SURVEY ON FLY ASH BASED GEOPOLYMER CONCRETE

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Abstract- A comprehensive summary of the extensive studies conducted on fly ash-based geopolymer concrete is presented. Test data are used to identify the effects of salient factors that influence the properties of the geopolymer concrete in the fresh and hardened states. These results are utilized to propose a simple method for the design of geopolymer concrete mixtures. The economic merits of the geopolymer concrete are also mentioned. The behaviour of in filled stub column and hollow stub column is studied experimentally by applying gradual load along with analytical integrated the engineering behaviour of fly ash and GGBS synthesized binder at different mix proportions as well as at dissimilar curing environments and these properties are compared with conventional concrete. In addition, another local waste material, manufactured sand (M-sand), was used as a replacement for conventional sand by many researchers in the development of green geopolymer concrete, the finding of this review is we can use Fly Ash ,MK, GGBS, as binders to wholly replace conventional ordinary concrete would lead to alternate eco-friendly geopolymer matrix.

Keywords Durability; Fly ash; Geopolymer Binder; GGBS; Properties.

1. INTRODUCTION

1.1 BACKGROUND

Concrete made with Portland cement is the most widely used material on earth. The concrete industry is the largest user of natural resources in the world. Globally, over 14 billion tonnes of concrete is placed per year and accounts for the annual 2.8 billion tonnes of Portland cement produced. Significant increases in cement production have been observed and are anticipated to increase due to the massive increase in infrastructure and industrialization in India, China and South America .It is generally agreed that the production of Portland cement clinker is expensive and ecologically harmful. The emissions generated by Portland cement productions are principal contributors to the greenhouse gas (GHG) effect. For instance, the production of Portland cement for concrete accounts for an estimated 5 percent of global anthropogenic carbon dioxide. Recent estimates of the emissions from cement production reveals that 377 million metric tons of carbon was generated in 2007; this indicates that emissions have more than doubled since the mid-1970s from fossil-fuel burning and cement production [1]. Whilst measures may be undertaken to reduce the generation of carbon dioxide from cement kilns, carbon dioxide emission is still in the order of 600 kg of carbon dioxide per ton of cement of which 400 kg per tonne is the result of the calcination of limestone. The United Nations Intergovernmental Panel on Climate Change (IPCC) has identified the unmindful pumping of CO2 into the atmosphere is the main culprit for the climate change and highlighted that the "largest mitigation potentials are in the steel, cement and pulp and paper industries" . Carbon emission data is alarming; the 2007 carbon emission estimate was an all-time high and 1.7 percent increase from the previous year alone. The highest average growth rates in industrial-sector CO2 emissions are projected for developing countries. As one such rising economy, India has an international obligation of reducing CO2 emissions [2].

In view of the serious impact of carbon dioxide on the environment and the continued anticipated growth of industrialization and urbanization, there is a need to redirect the building industry away from its overwhelming reliance on Portland cement by developing alternative binder systems. The two options which have attracted attention as alternative binders are (i) the partial replacement of cement by industrial by products like fly ash and slag and (ii) the use of geopolymer binders. The first alternative has been widely researched and abundant information on the fresh and hardened properties of concrete with partial replacement of cement has led to the use of such blended cements. In one such application, a post-tensioned structure with 50-70 percent replacement of cement by slag resulted in an estimated reduction on carbon dioxide emissions for the project of 4500 tonnes. Partial replacement of cement in binders has been found to comply with Indian standards for masonry cement and could be used up to 25 percent partial replacement without deleterious effect on strength. The second alternative, geopolymer binders, is an emerging area of technology. Davidovits first proposed that an alkaline liquid could be used to react with the silicon (Si) and aluminium (Al) in a source material of geological origin or in by-product materials such as fly ash and rice husk ash to produce cementations binders. Because the chemical reactions that takes place in this case is a polymerization process and the source materials are of geological origin, he coined the term „geopolymer" to represent these binders [3].

