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Geopolymer Concrete as a Sustainable Material With Wastes- Anoverview

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ABSTRACT:
Geopolymer concrete (GPC) has been researched during the past few decades as an alternative to sustainable construction materials, which can minimize CO_2 emission for its use of industry by-products. Past researches on GPC show that it can be suitable for the structural applications, with a workable slump, and comparable grade of strength to ordinary Portland cement concrete. In this review paper, the mix design, mechanical properties, durability and microstructure of GPC have been discussed to figure out and report the last data and information regarding geopolymer concrete with waste.

Keywords: Geopolymer Concrete, Waste, Construction Material, Mechanical properties

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I. INTRODUCTION

Concrete is the world's most versatile, durable and reliable construction material. Next to water, concrete is the most used material, which required large quantities of Portland Cement. Ordinary Portland Cement production is the second only to the automobile as the major generator of carbon di oxide, which polluted the atmosphere.

In addition to that large amount energy was also consumed for the cement production. Hence, it is inevitable to find an alternative material to the existing most expensive, most resource consuming Portland Cement.

Geopolymer concrete is an innovative construction material which shall be produced by the chemical action of inorganic molecules. Fly Ash, a by- product of coal obtained from the thermal power plant is plenty available worldwide. Flyash is rich in silica and alumina reacted with alkaline solution produced aluminosilicate gel that acted as the binding material for the concrete. It is an excellent alternative construction material to the existing plain cement concrete. Geopolymer concrete shall be produced without using any amount of ordinary Portland cement. This paper briefly reviews the constituents of geopolymer concrete, its strength and potential applications.

Geopolymer cement concrete is made from utilization of waste materials such as fly ash and ground granulated blast furnace slag(GGBS). Fly ash is the waste product generated from thermal power plant and ground granulate blast furnace slag is generated as waste material in steel plant.Both fly ash and GGBS are processed by appropriate technology and used for concrete works in the form of geopolymer concrete. The use of this concrete helps to reduce the stock of wastes and also reduces carbon emission by reducing Portland cement demand.

The main constituent of geopolymers source of silicon and aluminium which are provided by thermally activated natural materials (e.g. kaolinite) or industrial byproducts (e.g. fly ash or slab) and an alkaline activating solution which polymerizes these materials into molecular chains and networks to create hardened binder. It is also called as alkali-activated cement or inorganic polymer cement.

Following materials are required to produce this concrete:

- ✓ Fly ash – A byproduct of thermal power plant
- ✓ GGBS – A byproduct of steel plant
- ✓ Fine aggregates and coarse aggregates as required for normal concrete.
- ✓ Alkaline activator solution for GPCC as explained above. Catalytic liquid system is used as alkaline activator solution. It is a combination of solutions of alkali silicates and hydroxides, besides distilled water. The role of alkaline activator solution is to activate the geopolymeric source materials containing Si and Al such as fly ash and GGBS.

In geopolymerization, alkaline solution plays an important role. The most common alkaline solution used in geopolymerization is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate (Na2SiO3) or potassium silicate (K2SiO3). In this study, a combination of sodium hydroxide and sodium silicate was choosen as the alkaline liquid. Sodium based solutions were choosen because they are cheaper than Potassium based solutions. Generally sodium hydroxide and sodium silicate are readily available in market in the form of pellets and gel (liquid).

II. REVIEW OF LITERATURE

[1]Aly Muhammed Aly et.al (2019)focused on the performance of slag based geopolymer concrete with replacement of both fine and coarse aggregates by different percentages of crumb rubber. The compressive strength of slag based geopolymer concrete could be enhanced slightly with the increase in crumb rubber content up to 10% which can lead to structurally environmentally friendly mixture from by products and wastes with high compressive strength to be used in structural elements due to the positive effect of NaOH pre-treatment on crumb rubber particles against the negative effect of increasing percentage of crumb rubber on concrete.Increasing percentage of crumb rubber more than 10% lead to decreasing in compressive strength due to the effect of increasing percentage of crumb rubber on concrete working against the behaviour of NaOH pre-treatment on crumb rubber particles. The highest splitting tensile and flexural tensile strengths were obtained from control mixture, and the systematic decrease of strengths was observed as crumb rubber content increased.The impact resistance of geopolymer concrete significantly improved due to the rubber particles low stiffness, which in turn increased the flexibility of the rubber-binder composite and considerably enhanced the energy absorption of the mixture as compared to geopolymer concrete without crumb rubber replacement.The increase in replacement level of crumb rubber led to significantly increasing the gap between number of blows till the initial crack and those till the ultimate failure, which indicate the increase in ductility of rubberized geopolymer concrete.Geopolymer rubberized concrete proved to be a promising alternative construction material for the Portland cement based concretes especially those used in the road, and airports paving slabs for the runways and taxiways.

