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ACID AND ITS EFFECT ON VARIOUS TYPES OF GEOPOLYMER CONCRETE-A REVIEW

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Abstract: Durability tests on concrete are done as Acid attack on concrete, because of alkaline nature of concrete. Geopolymer is also an alkaline concrete of sodium ion, rather than conventional concrete of calcium ion. Geopolymer concrete is now used for practical applications. Hence study on Acid attack of Geopolymer concrete is must as it has to withstand the Acid rain and other damages caused by nature. This Paper reviews various Acid attack tests carried out on various types of geopolymer concrete.

Index Terms: **Acid attack, concrete, Geopolymer, Acid rain**

I.INTRODUCTION

Acid rains are now widely prevalent due to industrial activities and high concentration of carbon di oxide, sulphur di oxide and nitrogen di oxide. These form corresponding acids viz. carbonic acid, sulphuric acid and nitric acid, when they come in contact with rain water. When acid rains fall on the manmade structures, the acid in rain neutralizes and corrodes calcium based alkaline compounds to create soluble compounds, hence weakening the cement concrete, cement mortar and corroding the steel in RCC.

Geopolymer Concrete is basically an alkaline material. Geopolymers are the three-dimensional networks made by reacting materials containing alumina and silica with alkaline liquids [6]. Due to Al3+ of (AlO4)−1 is four-fold coordination, Na+in the alkaline activating solution balances the surplus negative charge [1]. Geopolymer concrete undergoes degradation due to depolymerisation and de-alumination of geopolymer gels[2].

The geopolymer concrete has a various advantages over conventional concrete. One of them is acid resistance and less weight loss in acid attack. The exposure of the geopolymer to acid solution creates the weight loss due to the exposure 0.5% compared to normal concrete when immersed in 3% sulphuric acid. [3] According to Bakharev [4], in acidic exposure, high-performance geopolymer materials deteriorate with the formation of fissures in an amorphous polymer matrix whereas low performance geopolymers deteriorate through the crystallization of zeolites and the formation of fragile grainy structures. Crystalline geopolymer material prepared with sodium hydroxide is more stable in the aggressive environment of sulphuric and acetic acid solutions than amorphous geopolymer prepared with a sodium silicate activator.

There are large number of Al-O and Si-O structures in geopolymers [5]. Geopolymers do not react with acids at room temperature and can be used to make acid-resistant materials. When the Geopolymer concrete samples [6] were submerged in 5% H2SO4 solution for 30 days, the mass loss of metakaolin-based geopolymers was 7%. The fly ash-based geopolymer microstructure was retained for 3 months after being placed in HNO_3.

Geopolymers [7] contains polymeric alumino- silicate gels in their structures. Addition of calcium rich binders like GGBFS or metakaoline brings cementitious properties to GPC due to the formation of C-S-H gels. The co-existence of two gel phases contributes to mechanical properties of geopolymer. The absence of (C-S-H) gels in GPC gives better acid resisting properties to GPC. Wallah [8] experimented on long term properties of geopolymer concrete, the durability of geopolymer very high compared to Portland cement concrete in both acid and sulphate environment.

II.REVIEW

Suresh Thokchom[9] et al., investigated Durability of fly ash based geopolymer mortar specimens in Nitric acid solution on three different specimens manufactured by akali activating fly ash with a mixture of sodium hydroxide and sodium silicate solution containing Na2O from 5% to 8% of fly ash. Specimens were immersed in 10% by weight Nitric acid solution for 24 weeks. Studies were conducted in terms of visual appearance, change in weight and change in compressive strength. Mineralogical and microstructure changes due to nitric acid attack were also evaluated. Geopolymer mortar specimens showed excellent durability in terms of extremely less weight loss as well as high retention of compressive strength. Specimens with higher alkali content exhibited better resistivity to nitric acid.