1.2 INTRODUCTION

Conventional concrete is recognized most significant material in civil Engineering, every year 3 tons of concrete is devoured by each individual person on the ground. Cement production releases environment harm gases into atmosphere, which is all around 8% in the total contribution of CO2 emissions in the world another problem in the production of cement is the utilization of more raw materials like Lime stone. Joseph Davidovits was introduced geopolymer binders in the year 1972 to give significant alternative material to ordinary Portland binders to conquer the problems of CO2 emissions as well as to decrease the raw material usage. By products like GGBS, flyash and silica fume with soluble solutions (Sodium or Potassium) are used to produce alkali-activated binder. Recent researches indicate the evidence, that geopolymer concrete marked their importance in the construction industry all over the world. Manufacture of geopolymer concrete is quite different compared to conventional concrete, because of its utilization of industrial by products and consumption of fewer raw materials. Alkaline solutions prepared 24 hours before preparing the geopolymer binder by synthesizing inorganic waste materials like metakaolin, silica fume, flyash and GGBS. Flyash synthesized geopolymer concrete requires oven curing, but fly ash and GGBS synthesized concrete is not required any oven curing, sunlight curing is sufficient to achieve full strength in 28 days [4].

The stainless steel tubular stub column in filled with concrete is an innovative technique in the construction industry and has gained a lot of attention due to its aesthetic appearance, high resistance towards corrosion and enhanced structural performance. In-fill concrete columns offer high classes of fire protection and also being effectively involved in construction of seismic resistant structures. The size of the composite column to support an equivalent mass of RCC column is reduced significantly. The high tensile strength and ductile behaviour are the highlights of stainless steel infill columns.

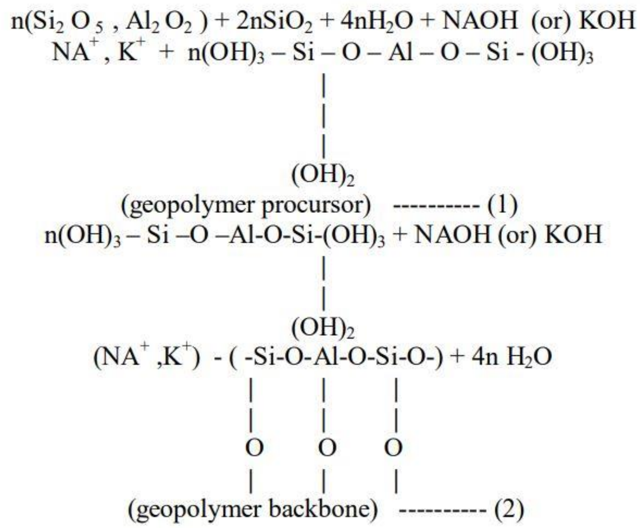
Steel-concrete composite columns are used extensively in modern buildings, the foundation of transmission tower and used as vibration controllers in automobile industries. They can also be used for the erection of the building and resist all construction loads. However, concrete members can increase the compressive strength and stiffness to assist the resistance of service loads. As a choice of interest, the key components of any particular project such as steel, concrete or any other composite structural system are chosen not purely based on their accessibility, cost or any particular strategies, but also considering their aesthetic norms. Also, the classification of stainless steel is done based on their metallurgical characteristics as a result of cooling process from elevated temperature [5].

1.3 GEOPOLYMERS

Davidovits proposed that an alkaline liquid could be used to react with the silicon (SI) and the aluminium (Al) in a source material of geological origin or in by –product materials such as fly ash and rice husk ash to produce binders. Because the chemical reaction that takes place in this case is polymerization process coined the term „Geopolymers" to represent these binders.

Geopolymers are member of the family of inorganic polymers. The chemical composition of the geopolymer material is similar to natural zeolitic materials, but the microstructure is amorphous. The polymerization process involves a substantially fast chemical reaction under alkaline condition on Si-Al minerals, that results in a three dimensional polymeric chain a ring structure consisting of Si-O-Al bonds [6].