[2] **Abbas Mohajerani et.al (2019)** Has presented the review research into waste-incorporated geopolymers and highlight the barriers to industry adoption with a view to pointing the way forward for future research.The widespread industry adoption of geopolymer concrete has the potential to positively contribute to environmental sustainability in both the industrial and construction sectors, through the recycling of waste materials, and the reduction in carbon emissions. Extensive research has been conducted into geopolymers during the past two decades, demonstrating the potential for the alkali-activated cement to replace ordinary Portland cement. However, there are a number of challenges facing the adoption of geopolymers. Much of the research into geopolymers uses sodium silicate solution as the alkali activator. Studies have noted that sodium silicate solutions are highly corrosive, and, as such, can be defined as user-hostile systems. Alternative alkali activators, such as potassium silicate solutions, have been proposed as more user-friendly and therefore more favourable for industry adoption. The highly variable nature of waste materials needs to be a focus of future research, with mix designs that focus on locally available waste materials with minimal processing. Much research has focused on heat-cured geopolymers; however, this increases the embodied energy while reducing the environmental benefit, which also acts as a limiting factor for in situ applications. Research into ambient temperature curing, addressing the issues of compressive strength, the rate of strength development, and curing time is required. Durability issues need to be addressed with studies finding the compressive strength of geopolymers being reduced after relatively short time periods of immersion in water, and potential problems relating to chloride induced corrosion of reinforcing steel. Further research is recommended for developing standardized leachate analysis for geopolymers containing recycled waste materials.

[3] Faiz Uddin Ahmed Shaikh(2016) This paper presents mechanical and durability properties of geopolymer concrete containing recycled coarse aggregate (RCA). TheRCA is sourced from local construction and demolition (C&D) waste in Perth, Australia. The RCA is used as a partial replacement ofnatural coarse aggregate (NCA) in geopolymer concrete at 15%, 30% and 50% by wt. which corresponds to series two, three and four,respectively, while the geopolymer concrete containing 100% NCA is control and is considered as the first series. Class F fly ash is used asthe source material for the geopolymer and 8 M sodium hydroxide and sodium silicate alkali activators are used to synthesise the fly ashgeopolymer in this study. In all four series a constant alkali activator to fly ash ratio is used. Compressive strength, indirect tensilestrength and elastic modulus of above geopolymer concrete are measured at 7 and 28 days, while sorptivity, immersed water absorptionand volume of permeable voids of above geopolymer concrete are measured at 28 days. Relevant Australian standards are used to mea-sure all the above properties except the sorptivity which is measured according to ASTM standard. Results show that the compressivestrength, indirect tensile strength and elastic modulus of geopolymer concrete decrease with an increase in RCA contents, which is alsotrue for both 7 and 28 days. Excellent correlations of compressive strength with indirect tensile strength and elastic modulus are alsoobserved in geopolymer concrete containing RCA. Existing empirical models for cement concrete and geopolymer concrete containingNCA underestimate and overestimate the indirect tensile strength and elastic modulus, respectively of geopolymer concrete containingRCA.

[4]Ashwin Raval1, B M Purohit & A R Darji (2017)

From the above research papers, it is concluded that copper slag and recycled aggregates can be effectively used as replacement material for fine aggregate and replacement enables the large utilization of waste product. Copper slag has lower absorption and higher strength properties than fine aggregate. In other hand replacement of fine aggregate by recycled aggregate also effective. By increasing amount of RA, the strength decrease. Therefore it is advisable to replace FA by RA at limited extent. Replacement of copper slag increases the self-weight of concrete specimens to the maximum of 30% to 40% and replacement of RA of 15% to 20% does not decrease the strength of concrete.