Rangan [10] suggests that the design provisions contained in the current standards and codes can be used to design reinforced low-calcium fly ash-based geopolymer concrete structural members. Heat-cured low-calcium fly ash-based geopolymer concrete also shows excellent resistance to sulfate attack, good acid resistance, undergoes low creep, and suffers very little drying shrinkage. The Report has identified several economic benefits of using geopolymer concrete.

Aprilina Purbasari [11] studied the durability and microstructure of geopolymer mortars from co-combustion residuals of bamboo and kaolin when exposed to 5% sulfuric acid solution for 2, 4, and 6 weeks, respectively. The results revealed that geopolymer mortars showed better sulfuric acid resistance compared to ordinary Portland cement mortars in terms of lower mass loss and lower compressive strength loss.

Ganesan Lavanya[12] investigated the durability of geopolymer concrete prepared using high calcium fly ash along with alkaline activators when exposed to 2% solution of sulphuric acid and 5% magnesium sulphate for up to 45 days. The durability was also assessed by measuring water absorption and sorptivity. Ordinary Portland cement concrete was also prepared as control concrete. After 45 days of exposure to the magnesium sulphate solution, the reduction in strength was up to 12% for geopolymer concrete and up to 25% for ordinary Portland cement concrete. After the same period of exposure to the sulphuric acid solution, the compressive strength decrease was up to 20% for geopolymer concrete and up to 28% for ordinary Portland cement concrete.

Song [14], et al., presents experimental data on the durability of fly ash based Geopolymer concretes exposed to 10% sulphuric acid solutions for up to 8 weeks. The results confirmed that Geopolymer concrete is highly resistant to sulphuric acid in terms of a very low mass loss, less than 3%. Moreover, Geopolymer cubes were structurally intact and still had substantial load capacity even though the entire section had been neutralized by sulphuric acid.

Kumaravel [15] investigated strength of Geopolymer concrete with acid and salt exposure, The nominal strength geopolymer concrete is used. The 12 mole GPC specimens show excellent resistance against acid and salt.

Athira Ajay [16]reviewed the mechanism of acid attack, says that it varies based on the acid type and the characteristics of the calcium salt that are formed. Conventional concrete made with Ordinary Portland Cement (OPC) are not resistant to acids. Also, as we strive towards sustainable development, alkali activated or geopolymer concrete has started to

gain attention as it is found to have better mechanical properties and durability comparing to conventional concrete.

Citric acid[16] was found to be the most aggressive among organic acids and there is rapid loss of thickness. The high concentration used, poly-acidity of citric acid and the non-protective nature of precipitate formed seems to have increased the aggressiveness of citric acid. Nitric acid attack is a typical acidic corrosion causing volume reduction of the corroded layer due to the leaching of highly soluble calcium nitrate salt that is formed. Acetic acids are found mainly in waste waters and it is found to be aggressive when it comes to acid attack. The corrosion process is rapid comparable to that of strong acids such as sulphuric acid but lesser aggressive compared to citric acid at equivalent concentrations. These acids produce soluble calcium salts by dissolution of calcium hydroxide in concrete.

The durability[17] of GPC can be determined by the properties like sorptivity, immersed absorption, water absorption, apparent volume of permeable voids (AVPV), chloride ingress, sulphate, or other acid attack.

T.Srinivas[18] observed that in both natural and recycled aggregate of Geopolymer concrete is highly resistant to acids such as sulphuric acid and hydrochloric acid compared to conventional concrete of respective aggregates.

Madhan Gopal[19] studied behavior of fly ash based geopolymer concrete exposed to 5% acid solutions for up to 4 weeks. A class F fly ash based geopolymer concrete was initially cured for 24 hours at 60°C. And also the obtained results were compared with the conventional concrete exposed to 5% acid solutions for up to 4 weeks. The compressive strength of geopolymer concrete and conventional concrete of 150-mm cubes at an age of 28 days were 32MPa and 48.5MPa, respectively. Initially concrete cubes were cured for a period of 28 days and later cubes were immersed in acid solutions, After immersion in a 5 % acid solutions, samples were tested at 7, 14 and 28 days. The mass loss, compressive strength reductions were determined. In this experimental work 3 type of acid solutions are used, i.e., HCl, H_2SO_4 and $MgSO_4$.The results confirmed that Geopolymer concrete is highly resistant to acid in terms of a very low mass loss and compressive strength loss when compared to conventional concrete.