The schematic formation of geopolymer material can be shown as described by equations (1) and (2) .



The last term in equation (2) reveals that water is released during the chemical reaction that occurs in the formation of geo polymers. This water expelled from the geopolymer matrix during the curing and further drying periods, leaves behind discontinuous Nano-pores in the matrix, which provide benefits to the performance of geo polymers [7].

1.4 GEOPOLYMER CEMENTS

There are nine different classes of geopolymers, but the classes of greatest potential application for transportation infrastructure are comprised of alumina silicate materials that may be used to completely replace Portland cement in concrete construction. These geopolymers rely on thermally activated natural materials (e.g., kaolinite clay or weathered rocks) or industrial by products (e.g., fly ash or slag) to provide a source of silicon (Si) and aluminium (Al), which polymerizes into molecular chains and networks to create the hardened binder [8].

The polymerization process involves a substantially fast chemical reaction under alkaline conditions on silicon-aluminium minerals that results in a three-dimensional polymeric chain and ring structure. The ultimate structure of the geopolymer depends largely on the ratio of Si to Al with the materials most often considered for use in concrete application typically having an Si:Al between 2 and 3.5.

A critical feature is that water is present only to facilitate workability and does not become a part of the resulting geopolymer structure. In other words, water is not involved in the chemical reaction and instead is expelled during curing and subsequent drying [9].

This is in contrast to the hydration reaction that occurs when Portland cement is mixed with water (Figure 1.1), which produce the primary hydration products calcium silicate hydrate and calcium hydroxide. This difference has a significant impact on the mechanical and chemical properties of the resulting geopolymer concrete, and also renders it more resistant to heat, water ingress, alkali-aggregate reactivity, and other types of chemical attack [10].

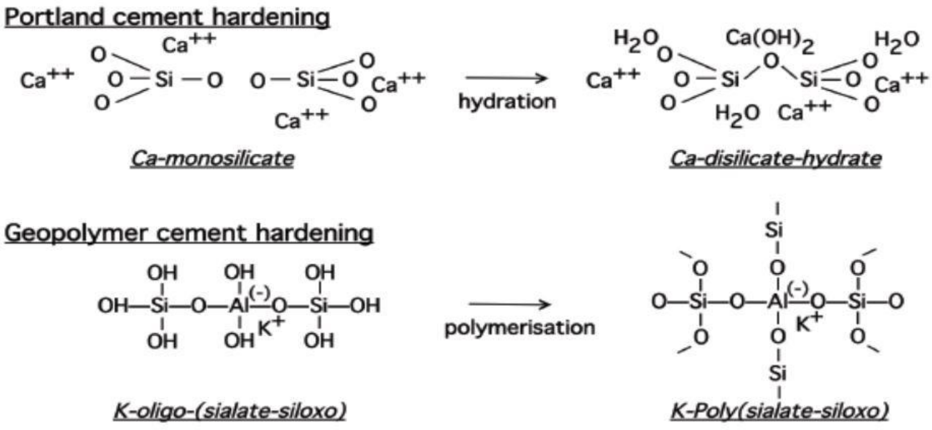


Fig. 1.1: Polymerisation Process

Conceptually, the formation of geopolymers is quite simple. In the case of geopolymers based on alumina silicate, suitable source materials must be rich in amorphous forms of Si and Al. One distinguishes three types of geopolymer cement, so far:

Metakaolin (MK-750) / Slag / Alkali-silicate - based; -

Rock (volcanic tuffs, granitic) / Slag / Alkali-silicate - based; -

Fly ash / Slag / Alkali-silicate - based.

1.5 GEOPOLYMER CONCRETE

There are two main constituents of geopolymers, namely the source materials and the alkaline liquids. The source materials for geopolymers based on alumina-silicate should be rich in silicon (Si) and aluminium (Al). These could be natural minerals such as kaolinite, clays, etc. Alternatively, by-product materials such as fly ash, silica fume, slag, rice-husk ash, red mud, etc could be used as source materials. The choice of the source materials for making geopolymers depends on factors such as availability, cost, type of application, and specific demand of the end users. The alkaline liquids are from soluble alkali metals that are usually Sodium or Potassium based. The most common alkaline liquid used in geo polymerisation is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate [11].