[5] Bhavik kumar B. Patel1& Dr. Jayesh kumar Pitroda (2017)

The Literature review based on Using Industrial waste in Geopolymer concrete concluded that by using various Industrial waste materials as a partial substitute of fine aggregate, coarse aggregate cement and sand of design mix in Geopolymer concrete, overall cost of making of Geo polymer concrete can reduce. It can reduce the disposal problems of Industrial waste materials and also consume the cement used for making of Geo polymer concrete. Different tests have been conducted as per the standards on the Geopolymer concrete. The common parameter calculated by various researchers is compressive strength. It is seen that waste materials like fly ash, GGBS, Micro silica were used extensively and sufficient research have been done on them. When cement is replaced by various industrial waste compressive strength, flexural strength and split tensile strength of Geo polymer concrete for various mixes is depends upon the type of Industrial waste materials used for making of Geo polymer concrete. The study in turn is useful for various resource persons involved in using industrial or agricultural waste material to develop sustainable construction material.

[6] Er. Irfat Bashir, Dr. Hemant Sood & Er. Kshipra Kapoor (2017)

From the past research studies, it can be sequel that: The reduced CO2 emissions of Geopolymer cements build them a good alternative to Ordinary Portland Cement. Geopolymer cement produces a substance that is comparable to or better than traditional cements with respect to most properties. Higher concentration of sodium hydroxide solution results in higher compressive strength of geopolymer concrete. Geopolymer concrete has excellent properties within both acid and salt environments. Low calcium fly ash based geopolymer concrete has excellent compressive strength, exposure to aggressive environment, workability, exposure to high temperature and is suitable for structural applications

[7] M Lenin Sundar1, Sherine Raj & M Vadivel (2016) has reported the cement is fully replaced by industrial by-products fly ash and GGBS. The following points are arrived from the present study. From the past studies it has been proved that using E-waste doesn't affect the properties of geopolymer concrete majorlyGeopolymer concrete with E-Waste gives high compressive and tensile strength than conventional geopolymer concrete. Compressive and split tensile strength of geopolymer concrete increases by 20 percentage replacement of E-Waste in fine aggregate. Use of E-waste as partial replacement of fine aggregate is economical and can be easily used as fine in geopolymer concrete. Reuse of E-waste reduces environmental hazards and protects from the toxic substances. Increase in E-waste as fine aggregate reduces the strength of concrete. Partial replacement of E-waste as fine aggregate proved as well graded aggregate and recent technique for disposal of non-metallic E-Waste. Geopolymer concrete represent as a "Green concrete" and also as a "Eco-friendly concrete" as it reduces the CO2 emission in the world and usage of fly ash reduce the water content.

[8] Gladwin Vimal Raj.P& R.Vijaya Sarathy(2016)

Geo-polymer was widely used in structural work, road construction, aero-space materials, transportation; metallurgy mining etc. it was given better strength and durability of the concrete. By used these can recycle the waste material. Government taken steps to collected the sodium hydroxide and sodium silicate in chemical industries waste materials. So it reduced the cost of

construction materials. Ambient cured in the range up to 1200oC given better compressive strength. Beyond 1200oC reduced the strength of concrete. The major disadvantage of ambient cured reduced the weight of concrete and it losses the early strength of the concrete. So used sunlight cured at least in tropical countries. The sunlight cured taken 90 days for getter stability. But there is no loss in weight of concrete. The water content presented in the concrete was very low due to low water fly ash ratio. So the super-plasticizers were used mainly to make the workability in concrete

[9] Mayank Kumar(2015)

Has presented brief details of GPC, its properties, relevant comparisons with conventional concrete, economic benefits to the society, and its applications. Following conclusions can be arrived at about GPC. Geopolymer concrete has many superior properties compared with its counterpart OPC concrete and GPC is an environmentally friendly sustainable construction material which is becoming increasingly popular. The reduced CO2 emissions of Geo-polymer concrete make it a good alternative to Ordinary Portland Concrete. 3. Geo-polymer concrete shows significant potential to be a material for the future because it is not only environmentally friendly but also possesses excellent mechanical properties. It is possible to utilize various waste products from different industries (FA, GGBS, Red mud, Copper ash, RHA etc.) through geo-polymer technology for the development of eco- friendly construction material. Recommendations on use of geo-polymer concrete technology in practical applications such as precast concrete products and waste encapsulation need to be developed.

