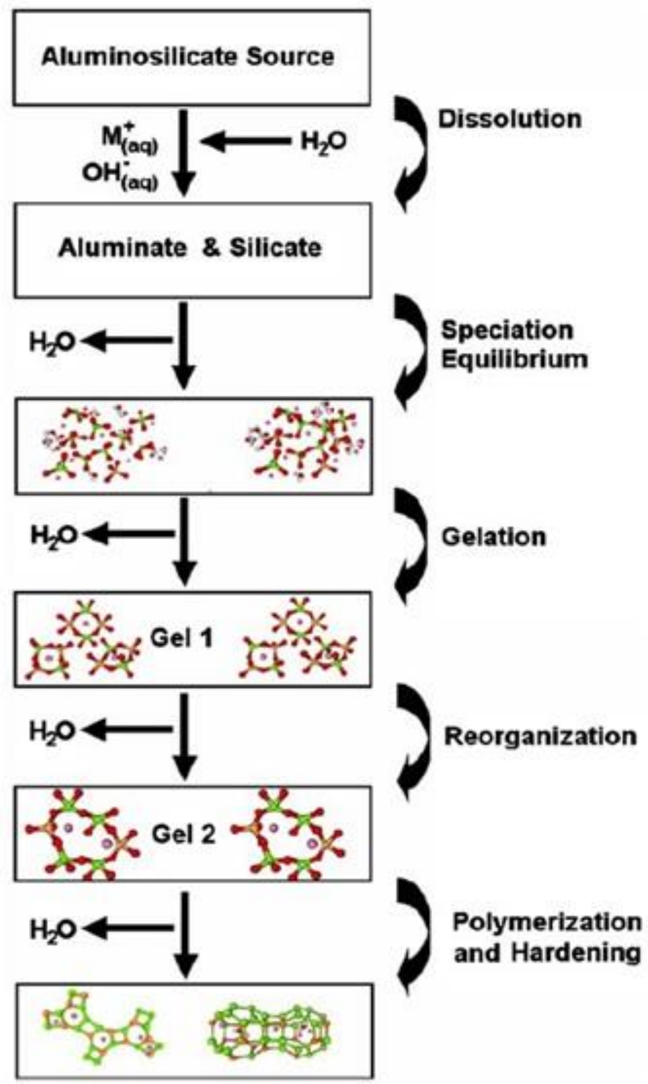

Figure 1: Geopolymerisation (source: omicsonline.org)

FLY ASH ANALYSIS

Fly ash is a waste material from coal based thermal power plants obtained after combustion of coal for power generation and collected from precipitator. Huge quantities of fly ash is produced every year in India in coal based thermal power plants in different states. More coal based thermal power plants are being established and thus the quantity of fly ash available shall also increased proportionately, its use therefore as a resource material is both interesting, useful and challenging.

The fly ash particles are very small (10 to 100 microns) composed of silicates, metallic oxides heavy metals and some proportion of unburnt coal .Fly ash due to its physico-chemical properties makes useful mix with lime, gypsum, sand to form bricks and blocks which are useful in construction of buildings ,embankments, rural and urban pavements .

Using a fly ash (pozzolan) consumes calcium hydroxide (CH: the weak link) to form more calcium silicate hydrate (CSH: Strength)

• Portland Cement Reaction: Cement + Water → CSH + CH

• Pozzolanic Reaction: CH + Pozzolan → CSH

Fly ash bricks and concrete mix have great advantages over the conventional materials for bricks, blocks and plasters. The fly ash bricks are ligther in weight, stronger in strength, fine and uniform requiring less moldings material in construction of structures more durable, fire resistant and can decrease permeability .These bricks are less costly (20 to 35 %) depending on the quality as compared to clay bricks likewise fly ash concrete mix reduces the amount of cement in the concrete mix with two distinct advantages that are:-

1. Cost Reduction

2. Environment benefits on account of lower emission produced during the production of cement.

The fly ash concrete mix also has a unique advantages for strength, durability, permeability, fineness, heat and hydration properties, weight and ease in construction of buildings and embankments being uniform in size.

Fly ash is nowadays is not considered as waste from coal based thermal power plants but as a potential resource material for construction industry, soil amendments and landfills, however fly ash also posses significant challenges as an environmental pollutant. The fly ash is very light in weight and can be easily air borne if not properly managed. Fly ash pollution in air is hazardous for human and animal health as the air borne fly ash particles can deposit in lungs and cause respiratory problems. The fly ash contained heavy metals and oxides can adversely impact the quality of potable water as well as underground water content or account of change in pH, turbidity, oxides and heavy metal contents, also the huge areas of agriculture land are required for its dumping and storage which spoils the quality of land for agriculture use.