1.6 CONSTITUENTS OF GEOPOLYMER CONCRETE

Geopolymer concrete can be manufactured by using the low-calcium (ASTM Class F) fly ash obtained from coal-burning power stations. Most of the fly ash available globally is low-calcium fly ash formed as a by-product of burning anthracite or bituminous coal. Although coal burning power plants are considered to be environmentally unfriendly, the extent of power generated by these plants is on the increase due to the huge reserves of good quality coal available worldwide and the low cost of power produced from these sources. Low-calcium fly ash has been successfully used to manufacture geopolymer concrete when the silicon and aluminium oxides constituted about 80% by mass, with the Si-to-Al ratio of about 2. The content of the iron oxide usually ranged from 10 to 20% by mass, whereas the calcium oxide content was less than 5% by mass. The carbon content of the fly ash, as indicated by the loss on ignition by mass, was as low as less than 2%. Coarse and fine aggregates used by the concrete industry are suitable to manufacture geopolymer concrete. A combination of sodium silicate solution and sodium hydroxide (NaOH) solution can be used as the alkaline liquid. It is recommended that the alkaline liquid is prepared by mixing both the solutions together at least 24 hours prior to use [12].

1.7 MIXTURE PROPORTIONS OF GEOPOLYMER CONCRETE

The primary difference between geopolymer concrete and Portland cement concrete is the binder. The silicon and aluminium oxides in the low-calcium fly ash reacts with the alkaline liquid to form the geopolymer paste that binds the loose coarse aggregates, fine aggregates, and other un-reacted materials together to form the geopolymer concrete. As in the case of Portland cement concrete, the coarse and fine aggregates occupy about 75 to 80% of the mass of geopolymer concrete. This component of geopolymer concrete mixtures can be designed using the tools currently available for Portland cement concrete [13].

1.8 NECESSITIES OF GEO POLYMER CONCRETE

Construction is one of the fast growing fields worldwide. As per the present world statistics, every year around 260,00,00,000 Tons of Cement is required. This quantity will be increased by 25% within a span of another 10 years. Since the Lime stone is the main source material for the ordinary Portland cement an acute shortage of limestone may come after 25 to 50 years. More over while producing one ton of cement, approximately one ton of carbon di oxide will be emitted to the atmosphere, which is a major threat for the environment. In addition to the above huge quantity of energy is also required for the production of cement. Hence it is most essential to find an alternative binder. The Cement production generated carbon di oxide, which pollutes the atmosphere. The Thermal Industry produces a waste called flyash which is simply dumped on the earth, occupies larges areas. The waste water from the Chemical Industries is discharged into the ground which contaminates ground water. By producing Geopolymer Concrete all the above mentioned issues shall be solved by rearranging them. Waste Fly Ash from Thermal Industry + Waste water from Chemical Refineries = Geo polymer concrete. Since Geopolymer concrete doesn’t use any cement, the production of cement shall be reduced and hence the pollution of atmosphere by the emission of carbon di oxide shall also be minimized [14].

1.9 PROPERTIES OF GEO POLYMER CONCRETE

The superior properties of Geopolymer concrete, based on Prof. B. Vijaya Rangan and Hardijito, are

1. Sets at room temperature
2. Non-toxic, bleed free
3. Long working life before stiffening
4. Impermeable
5. Higher resistance to heat and resist all inorganic solvents
6. Higher compressive strength

Compressive strength of Geopolymer concrete is very high compared to the ordinary Portland cement concrete. Geopolymer concrete also showed very high early strength. The compressive strength of Geopolymer concrete is about 1.5 times more than that of the compressive strength with the ordinary Portland cement concrete, for the same mix. Similarly the Geopolymer Concrete showed good workability as of the ordinary Portland Cement Concrete.

