Original Research Article

DURABILITY STUDY ON FLY ASH BASED GEOPOLYMER CONCRETE FOR ACIDIC ENVIRONMENT

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ABSTRACT

The production of cement is harmful to the environment. It is important to decrease the creation of Ordinary Portland Concrete. On the opposite side, the thermal power plant expends hectares of land for the dumping of fly fiery remains which is waste material. This paper concentrates on low calcium fly ash based geopolymer concrete. In the geopolymer concrete, the diverse centralization of sodium hydroxide, for example, 8, 10, 12, 14, 16, 18, and 20 molar was utilized. The sodium silicate to sodium hydroxide proportion kept up as 2.5. The eight rate convergence of sulfuric and hydrochloric acid were utilized for the corrosive assault on fly ash based geopolymer concrete. The test perform for oven and steam cured fly ash based geopolymer concrete. The streamlined level of warming utilized for various curing techniques. After the curing, the cube kept in sulfuric and hydrochloric acidic condition for up to the half-year. The acidic impact assessed at once interim of 0, 45, 90, 135, 180 days. It is watched that the sulfuric corrosive is unsafe to the fly powder based geopolymer concrete as contrast with hydrochloric corrosive. The cube sample cured for oven and steam curing. The optimized degree of heating used for different curing methods. After the curing, the cube sample were kept in sulfuric and hydrochloric acidic environment for up to the six months. The acidic effect evaluated at a time interval of 0, 45, 90, 135, 180 days. It is observed that the sulfuric acid is harmful to the fly ash based geopolymer concrete as compare to hydrochloric acid.

1. INTRODUCTION

Concrete, as a major construction material, is being used at an ever-increasing rate all around the world. Almost all of this concrete is currently made using ordinary Portland cement, leading to a massive global cement industry. Every year the production of Portland cement is increasing with the increasing demand of construction. It was estimated that each ton of cement produced generates an equal amount of carbon dioxide. The production of cement is responsible for 5% of global greenhouse gas emission created by human activities. Therefore incorporating sustainability concerns into the design of civil engineering materials is urgently needed [1]. On the other side, fly ash is the waste material of coal based thermal power plant, available abundantly but create a disposal problem. Several hectors of valuable land are acquired by the thermal power plant for the disposal of fly ash. As it is light in weight and easily flies, it creates health problems like asthma, bronchitis, etc. In India, the survey shows that the present availability of fly ash has already exceeded 130 million tons, and its generation is likely to reach 170 million tons by 2011–2012 [2]. There are environmental benefits in reducing the use of Portland cement in concrete and using a by-product cementitious material, such as fly ash, silica fume, ground granulated blast furnace slag, rice husk ash, etc. as a partial substitute. With silicon and aluminum as the main constituents, fly ash has great potential as a cement replacing material in concrete. The concrete made with such industrial wastes is eco-friendly and hence called as “Green Concrete”.

Pozzolanic material like fly ash is utilized in the production of Portland pozzolans cement as part replacement of cement in concrete. In recent years, attempts have been made to replace the cement by more than 50% with fly ash in concrete to produce high volume fly ash concrete [2]. Geopolymer is new types of materials which can be synthesized by various natural materials or by-products as source material. Fly ash is a type of by-product that can be used in the synthesis. Source materials are activated by alkaline solutions and silicate solution [3].

2. RESEARCH BACKGROUND

Many researchers work on the geopolymer concrete with a different parameter such as the degree of heating, types of fly ash, testing age, fineness of fly ash, types of the activators etc. The mechanical properties of geopolymer concrete under different aggressive chemical environment and compared it with ordinary Portland concrete. Geopolymer concrete and ordinary Portland concrete cubes were immersed in 0.05 M & 0.005 M sulfuric acid, 10% sodium sulfate and sodium chloride solution for 30, 60 & 90 days. Geopolymer concrete has excellent mechanical properties and durability in the aggressive chemical environment than ordinary Portland concrete [4]. The compressive strength and the durability of lignite bottom ash geopolymer mortars in 3% sulfuric acid and 5% sodium sulfate solutions. It was found that the fine bottom ash was more reactive and gave geopolymer mortars with higher compressive strengths than those of the coarser fly ashes. All bottom ash geopolymer mortars were less susceptible to the attack
by sodium sulfate and sulfuric acid solutions than the traditional Portland cement mortars [5]. The resistance of fly ash based geopolymer mortar specimens in sulfuric acid. The concentration of sulfuric acid in solution 10% up to a period of 18 weeks and evaluation of its resistance in terms of visual appearance, residual alkalinity, changes in weight and compressive strength at regular intervals. It was observed that after exposure in the acid solution for 18 weeks, the geopolymer samples almost lost its alkalinity and very low weight loss [6, 7]. The different mole’s concentration of sodium hydroxide on geopolymer concrete. It was cured and tested for compressive strength. The durability of geopolymer concrete is tested by immersion in chemicals that are sulfuric acid and sodium sulfate. The sodium hydroxide concentrations such as 8 M, 10 M, 12 M and 14 M were used. These specimens were immersed separately in 5 percent of sodium sulfate and different concentrations of sulfuric acid for 90 days. It was found that 12-mole geopolymer concrete shows excellent resistance against acid and salt [8].