[10] Akshay C. Sankh1 et.al(2014)have reported the view of alternatives available in place of natural sand in mortar and concrete. There are various materials available, which are recognized as waste product of industry or from Domestic. But from the above conclusion shows that many researchers have recognized these materials and spent their valuable time and shared their knowledge to make aware of these materials for the construction industry. They showed that no material in the world is waste, but one has to see it in different way to recognize, how best the waste canbe handled. Few alternative materials discussed in this paper are from hard work of various research scholars. But those materials can be utilized effectively for concrete mix and building mortar and awareness should be spread to society. The utilization of these materials should be in such a way that the locally available such alternative materials should be selected so as to achieve economy and required design strength.

[11] Rajamane et al (2013) have reported the overview of 'geopolymeric cement concrete' based on extensive works carried out and published information. The GPCs may be either self curing or high temperature curing, with compressive strength ranging from 20 to 75 MPa. A look at the properties of GPCs with reference to stress-strain curves, bond strength, corrosion and sulphate resistance, thermal conductivity and expansion coefficient, electrical resistance ultrasonic pulse velocity, flexure and shear behaviour indicates that the industrial waste based GPCs can possess satisfactory strength and durability related characteristics depending upon their formulations.

[12]Madhan Gopal and Naga Kiran (2013) have presented experimental data on the behavior of fly ash based geopolymer concrete exposed to a 5% acid solution. Geopolymer concrete was initially cured for 24 hours at 60oC. The results obtained were compared with the conventional concrete exposed to 5% acid solutions. The compressive strength of geopolymer concrete and conventional concrete of 150 mm cubes at an age of 28 days were 32 MPa and 48.5 MPa respectively. The percentage of weight loss by geopolymer samples after acid immersion in sulphuric acid for 7, 14 and 28 day is 1%, 1.7% and 2.2% respectively and the residual compressive strength was 14.5%, 19.7% and 27.5%. The results confirmed that Geopolymer concrete is highly resistant to acid when compared to conventional concrete. Suresh Thokchom et al (2009) have presented experimental on acid resistance of fly ash based geopolymer concrete. The results conclude that geopolymer has a very good resistance in acid media in terms of weight loss and residual compressive strength. Research reported by Mehta (1985) indicates that the presence of high alumina cement in concrete increase the resistance to acids.

[13] Antony Jeyasehar and Saravanan (2013) have evaluated the strength and durability of geopolymer bricks by conducting tests on the compressive strength, the split tensile strength and the flexural strength. To improve the 24 quality of geopolymer mortar durability tests such as water absorption test and acid resistance test (HCl and H2SO4) were also conducted. The main focus of the investigation is on the optimum utility of the available fly ash and minimizing the water absorption and attaining high compressive strength. The results suggest that increase in curing temperature results in an increase in the compressive strength of the geopolymer mortar. Steam curing increases the compressive strength and the strength of stream cured bricks is more when compared to air curing. The percentage weight loss of geopolymer bricks when immersed in different concentration of H2SO4 and HCl is found to be very much lower when compared to other types of bricks. Further, the percentage weight loss increases with the increase in acid concentration. The increase in percentage of weight due to water absorption of geopolymer bricks is very small fraction when compared to that of other types of bricks.

[14]Rajamane et al (2012) have conducted an experimental investigation to study the resistance of geopolymer concrete to sulphates. Test specimens of typical GPCs and Portland Pozzolana Cement Concrete (PPCC) were submerged separately in 5% Na2SO4 and 5% MgSO4 solutions for 90 days. The test results indicate that for 30 and 90 days exposure, there were small changes in weight, ranging from weight gain of about 2% to weight loss of about 2.4%. There were quite different significant losses of strength in the concretes the ranges being about 2% to 29% for GPCs as compared to 9% to 38% for PPCC depending upon the exposure time and type of sulphate. However GPCs were found to resist sulphate attack (both magnesium and 23 sodium based) always better than PPCC as seen from their higher residual strengths after exposure to sulphates. Eco-friendliness of GPCs were examined by computing parameters such as 'Embodied Energy' and 'Embodied Carbon' or 'Embodied CO2 Emission', per unit volume of concrete, Energy and CO2 emission involved to produce unit strength in concretes. It was observed that GPCs were superior to PPCC in terms of these parameters also.