1.10 APPLICATION OF GEO POLYMER CONCRETE

the short term, there is large potential for geopolymer concrete applications for bridges, such as precast structural elements and decks as well as structural retrofits using geopolymer-fiber composites. Geopolymer technology is most advanced in precast applications due to the relative ease in handling sensitive materials (e.g., high-alkali activating solutions) and the need for a controlled high-temperature curing environment required for many current geopolymer. Other potential near term applications are precast pavers & slabs for paving, bricks and precast pipes [15].

1.11 LIMITATION OF GEOPOLYMER CONCRETE

The followings are the limitations

1. Bringing the base material fly ash to the required location
2. High cost for the alkaline solution
3. Safety risk associated with the high alkalinity of the activating solution.
4. Practical difficulties in applying Steam curing / high temperature curing process Considerable research is on-going to develop geopolymer systems that address these technical hurdles.

1.12 ENVIRONMENTAL BENEFITS OF THE TECHNOLOGY

The use of fly ash as a source material has environmental advantages in addition to those presented by the replacement of Portland cement. The use of the industrial by products such as fly ash in a high value product like concrete imparts better value-addition to these materials rather than low end usage as landfills and pavement sub-bases. It significantly decreases the use of natural resources and energy, for example, every million tons of fly ash that replaces Portland cement helps to conserve one million tons of lime stone, 0.25 million tons of coal and over 80 million units of power. The cement industry is the main culprit for the atmospheric pollution and mainly responsible for the emission of Green House Gases like CO2. Production of one ton of cement approximately releases one ton of CO2 into the atmosphere. Hence every million ton of fly ash used for geopolymer concrete helps the abatement of 1.0 million tons of CO2 to atmosphere. It also obviates the problem of their safe storage and/or disposal. Presently, most fly ash is being handled in wet form and disposed off in ash ponds which are harmful for the environment and occupy a vast area. The World Bank has cautioned India that by 2015, disposal of coal ash would require 1000 square kilometres or one square metre of land per person. Hence, use of geopolymer concrete helps us to increase the land available for agricultural and other purposes. Further, nontoxic chemicals are used for the production of geopolymer concrete. These chemicals can be handled by land without any additional protection. Hence, geopolymer concrete developed using fly ash is an environment friendly green material [16].

1.13 ECONOMIC BENEFITS OF THE TECHNOLOGY

In preparing the geopolymer concrete, the Ordinary Portland Cement is replaced 100 percent by fly ash and hence geopolymer concrete is termed as cement less concrete. The price of fly ash based geopolymer concrete is estimated about 10 to 30 percent cheaper than Portland cement concrete. Heat-cured low-calcium fly ash-based geopolymer concrete offers several economic benefits over Portland cement concrete. One ton low-calcium fly ash can be utilized to manufacture approximately three cubic meters of high quality fly ash based geopolymer concrete, and hence earn monetary benefits through carbon-credit trade. The heat-cured low-calcium fly ash based geopolymer concrete may yield additional economic benefits when it is utilized in infrastructure applications. In the case of infrastructure applications, space available for keeping precast elements is very much restricted. Precast elements made out of normal concrete require 28 days for gaining full strength. But at the same time, heat cured geopolymer concrete attains full strength in one day. This results in savings in cost of expensive moulds and at the same time less space is required to keep the geopolymer concrete precast elements as they can be moved out of casting yard quickly. Further, expensive steam curing chamber is not required at site. Cost effective steam curing arrangement made out of tarpaulins would be sufficient at site [17].

2. LITERATURE REVIEW

Lloyd and Rangan et al [2009] [1] conducted a study on geopolymer concrete with fly ash. For their study, they used low calcium (ASTM Class F) fly ash as their base material. The observations are made with the effect of water – geopolymer solids. They concluded that geopolymer possess excellent properties and is well suited to manufacture precast concrete products that are needed in rehabilitation and retrofitting of structures after disaster.