3. MATERIALS AND METHODOLOGY

3.1. Processed fly ash, alkaline activators, aggregate

A fly ash is a by-product or the finely divided residue resulting from the combustion of pulverized coal in thermal power plants. Fly ash usually refers to ash produced during combustion of coal. The types of processed fly ash purchase from dirk India private limited (Nasik). Fly ash may have a specific surface of about 350 to 500 m²/kg. i.e. finer than Portland cement. The laboratory grade sodium hydroxide pellets form were used. A combination of sodium hydroxide and sodium silicate solutions were used for the activation of fly ash. The locally available fine as well as a coarse aggregate were used in this investigation.

3.2. Preparation of mix and sample

The geopolymer concrete was design for characteristics strength of M30 grade. The cement is totally replaced by Pozzocrete processed fly ash P60. For the mixing of the solution to fly ash ratio maintained as 0.35 for all types of curing. The alkali activators ratio i.e. sodium silicate to sodium hydroxide solution ratio by mass is maintained constant as 2.5 and the solution to fly ash ratio is 0.35. The curing hours maintained 18 hours for different types of curing. After the curing, the concrete cube sample was tested after 7 days. In this study, the fresh geopolymer concrete was found by proper mixing of dry solid and activators. The geopolymer concrete is made up of using fly ash; fine aggregate, coarse aggregate and alkaline liquid. The alkaline liquids are sodium hydroxide (NaOH) and sodium silicate (Na₂SiO₃). For the preparation of 1M solution 40 grams of sodium hydroxide pellets of solid form was used. While we mix 40 grams pellets in one liter solution then we get 1M sodium hydroxide solution. Similarly, we prepare 16 M solution for geopolymer concrete by adding 16 X 40 = 640 grams sodium hydroxide pellets then we get 16 M one liter sodium hydroxide solution. The heat evaluation rate is so high at the time of mixing pellets into water. Due to this, sodium hydroxide solution was prepared one day prior to the casting of concrete cubes.

In the laboratory, the dry mix of fly ash and aggregate were mixed in pan mixer. Then, a quantity of sodium hydroxide solution and sodium silicate solution with extra water was mixed until a homogeneous mix was formed. After making the homogeneous mix, workability test by slump cone test was carried out. Then, cubes of size 150 mm X 150 mm X 150 mm were cast in three layers as per standard process. Then after demoulding of cube these cube placed for curing of geopolymer concrete. The cubes cured at various temperatures 60°C to 150°C for different types of curing method. These cubes were placed at room temperature after curing up to the testing age. The testing age for cube will be assumed as 7 days which was optimized. In the present study, the effect of the oven, steam, membrane and accelerated curing were analyzed in an acidic environment for 45, 90, 135, 180 days. In this study, the effect of degree of heating and duration of heating were evaluated for different types of curing.

3.3. Preparation of acidic environment

The sulfuric corrosive assault on oven and steam cured fly powder based geopolymer cement can be watched for compressive strength of concrete. The concentrated sulfuric and hydrochloric corrosive weakened by utilizing faucet water in eight rate fixation. The block were cured at streamlined curing term, level of warming and testing time of geopolymer concrete in oven and steam chamber. The cast test was cured for 18 hours for oven and steam heating. After the curing the specimen kept for rest period for 7 days. The geopolymer cube after the testing age was immersed into sulfuric and hydrochloric acidic condition for 0, 45, 90, 135 and 190 days. This acidic condition were changed following 45 days of span and give the 190 days corrosive condition to the fly based geopolymer concrete. The inundated example was tried after the interim of 0, 45, 90, 135 and 190 days. The sample was removed from solution and kept for drying for 24 hours. These samples were weighed for calculating the weight losses and then to carry out the compressive strength test.