Jean-Baptiste Edouard[20] evaluated the durability characteristics of low calcium fly ash-based geopolymer concretes subjected to the marine environment, compared to ordinary Portland cement concrete with similar exposure. To achieve this goal, 8 molar geopolymer, 14 molar geopolymer and ordinary Portland cement concrete mixes were prepared and tested for exposure in seawater. Compressive strengths in the range of 2900 to 8700 psi (20-60 MPa) were obtained. The corrosion resistance performance of steel-reinforced concrete beams, made of these mixes, was also studied, using an accelerated electrochemical method, with submergence in salt water. The test results indicated that the geopolymer concrete showed excellent resistance to chloride attack, with longer time to corrosion cracking, compared to ordinary Portland cement concrete.

In a project by Antony Jeyasehar et al., [21] concluded that all the geopolymer concrete were showing percentage of mass increase when compared with initial mass. Hence, geopolymer concrete showed an excellent resistance to acid attack

III.Test Procedures Adopted

To study [9] the effect of alkali (Na_2O) content on performance of geopolymer mortar samples in nitric acid, specimens were soaked in 10% nitric acid solution after 28 days from manufacture for 24 weeks. The volume of acid solution was taken as four times the volume of specimens and refreshed after 12 weeks. The effects of nitric acid on the geopolymer mortar specimen were constantly monitored through visual inspection, weight measurements and strength tests at predetermined intervals during the exposure period. For investigating the surface changes, an optical microscope was used to observe the surfaces after removal from solution at regular intervals. Samples for weight change measurements were initially primed in water for 3 days and its weight in saturated surface dry condition was taken as initial weight. Average values of minimum three specimens have been reported for weight changes and residual compressive strengths. A JEOL JSM 6360 scanning electron microscope equipped with Inca Oxford EDX analyzer was employed to examine changes in microstructure as well as for microanalysis of specimens. For mineralogical investigation, Rigaku Miniflex XRD machine was utilised at a scanning rate of 1oper minute for scanning angle 2θranging from 5° to 65°. Mercury intrusion porosity of specimens was determined with a Quantachrome Poremaster 60 at a contact angle of 140°.

Rangan [10] performed tests to study the sulphuric acid resistance of heat-cured low-calcium fly ash-based geopolymer concrete. The concentration of sulphuric acid solution was 2%, 1% and 0.5%. The sulphuric acid resistance of geopolymer concrete was evaluated based on the mass loss and the residual compressive strength of the test specimens after acid exposure up to one year. The test specimens, 100x200 mm cylinders and heat-cured at 60o C for 24 hours after casting . The visual appearance of specimens after exposure to sulphuric acid solution showed that acid attack slightly damaged the surface of the specimens. It can be seen that the specimens exposed to sulphuric acid undergoes erosion of the surface. The damage to the surface of the specimens increased as the concentration of the acid solution increased.

Geopolymer mortars[11] sized 5 x 5 x 5 cm were prepared from co-combustion residuals of bamboo and kaolin with alkaline activators, i.e. mixture of 10 N potassium hydroxide solution and sodium silicate solution, and cured at 60oC in oven for 8 hours and then at room temperature for 28 days. Mortars from ordinary Portland cement were also prepared as control mortars. The parameters studied were visual appearance changes, mass changes, compressive strength changes, and microstructure changes. Microstructure changes were examined using Fourier transform infrared (FTIR) spectroscopy, X-ray diffraction (XRD), and scanning electron microscopy (SEM).