Hardjito et al [2005] [2] studied fly ash based Geopolymer Concrete. The material used was low calcium ASTM class F dry fly ash obtained from power station. The calcium content of the fly ash was about 2 percent by mass. They observed the compressive strength data and concluded that fly ash based geopolymer concrete has good compressive strength and is suitable for structural application. The fly ash based geopolymer concrete also showed excellent resistance to sulphate attack and the elastic properties of hardened concrete and the behaviour and the strength of reinforced structural members are similar to the Portland cement concrete.

Paratibha et al [2015] [3] In this paper the fresh geopolymer concrete was easily handled up to 120 minutes without any sign of setting. The addition of high range water reducing admixture improved the workability of concrete. They concluded that higher concentration of sodium hydroxide solution and curing temperature in the range of 30ºc to 90ºc results in a higher compressive strength of geopolymer concrete. Higher concentration (in terms of molar) of sodium hydroxide solution results in a higher compressive strength of geopolymer concrete. The rest period between casting of specimens and the commencement of curing up to 60 minutes has no effect on the compressive strength of geopolymer concrete

Rangan et al [2009] [3] carried out experiments on Reinforced low – calcium fly ash based Geopolymer concrete beams and columns. Heat-cured low-calcium fly ash-based geopolymer concrete has advantages such as excellent structural properties, low creep, very little drying shrinkage, excellent resistance to sulphate attack, and acid resistant. Heat-cured low-calcium fly ash-based geopolymer concrete has an excellent compressive strength and is suitable for structural applications. The elastic properties of hardened concrete and the behaviour and strength of reinforced structural members are similar to those of Portland cement concrete. Therefore, the design provisions contained in the current standards and codes can be used to design reinforced fly ash-based geopolymer concrete structural members.

Kunal kupwade – patil and Erez Allouche et al [2006] [4] researcher explained conducted test on the effect of alkali silica reaction in geopolymer concrete. In their study, alkali silica reaction occurs due to chemical reactions between hydroxyl ions in the pore water within the concrete matrix and certain forms of silica. This reaction could lead to strength loss, cracking, volume expansion and potentially failure of the structure. The results suggest that the extent of alkali silica reactions owing to the presence of reactive aggregates in flyash based geopolymer concrete is substantially lower than OPC based concrete, and well below the ASTM specified threshold

Paratibha et al [2015] [5] In this paper Class - F fly ash have used & procured from NTPC (National Thermal Power Corporation, Vijayawada). GGBS is acquired through extinguish Iron manufacturing plants from a fire furnace in liquid or vapour form to bring a smooth finishing item i.e., then dried out & chipped into a small particles. In the current study GGBS was taken from SVK Ready Mix Plant, Perecharla. And their properties like specific gravity and density are shown in Table:2. The mineralogical compositions of flyash & GGBS, analyzed from XRD (X-Ray Diffraction) method and these are interoperated in origin software (Figure:1).

Robbie, et al 2017[6] Studied Conventional concrete is recognized most significant material in civil Engineering, every year 3 tons of concrete is devoured by each individual person on the ground. Cement production releases environment harm gases into atmosphere, which is all around 8% in the total contribution of CO2 emissions in the world

Schneider et al., 2011 [7] Studied another problem in the production of cement is the utilization of more raw materials like Lime stone (Robbie, 2017; Schneider et al., 2011). Joseph Davidovits was introduced geopolymer binders in the year 1972 to give significant alternative material to ordinary Portland binders to conquer the problems of CO2 emissions as well as to decrease the raw material usage

Nakshatra, et al [2018][8] By products like GGBS, flyash and silica fume with soluble solutions (Sodium or Potassium) are used to produce alkali-activated binder