4. RESULT AND DISCUSSION

4.1. Effect of concentration sodium hydroxide

The molarity of sodium hydroxide plays a vital role in geopolymer concrete. In this investigation, the temperature (90°C), curing duration (24 hrs) and testing age (7days) are used from past study. The molarity of sodium hydroxide varies such as 8, 10, 12, 14, 16, 18, and 20 molar. The sodium silicate-to-sodium hydroxide ratio by mass was maintained as 2.5 and the liquid form of sodium silicate was mixed with different molar sodium hydroxide. It is observed that the concentration of sodium hydroxide is optimized at 16M. The effect of concentration of sodium hydroxide on geopolymer concrete is shown in Figure 1.

![Figure 1. Effect of concentration of NaOH](image-url)
4.2. Effect of sodium silicate-to-sodium hydroxide ratio by mass

The sodium silicate-to-sodium hydroxide ratio by mass varies from 1, 1.5, 2, 2.5, 3, and 3.5. In this investigation, the concentration of sodium hydroxide 16 M is used. The effect of alkaline activators is analyzed on the compressive strength of geopolymer concrete. It is observed that the compressive strength of geopolymer concrete varies as the ratio increases but in case 3.5 ratios, it was decreasing. The optimized ratio of sodium silicate-to-sodium hydroxide is 2.5 with consideration of cost as well the strength of geopolymer concrete.

![Figure 2. Effect of sodium silicate-to-sodium hydroxide ratio by mass on GPC](image)

4.3. Effect of oven curing on degree of heating

The degree of heating was varied such as 60°C, 90°C, 120°C, and 150°C for oven curing. The curing duration was varied from 6, 12, 18, and 24 hours. The testing age for geopolymer concrete was kept constant 7 days. After the 7 days, the cube sample was tested under compression testing machine. The investigation based on the degree of heating for fly ash based geopolymer concrete. It is observed that the rate of gain of strength increases with increasing degree of heating, but after the 120°C the strength decreases. It is also observed that the target strength is achieved for 90°C. Again it is increasing at 120°C but the consumption of electric energy for oven curing is more as compared to 90°C. Therefore the degree of heating for oven curing is optimized at 90°C. The optimized degree of heating used for the further investigation. Figure 3 shows the rate of gain of strength is reduced at 150°C and the rate of gain of strength is higher up to the 90°C, but it is slower in between 90°C to 120°C.

![Figure 3. Effect of curing duration and degree of heating on geopolymer concrete](image)

4.4. Effect of oven curing on curing duration

Figure 3 shows the effect of curing duration on compressive strength of fly ash based geopolymer concrete. The curing duration was varied from 6, 12, 18, and 24 hours. For oven curing optimized degree of heating (90°C) is used. The testing age (rest period) remains constant for 7 days.

It is observed that the increasing curing duration increases compressive strength but it is not significant after 18 hours because the target strength is achieved in 18 hours. For 24 hours of curing duration, the target strength achieved but energy consumption is more as compared to 18 hours of curing duration. Hence the optimum curing duration is 18 hours for oven curing at 90°C. The rate of gain of strength is more after the 6 hours of curing duration but it is not significant after 18 hours.

![Figure 4. Effect of curing duration and degree of heating on GPC using steam curing](image)

4.5. Effect of steam curing on degree of heating

The steam cured sample was tested for compressive strength. The degree of heating was varied such as 60°C, 80°C, 100°C, and 120°C. The testing age for steam curing remains constant from literature review as 7 days. It is observed that the degree of heating increases with increasing strength of geopolymer concrete, but at 120°C the rate of gain of strength is slower as compared to 100°C. The target strength obtained at 120°C but the energy required is more which is not suitable for energy consumption (cost effectiveness). The target strength also achieved at 100°C. Due to that, the steam curing for geopolymer concrete is optimized at 100°C with consideration of energy consumption. From Figure 4 the rate of gain of strength is higher up to the 100°C after that the rate of gain of strength is decreased.