All Fly ash based geopolymer concrete specimens (GPC) [12] were prepared with an alkaline solution ratio (sodium silicate to sodium hydroxide) of 2.5 by mass, since the strength was maximum, when the ratio of sodium hydroxide and sodium silicate was 2.5. The grades of concrete chosen were based on IS 456-2000. The molarity of sodium hydroxide was chosen as 12. The mix proportion for geopolymer concrete is given in Table 2. Both coarse and fine aggregates were used in saturated surface dry condition. The fly ash and the aggregates were first dry-mixed in a pan. Then the alkaline solution containing sodium hydroxide and sodium silicate was added and mixed. he cube specimens of size 150×150×150 mm and cylinder of size 100×200 mm were casted. After casting, the specimens were covered using polythene sheets to avoid the evaporation the test specimens were let to room temperature curing of 28∘ Cto31∘C. OPC specimens were also prepared for comparison purposes. The sorptivity tests were undertaken for cylindrical specimens with 100 mm diameter and 50 mm height in accordance with ASTM C1585-04. The cylinders after demoulded were submerged in water for 45 days. After curing, the samples were dried in oven for 24 hours at 110∘ C temperature the specimens were drowned with water level not more than 5mm above the base of specimen and the low from the peripheral surface is prevented by sealing it properly with non-absorbent coating to maintain the uniaxial water low during the test. The quantity of water absorbed in a time period of 30 minutes was measured. Finally the sorptivity coeicient was calculated using the equations given as fol-lows:

$$S = \frac{I}{\sqrt{t}},$$

where S[12] is the sorptivity in mm and t is the elapsed time in

min. Consider

$$I = \frac{\Delta W}{AD}. \qquad (2)$$

ΔW is [12] change in weight which equals $W2 - W1$,where W1 is the oven dry weight of cylinder in grams and W2 is the weight of cylinder ater 30 minutes of capillary suction of water in grams, A is the surface area of the specimen through which water penetrated, and D is the density of water. The response of the geopolymer and ordinary cement concrete specimens in sulphuric acid and magnesium sulphate environment was studied by immersing the specimens in 2% sulphuric acid [13] and 5% magnesium sulphate Solution separately after 7 days of casting. The choice of solution and concentration was based on practical utilization of concrete as a construction material in sewage pipes, mining, and food processing industries. he specimens were kept fully immersed in these solutions, having four times the volume of specimens for 45 days. The solutions were replaced weekly with fresh solutions in order to maintain the con-centration of the solution [8]. The efects of these solutions on the specimens were regularly monitored through visual inspection, measurement of weight change, and strength test. Samples for weight change test were primed in water for 3 days prior to immersion in these solutions and its saturated surface dry weight was considered as initial weight. These samples were removed from the solution and weighed at various stages of exposure in similar condition as the initial weight.

A class F fly [14] ash based Geopolymer concrete was initially cured for 24 hours at either 23 ˚ C or 70˚ C. The compressive strength of 50-mm cubes at an age of 28 days ranged from 53MPa to 62MPa. After immersion in a 10% sulphuric acid having a fixed ratio of acid volume to specimen surface area of 8 ml/cm2, samples were tested at 7, 28, and 56 days. The mass loss, compressive strength reduction, and the residual alkalinity were determined on the basis of modified ASTM C267 tests.

Geopolymer concrete [15] with different NaOH concentrations, such as 8 M, 10M, 12M and 14Moles. The concrete cylinders are cured and tested for compressive strength. The durability of Geopolymer concrete is tested by immersion in chemicals that are sulphuric acid and sodium sulphate. Alumina-Silicate is the binder in GPC, which react with acid and salt. These specimens are immersed separately in 5 percent of sodium sulphate and different concentrations of sulphuric acid for 90 days. The weight and compressive strength of acid and sulphate reaction on geopolymer concrete cylinders are determined

The sulphuric acid[18] and hydrochloric acid resistance of geopolymer concrete is evaluated by casting 100 mm x 100 mm x100 mm cubes. To carry the acid attack an immersion techniques has been adopted. After casting and curing specimens have been immersed in acid solutions. The concentration of sulphuric acid and hydrochloric acid solutions are 5%. The tests are conducted after 15, 45, 75 and 105days from the date of immersion. Solutions are kept at room temperature. The solution is replaced at regular intervals of 15 days to maintain concentration of solution throughout the test period. The weight loss, compressive strength loss in percentage is evaluated. The weight of geopolymer concrete decreases when the acid concentration increases and the same effect is reflected after 105 days of immersion in acid.