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Yellaiah et al., 2014 [10]Manufacture of geopolymer concrete is quite different compared to conventional concrete, because of its utilization of industrial by products and consumption of ewer raw materials (Yellaiah et al., 2014). Alkaline solutions prepared 24 hours before preparing the geopolymer binder by synthesizing inorganic waste materials like metakaolin, silica fume, flyash and GGBS. Flyash synthesized geopolymer concrete requires oven curing, but fly ash and GGBS synthesized concrete is not required any oven curing, sunlight curing is sufficient to achieve full strength in 28 days. With this paper presented the properties of inorganic materials (Flyash and GGBS) used in geopolymer mix. The preliminary parameters like compression, tension and flexural strengths of geopolymer concrete at dissimilar curing conditions are presented and compared with conventional concrete. The best results are obtained at sunlight curing of 28 days for M5 mix

Pan et.al.,[2016] [11] Alkali-activate binders‘ development is taken place from 1930 itself; these are utilized in various fields of structural development

Bellum et al., [2018] [12] The development of inorganic materials from 1939-2018 along with the reference are presented

Mathur et al. [1999] [13] looked at the physical properties of blast furnace slag and steel slag and concluded that both materials were suitable to replace natural stone aggregates in base and sub base road layers, as long as the steel slag was adequately weathered. The study also mixed various slogs together and determined that a mixture of ACBF slag (50%), steel slag (20%), granulate blast furnace slag (20%), fly ash (6%), and lime (4%) would self-stabilize over time and form an adequate bound base or sub base road layer. They have got that the concrete containing above these material better corrosion resistances. Artificial stones and cover blocks using steel slag hydrated matrix were manufactured and placed in a shore protection repair project at JFE Steel's West Japan Works (Kurashiki) between Sept. 2000 and Sept. 2002.

H.Matsunaga et al [2000][14] have taken the mixture proportion of steel slag making ground granulated blast furnace slag, fly ash, water and small amount of an activator (calcium hydroxide or lime dust). Cement and natural aggregate were not used. The physical properties of steel slag hydrated matrix were measured. The compressive strength of steel slag hydrated matrix products increases with curing time and exceeds 18N/mm2, which is the general design strength of breakwater blocks. Compared the compressive strength at 91 days and 28 days strength is approximately 1.3 times greater with extended curing. That is the compressive strength of steel slag hydrated matrix increases with longer curing periods and achieves a level higher than that of an ordinary concrete with long term.

Tatsuhito Takashashi and Kazuya Yabuta et al [2002][15] have study on the steel making slag and granulated blast furnace slag (GGBS). Availability of natural sand is decreasing year by year, for this serious problem they have used ground granulated slag (GGBS) which is named as BF slag sand or Sandy-S. In concrete they used as fine aggregate in place of natural sand.

Haruyoshi Tanabe and Masayki Nakada et al [2003][16] developed the marine block .They have prepared the mixture of steel making slag , ground granulated blast furnace slag ,lime and fly ash made the marine blocks , this blocks carbonated and reacted with carbon dioxide gas . They have used to pile on the sea bottom for investigating their effect on cultivating seaweed and other marine organisim.

M. Maslehuddi et al. [2003][17], have particularly worked in areas where good-quality aggregate is scarce. Their research study was conducted to evaluate the mechanical properties and durability characteristics of steel slag aggregate concrete in comparison with the crushed limestone stone aggregate concrete. The durability performance of both steel slag and crushed limestone aggregate concretes was evaluated by assessing by water permeability, pulse velocity, dimensional stability and reinforcement corrosion. The results indicated that the durability &characteristics of steel slag cement concretes were better than those of crushed limestone aggregate concrete.

Takashi Fuji, toshiki ayano and kenji sakata et al 2004][18] were study on the concrete Steel-slag hydrated matrix which is made of ground granulated blast furnace slag powder and steel-making slag and are by-product of iron manufacturing. Alkali activator is added if necessary. The cement is not required to produce the steel-slag hydrated matrix. The leaching of heavy metal from steel-slag hydrated matrix is very little. This type construction material is called environmental conscious material in Japan. This research presented that the strength of steel-slag hydrated matrix depend on pH of steel-slag hydrated matrix after mixing. By controlling pH of steel-slag hydrated matrix after mixing, dispersion of strength become small and it can be stably made the same grade as cement concrete. It is also clear that the resistance to carbonation and steel rod corrosion of steel-slag hydrated matrix has high performance for a long time by alkalinity of steel-making slag.