4.6. Effect of steam curing on curing duration

Figure 4 shows the effect of curing duration on compressive strength of fly ash based geopolymer concrete. The curing duration was varied from 6, 12, 18, and 24 hours. The degree of heating for steam curing is optimized at 100°C. The testing age remains constant for 7 days. It is also observed that the increasing curing duration increases compressive strength. The rate of gain of compressive strength up to 18 hours is higher. The compressive strength is also achieved in 24 hours but after 18 hours the rate of gain is slower. After 18 hours of curing, there is wastage of time and electric energy. Therefore the curing duration 18 hours is optimized.
The optimized parameter for oven, steam, membrane and accelerated was used for the further investigation. The different types of curing optimized for the degree of heating and duration of heating. This optimized degree of heating and duration for heating maintained constant and cast and cured a cube sample. These cube sample kept in sulphuric and hydrochloric acidic environment for 45, 90, 135, and 180 days. After removing the cube sample from acid the cube is dried for 24 hours. The weighted and tested for compressive strength.

4.7 Sulfuric acid attack on fly ash based geopolymer concrete

The sulfuric acid attack on the oven and steam cured fly ash based geopolymer concrete were investigated with the help of weight losses and compressive strength of fly ash based geopolymer concrete. The cube was cured at optimized curing duration, the degree of heating and testing age of geopolymer concrete. The different types of curing sample were kept in 0, 45, 90, 135 and 190 days in eight percent concentration of sulfuric acid. The cast sample cured for 18 hours for oven and steam curing. After the curing the sample kept for rest period for 7 days then these sample were immersed in eight percent concentric sulfuric acid. It is diluted by using tap water. The diluted sulfuric acid was prepared after 45 days of intervals for to maintain concentration of sulfuric acid. The immersed sample weretested after the interval of 0, 45, 90, 135 and 190 days. The samples were removed from solution and kept for drying for 24 hours. These samples were weighted for calculating the weight losses and then to carry out the compressive strength test. The test result of the effect of sulfuric acid on geopolymer concrete is shown in Figure 5.

It was observed that the weight loss was due to the concentric effect of the sulfuric acid attack on fly ash based geopolymer concrete. It was observed that after 90 days the weight losses in geopolymer concrete is rapid due to sulfuric acid attack. After the six-month, the cube sample was not in a position to take a compressive strength due to weight losses. The effect of sulfuric acid on weight losses of geopolymer concrete for different types of curing are shown in Figure 6. The weight losses and compressive strength also reduced with respect to a number of days the cube sample immersed in sulfuric acid. Figure 6 shows the effect of concentration of sulfuric acid on compressive strength of geopolymer concrete. It is also observed that the compressive strength and weight losses are more in the case of accelerated cured sample as compare to another type of curing.

4.8. Effect of hydrochloric acid attack on geopolymer concrete

The eight percent dilute hydrochloric acid was prepared with the help of tap water. This diluted hydrochloric acid changed after 45 days of interval due to maintain the concentration of hydrochloric acid. The oven and steam cured fly ash based geopolymer cube were immersed in hydrochloric acid for 0, 45, 90, 135 and 190 days. After completion of duration the sample were removed from solution and kept for drying for 24 hours. These sample weighted for calculating the weight losses and followed by compressive strength test. Figure 7 shows the effect of concentration of hydrochloric acid on compressive strength of geopolymer concrete. It is observed that the compressive strength and weight losses is very less as compare
to sulfuric acid attack. The effect of hydrochloric acid on weight losses of geopolymer concrete for different types of curing are shown in Figure 8. It was observed that the weight losses is less but the compressive strength reduces with increasing duration of hydrochloric acid attack on geopolymer concrete.

5. CONCLUSION

- The molarity of sodium hydroxide assumes a vital part to achieve compressive strength of fly based geopolymer concrete.
- The sodium silicate-to-sodium hydroxide proportion by mass of 2.5 gives a streamlined outcome for workability and compressive quality, however, past 2.5 proportion the compressive quality lessens, so sodium silicate-to-sodium hydroxide proportion by mass is kept steady as 2.5.
- The curing term assumes a critical part in accomplishing target compressive quality, it was watched that the objective quality accomplished at a higher level of warming in less curing length.
- The sulfuric corrosive influences the compressive quality and also weight misfortunes of fly based geopolymer concrete. It was seen that the level of weight and quality decrease was more on account of oven curing as contrast with another kind of curing.
- On account of hydrochloric corrosive, the weight misfortunes and compressive quality misfortunes were less as contrast with sulfuric corrosive assault. The weight misfortunes more on account of quickened curing was quantifiable as contrast with different sorts of curing.

CONFLICT OF INTERESTS

On behalf of all authors, the corresponding author states that there is no conflict of interest.

REFERENCES