[15]Ivana, Sanja Dimter& Ivanka Netinger(2010)

Application of slag as an alternative to standard materials in the world has been known for a number of years, and accordingly numerous research studies have been carried out in that area. Slag is used the most in asphalt mixtures, although its good properties are also used for application in other layers of pavement structure, primarily unbound base courses and embankment. An area of application that has not been studied extensively so far is the application of slag in stabilized mixtures for construction of base courses, which could be of great interest for domestic road construction. Namely, in the last ten years road building in the Republic of Croatia was based on motorway building, and in this process, given the very heavy traffic load, cement-bound base courses were designed to increase the bearing capacity. Domestic slag as a significant quantity of calcium oxide, CaO (25-30 %, whilst free CaO accounts for 0,22-0,28 %), which is the basic indicator of pozzolanic behaviour of the material. The quantity of CaO indicates primarily the existence of the possibility of utilization of slag as binder or a portion of binder, but also as aggregate in stabilized base courses, which creates a possibility of new research in this area.

[16] Liu Chunlin, Zha Kunpeng &Chen Depeng (2011)

In this work the effect of using steel slag and scrap tire particles on the strength and volume deformation of concrete were preliminary studied to investigate the possibility of replacing the traditional aggregates for concrete production. Compressive and flexural strength, volume deformation of concrete containing EAF slag as aggregate or (and) scrap tire particles were experimentally investigated. In accordance with the experimental phase carried out in this study, the preliminary study conclusions obtained are as follows: The strength performance of EAF slag concretes is similar to that of a more traditional concrete, with a higher compressive strength and a slightly less flexural strength. The volume deformation of SSAC shows dilatometric effect (less shrinkage) comparing with the conventional concrete. Concretes produced with partial substitution of fine aggregate (whether steel slag or sandstone) by scrap tire particles obtain alower volume deformation (shrinkage or expansion) before and after specimens being submerged in water respectively. The use of scrap tire particles decreases the strength performance of concrete, especially the flexural strength. While partial substitution of fine steel slag in SSAC by scrap tire particles shows obvious higher compressive and flexural strength than that of concrete like Group OC-P. Further researches must be investigated thoroughly for the theory and application of scrap tire particle modified steel slag aggregates concrete.

[17] Dhiraj Agrawal1et.al(2007)

The various methodologies for the use of industrial waste products by partial replacements of cement and fine aggregates in concrete and mortar have been reviewed. Various physico-mechanical and chemical properties of the concrete and mortar incorporating different waste materials are studied in accordance with the reviewed literature and the standards. It is seen that waste materials like fly ash, rice husk ash, GGBF, were used extensively and sufficient research have been done on them. The study in turn is useful for various resource persons involved in using industrial or agricultural waste material to develop sustainable construction material.

[18]T.W. Cheng & J.P. Chiu(2003)

The geopolymerisation behavior, physical, mechanical properties, and fire resistance characteristics of granulated blast furnace slag-based geopolymer, are strongly dependent upon the chemical composition in the reaction system. In making the geopolymer, it was found that the K2O content in the system plays an important role. With increasing K2O content, the setting time can be increased, the compressive strength can be raised, and the fire resistance characteristics can also be improved. It has therefore been established that granulated blast furnace slag-based geopolymers can be fabricated for construction purposes, and that these geopolymers have great potential for engineering applications. References Comrie, D.C., Davidovits,J., 1988. Long term durability of hazardous toxic and nuclear waste disposals. Geopolymer 88, First European

III. CONCLUSIONS

Review of literature indicates a big importance for geopolymer in the near future, in the construction sector. The use of industrial waste in geo-polymer concrete is particularly important, as the disposal of this waste is a worldwide problem. it is concluded that: Geopolymer cement produces a substance that is comparable to or better than traditional cements with respect to most properties. Higher concentration of sodium hydroxide solution results in higher compressive strength of geopolymer concrete. Geopolymer concrete has excellent properties within both acid and salt environments. Low calcium fly ash based geopolymer concrete has excellent compressive strength, exposure to aggressive environment, workability, exposure to high temperature and is suitable for structural applications.

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