Geopolymer concrete cubes[19] and conventional concrete cubes were cured for a period of 28 days. Generally, heat curing is recommended for geopolymer concrete and heat curing was done at a temperature of 60oc for a period of 24hours. After completion of curing process, weight of both conventional and geopolymer concrete cubes were taken. Later, concrete specimens were immersed in 5% of acidic solutions (HCl, H_2SO_4, $MgSO_4$) for a period of 7, 14, 28 days. After completion of immersion period, concrete specimens were taken out and allowed for drying for a period of 1 day and weight of concrete cubes were determined. And also, the compressive strength of concrete cubes after acid immersion was determined by using U.T.M. and the obtained results are compared. Residual compressive strength and percentage weight loss of geopolymer and conventional concrete cubes after acid immersion have been studied and compared.

To do the acid attack [21]studies in the present investigation immersion technique was adopted. After 28 days of casting, 100 x 200 (mm) cylinder specimens were immersed in H_2SO_4 solution. The solution was kept at room temperature and the solution was stirred regularly, at least twice a day to maintain uniformity. The solution was replaced at regular intervals to maintain concentration of solution throughout the test period. The evaluations were conducted after 60 days from the date of immersion. After removing the specimens from the solution, the surfaces were cleaned with a soft nylon wire brush under the running tap water to remove weak products and loose material from the surface. Then the specimens were allowed to surface dry and all the measurements were taken. From the initial measurement and measurements at particular intervals, the loss or gain of the weight were studied.

IV.CONCLUSION

From the review of work done by many eminent scholars, it is evident that the Geopolymer supersedes the ordinary Portland cement (OPC) based concrete in strength, durability, resistance to acid attack, sustainability and reuse of Industrial wastes. All the scholars concluded that acid resistance of Geopolymer is superior to OPC concrete. While OPC concrete suffers loss in weight, geopolymer sometimes [21] gains weight in H_2SO_4 curing. Hence Geopolymer concrete is truly a next generation Product which would replace OPC concrete in near future

REFERENCES

[1] Lahoti, M. K., K. H. Tan, and E. H. Yang. A critical review of geopolymer properties for structural fire-resistance applications. Construction & Building Materials, Vol. 221, 2019, pp. 514–526.

[2] Mo Zhang, "Geopolymer, Next Generation Sustainable Cementitious Material − Synthesis, Characterization and Modeling" A DissertationSubmitted to the Faculty of the Worcester Polytechnic Institute, in partial fulfillment of the requirements for the Degree of Doctor of Philosophy, May 2015, pp-II

[3] R. Sathia, K.G. Babu and M. Santhanam, In:Durability Study of Low Calcium Fly Ash Geopolymer Concrete, (The 3rd ACF International Conference-ACF/VCA, 2008).

[4] T. Bakharev // Cem. Concr. Res. 36 (2006) 1134.

[5] Lingyu, Tian, Dongpo, He, Jianing, Zhao and Hongguang, Wang. "Durability of geopolymers and geopolymer concretes: A review" Reviews On Advanced Materials Science, vol. 60, no. 1, 2021, pp. 1-14. https://doi.org/10.1515/rams-2021-0002

[6] Davidovits, J. Geopolymers – Inorganic polymeric new materials. Journal of Thermal Analysis, Vol. 37, No. 8, 1991, pp. 1633–1656.

[7] Cibi Peter, Lathi Karthi, "Durability of geopolymer concrete exposed to acidic environment – a review.", Sustainability, Agri, Food and Environmental Research, (ISSN: 0719-3726), 10(X), 2022:http://dx.doi.org/

[8] Wallah, S. E.; Rangan, B. V. 2006. Low calcium fly ash based geopolymer concrete: Long term properties,Research report GC2, Curtin University of Technology, Australia. 30 p.