Kyong Yun Yeaua, Eun Kyum Kimb et al [2005][19] have presented the experimental test results on corrosion resistance of concrete containing ground granulate blast-furnace slag (GGBS) and ASTM Type I or ASTM Type V cement. To investigate the problem, a series of tests were performed

Tomonari Kimura and Nobuaki Otskui et al [2006] [20] have developed, Steel Slag Hydrated Matrix (SSHM) as a construction material for reducing environmental problems. They have investigated on pre-treatment slag and blast-furnace slag powder which are by-products of steel making process. In SSHM, the corresponding substitute material for cement is the mix of blast furnace slag powder, fly ash and slaked lime whiles the corresponding substitute material for the fine and coarse aggregate is pre-treatment slag..

Takshi Fujii, Toshiki Ayanond and Kenji Sakta et al [2007][21] have developed the concrete using steel making slag which is reducing environmental load. They have made the concrete using Ground granulated blast furnace slag (GGBS),lime dust(LD),steel making slag(SS),high range water reducing admixture (HRWRA) and Air entraining agent (AE).Their result indicted that low resistance to freezing and thawing of the steel making slag concrete was due to small amount entrained air by the agent and adequate quantity of fly ash is necessary to consume calcium hydroxide around the aggregate.

Hanifi Binice et al. [2007][22] The aim of this research work is to investigate the seawater resistance of the concrete incorporating ground blast furnace slag (GBS) and ground basaltic pumice (GBP) each separately or both together. The variable investigated in this study is the level of fine aggregate replacement by GBS and GBP and normal concrete Compressive strength measured on 150 mm cubes was used to assess the changes in the mechanical properties of concrete specimens exposed to seawater attack for 3 years. From this study, they observations were found , GBP concrete presented an excellent behavior in both short and long-term compressive strength in seawater, higher compressive strengths and lower permeability's. Abrasion resistance of concrete was strongly influenced by its compressive strength and GBS and GBP content then the normal concrete.

Obuaki et.al [2006][23], have developed a new construction material called "steel slag hydrated matrix", hereafter this term will be abbreviated as SSHM, produced from steel making slag, ground blast furnace slag powder without using portland cement and natural gravel. However, its application has been limited to non-steel reinforcement material when used in structures under marine environment. They applied SSHM for steel reinforced structures and their results showed that the resistance to chloride ion penetration, oxygen permeability, resistance of steel bar to corrosion in SSHM were equal to or even better than that of steel reinforced concrete material under marine environment.

CONCLUSION

This review research into optimizing the use of MK, GGBS, as binders in the production of geopolymer mortars produced significant conclusions. Based on the tests conducted by researchers, the following conclusions were drawn:

(i) The compressive strength of the geopolymer mortar increased with the MK content up to 20%, while further replacement of MK showed a significant reduction in the strength.
(ii)The addition of GGBS up to 40% with 15% MK, produced the highest strength among the mixes.
(iii) It is possible to improve the compressive strength of the geopolymer mortars at the early ages by introducing initial heating at 65∘ C for 24 h after remoulding. Improvements are more significant at 3 days.
(iv) GGBS produces a cohesive mix, in which the density of mortar decreases with the increase in the percentage of GGBS, resulting in a decrease in density of approximately 12%.
(v) The finer particles of GGBS produce a dense mix; hence, the partial substitution of GGBS in the mortar should be maintained at 35%.
(vi)The compressive strength increases with the increases of molarity of sodium hydroxide solution.
(vii) It can also be concluded that the combined maximum volumes of MK, GGBS, can be used for the development of a sustainable construction material to replace OPC for the production of Eco environmentally friendly geopolymer mortars.

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