The fly ash collected from the thermal power plants need to be properly managed in scientific and economic waste so that it neither become air borne, nor percolate to water streams including underground water and pollutes soils because of splashes. Therefore the fly ash should be stored in tanks lined with bricks and the fly ash resources should be submerged under thin layer of water so that its entry into air and water can be controlled.

The physio-chemical properties of fly ash varies with quality of coal used in different thermal power plants accordingly the quality of fly ash based products that is bricks and blocks and concrete mix will also vary for different civil engineering parameters significant for construction industry. It is therefore imperative to analyze the quality of fly ash before determining its use.

CONCLUSIONS

The following conclusions can be drawn based on the results of experimental work:

a. Due to their chemical characteristic, Alumina and silica waste has proven to be an effective raw material in geopolymer production,
b. In this study, alumina and silica waste were chosen to be raw material, sodium hydroxide and sodium silicate as an alkaline activated solution.
c. The effect of fly ash content of AMC/fly ash composites shows that mechanical properties of composites such as bending strength and hardness increase, density and wear rate decrease with increasing fly ash content.
d. The Geopolymer binders may be treated as an alternative to Portland cement in certain industrial applications,
e. The study has proven that geopolymer products are no longer the hazardous waste.

ADVANTAGES OF GEOPOLYMER CONCRETE

High Strength

It has a very high compressive strength that demonstrated higher compressive strength than that of normal concrete. It additionally has fast quality pick up and cures rapidly, thus making it an amazing for fast forms. Geopolymer concrete has high malleable strength. It is less brittle than Portland concrete and can withstand greater rupturing. It is not totally earth shake verification, but rather shows improvement over conventional cement.

Very Low Creep and Shrinkage

Shrinkage can bring about serious and even dangerous cracks in the concrete from the drying and warming of the concrete or even the vanishing of water from the concrete. Geopolymer concrete does not hydrate; it is not as porous and won't encounter critical shrinkage. The creep of geopolymer cement is low. The tendency of the concrete to get permanently deformed due to the constant forces being applied against it is known as creep in concrete.

Resistant To Heat and Cold

It can remain stable even at temperature of more than 2200 degrees Fahrenheit. Excessive heat can lessen the stability of concrete making it spalling or have layers cutting off. Geopolymer concrete does not undergo spalling unless it comes to more than 2200 degrees Fahrenheit. As for old temperatures, it has got resistant to freezing. The pores are little however water can at present enter cured cement. At the point when temperature plunge to below freezing that water freezes and and then expands this will cause cracks to form. Geopolymer concrete won't freeze.

Chemical Resistance

It has an exceptionally chemical resistance. Acids, harmful waste and salt water won't affect geopolymer concrete. Erosion is not liable to happen with this solid as it is with traditional Portland concrete.

The use of geopolymer concrete reduces the necessity of OPC, thus reducing the environmental pollution that caused by the emission of CO_2 during the production of OPC.

DISADVANTAGES OF GEOPOLYMER CONCRETE

Difficult To Create

Geopolymer concrete requires skilled handling and is very difficult to prepare. It requires the use of chemicals, such as potassium hydroxide, sodium hydroxide and so forth that can be harmful to homosapiens.

Pre Mix Only

Geopolymer concrete is available only as a pre-cast or pre mix material due to the risk associated with creating it.

APPLICATIONS OF GEOPOLYMER CONCRETE

The Geopolymer binders can betaken as environment friendly alternative to Portland cement in certain industrial applications in future.

The study has also covered some of the application of geopolymer concrete and are listed in Table 1

Table 1 Application of geopolymeric materials based on Si:Al atomic ratio Si:Al ratio

Si:Al Ratio	Applications
1	• Bricks • Ceramics • Fire protection
2	• Low CO_2 cements concretes • Radioactive and toxic waste encapsulation
3	• Fire protection fibre glass composite • Foundary equipment • Heal resistant composites 200^0C to 1000^0C • Tooling for aeronautics titanium process
>3	• Sealants for industry, 200^0C to 600^0C • Tooling for aeronautics SPF aluminium
20-35	• Fire resistant and heat resistant fibrecomposits

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