[9] Suresh Thokchom, Partha Ghosh, Somnath Ghosh, "Durability Of Fly Ash Geopolymer Mortars In Nitric Acid – Effect Of Alkali (Na2o) Content, Journal Of Civil Engineering And Management ISSN 1392-3730 print/ISSN 1822-3605 online 2011 Volume 17(3): 393–399 doi:10.3846/13923730.2011.594225

[10] B. V. Rangan, "Fly Ash-Based Geopolymer Concrete", Research Report GC 4, Engineering Faculty, Curtin University of Technology, Perth, Australia, 2008

[11] Aprilina Purbasari, Tjokorde Walmiki Samadhi, Yazid Bindar, "Sulfuric Acid Resistance of Geopolymer Mortars from Co-combustion Residuals of Bamboo and Kaolin",

[12] Ganesan Lavanya and Josephraj Jegan, "Durability Study on High Calcium Fly Ash Based Geopolymer Concrete", Advances in Materials Science and Engineering, Hindawi Publishing Corporation, Volume 2015, Article ID 731056, 7 pages http://dx.doi.org/10.1155/2015/731056

[13] N. P. Rajamane, M. C. Nataraja, N. Lakshmanan, J. K. Dat-tatreya, and D. Sabitha, "Sulphuric acid resistant eco-friendly concrete from geopolymerisation of blast furnace slag,"Indian Journal of Engineering and Materials Sciences ,vol.19,no.5,pp. 357–367, 2012.

[14] X. J. Song, M. Marosszeky, M. Brungs, R. Munn, "Durability of fly ash based Geopolymer concrete against sulphuric acid attack", DBMC International Conference On Durability of Building Materials and Components LYON [France] 17-20 April 2005

[15] S. Kumaravel, K. Girija, Acid and Salt Resistance Of Geopolymer Concrete With Varying Concentration Of NaOH", Journal of Engineering Research and Studies, E-ISSN0976-7916, IV/Oct.-Dec.,2013, pp01-03

[16] Athira Ajay, K P Ramaswamy, Anu V Thomas, "A critical review on the durability of geopolymer composites in acidic environment", 5th International Conference on Modeling and Simulation In Civil Engineering, IOP Conf. Series: Earth and Environmental Science491 (2020) 012044, IOP Publishing, doi:10.1088/1755-1315/491/1/012044

[17] Gunasekara, C.; Law, D.W.; Setunge, S. Long term permeation properties of di erent fly ash geopolymer concretes.Constr. Build. Mater.2016, 124, 352–362.

[18] T.Srinivas, S.P.Raju Vundi, N. V. Ramana Rao, Deepak Kumar Shinde, "Resistance of Acid Attack on Geopolymer Concrete Developed With Partial Replacement of Course Aggregate by Recycled Aggregate", International Journal of Recent Technology and Engineering (IJRTE), ISSN: 2277-3878, Volume-8 Issue-4, November 2019

[19] Mr. K. Madhan Gopal, Mr. B. Naga Kiran, "Investigation on Behaviour of Fly Ash Based Geopolymer Concrete in Acidic Environment", International Journal of Modern Engineering Research (IJMER) ISSN: 2249-6645, Vol.3, Issue.1, Jan-Feb. 2013 pp-580-586.

[20] Jean-Baptiste Edouard, "Experimental Evaluation Of The Durability Of Fly Ash-Based Geopolymer Concrete In The Marine Environment", Thesis Submitted to the Faculty of The College of Engineering and Computer Science in Partial Fulfillment of the Requirements for the Degree of Master of Science Florida Atlantic University, Boca Raton, Florida, May 2011

[21] Dr. C. Antony Jeyasehar, Dr. M. Salahuddin , Dr. S. Thirugnanasambandam, "Development Of Fly Ash Based Geopolymer Concrete Precast Elements" Research Project funded by Ministry of Environment and Forests, New Delhi