



“EXPERIMENTAL ANALYSIS ON GEOPOLYMER SELF-CLEANING CONCRETE UTILIZING FLY ASH AND GGBS”

¹*Tejendra Prajapati*, ²*Gaurav Jhanji*

¹PG Student, ²Asst. Professor

^{1,2}Department of Civil Engineering

^{1,2}Mahakal Institute of Technology and Management, Ujjain, India

ABSTRACT—

The development of geopolymer concrete as a substitute for traditional Portland cement concrete has been aided by the growing demand for long-lasting and sustainable building materials. This study examines the mechanical characteristics, durability, and self-cleaning effectiveness of fly ash and ground granulated blast furnace slag (GGBS)-based geopolymer self-cleaning concrete. The main aluminosilicate binders are fly ash and GGBS, which are activated with an alkaline solution of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3). Through photocatalytic oxidation under light exposure, titanium dioxide (TiO_2) is used as a photocatalytic material to give self-cleaning capabilities. The study assesses how different fly ash–GGBS ratios and TiO_2 doses affect workability, split tensile strength, compressive strength, and water absorption. The degradation of specific surface contaminants or stains under regulated light exposure is measured in order to evaluate the self-cleaning performance. The goal of the study is to find a suitable mix of fly ash, GGBS, alkaline activator, and TiO_2 that enhances the concrete's surface-cleaning capacity and offers sufficient structural performance. The suggested geopolymer self-cleaning concrete might lessen reliance on regular Portland cement, make use of industrial byproducts, increase durability, and support low-maintenance, more sustainable building. A brief review about geopolymer self-cleaning concrete is deliberated in this study. RhB (Rhoda mine dye) discoloration under UV light, which is also regarded as a standard test for self-cleaning cementitious materials, is used to determine the self-cleaning property of the photocatalytic concrete. The findings will provide insight into the viability of substitutes for traditional concrete, and the concrete will be employed as an environmentally friendly self-cleaning agent thanks to the photocatalytic effect. A basic overview of self-cleaning concrete is also covered in this article. This study's primary goal was to compare the characteristics of concrete with fly ash and GGBS accumulation to the control mix in order to identify the benefits and drawbacks of doing so. Titanium dioxide (TiO_2) serves as the photocatalytic component in this research, incorporated into concrete at a concentration of 3.0% to assess its impact. Moreover, the incorporation of fly ash and GGBS can enhance the self-compacting characteristics of this concrete. For M 25 and M30 concrete classifications, diverse percentile mixtures of fly ash and GGBS can replace cement by as much as 50%, with the relative ratios between them adjusting accordingly. The hardened concrete sample will undergo several evaluations, such as tensile, flexural, and compressive strength assessments. Newly mixed concrete will be subjected to a workability assessment to determine the properties of the self-cleaning concrete. A sodium chloride (NaCl) solution was employed to evaluate the durability of the self-cleaning concrete. RhB (Rhoda mine dye) fading when exposed to UV light, a prevalent evaluation for self-cleaning cementitious substances, is employed to determine the photocatalytic concrete's self-cleaning capabilities. The results will elucidate the feasibility of alternatives to conventional concrete, and the concrete will serve as an eco-friendly self-cleaning agent due to its photocatalytic properties.

Keywords: Geopolymer Concrete, Self Cleaning Concrete, Green Concrete, Photocatalytic action, Compressive Strength, Tensile Strength, Flexural Strength.

1. Introduction -

Concrete is the most widely used and the primary building material in the construction industry. It is a composite substance primarily made up of water, aggregate, and cement. Typically, various additives and reinforcements are incorporated to achieve the desired physical characteristics of the final product. When these components are combined, they create a liquid mass that can be easily shaped. As time passes, the cement hardens into a solid matrix that holds the other materials together, resulting in a long-lasting stone-like substance with numerous applications.

Self-cleaning concrete harnesses energy from ultraviolet light to break down organic substances. This speeds up the natural oxidation process and promotes quicker decomposition of pollutants. The primary advantages of self-cleaning concrete are maintaining a dirt-free surface and contributing to a healthier environment. Photocatalytic materials play a crucial role in directly reducing air pollution. These substances capture ultraviolet rays from sunlight, generating hydroxyl radicals and superoxide anions that can interact with pollutant molecules like NO_x , transforming them into less harmful compounds. This feature could be especially beneficial in regions with elevated air pollution levels. The characteristics of photocatalysts include purifying water and air, enabling self-cleaning properties, and exhibiting antibacterial effects.

However, self-cleaning geopolymer concretes offer an environmentally beneficial remedy for this problem. They offer substantial environmental benefits, including lowering CO₂ emissions and being affordable, long-lasting, and sustainable. Geopolymer cement has unique properties that allow it to withstand high temperatures and withstand acid and salt. Even in industrial areas and contaminated surroundings, self-cleaning concrete, also known as photocatalytic concrete, keeps its color and surface clean. Because of its self-cleaning qualities, this kind of concrete is frequently referred to as "green concrete."

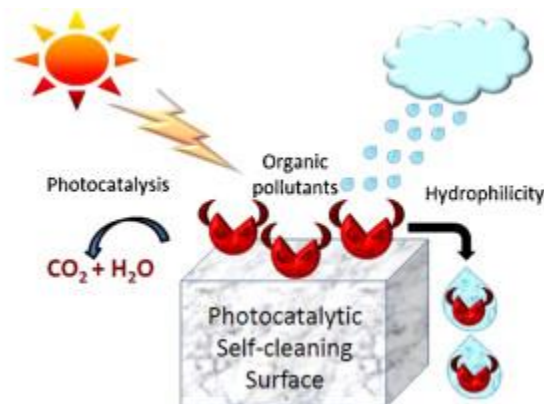


Figure - Photocatalytic reactions on self-cleaning surface

Constituents of Geo Polymer Concrete -

- A. Pulverized Fuel Ash - It is a byproduct generated from the combustion of coal in thermal generating facilities, possessing high silica and alumina content, which, when utilized in concrete, mitigates environmental impact as a substitute for cement.
- B. GGBS - The acronym for ground granulated blast furnace slag originates from the iron and steel sector and is presented as a fine powder. GGBFS can be characterized as a glassy, granular substance composed of silicates and alumina.
- C. Composites - Standard-sized conventional fine and coarse particles are utilized in geo-polymer concrete.
- D. Basic Solutions - Sodium and potassium hydroxides and silicates are utilized. These alkaline solutions, when interacting with silica and alumina derived from source materials like fly ash and GGBS, can generate binder material that enhances the strength of concrete.

Benefits:

Geo polymer concrete offers the subsequent benefits.

- Fully eradicates the necessity for Portland cement, thereby diminishing CO₂ emissions.
- Reduces pollutants and maintains sustainability
- Reduced deformation and little contraction when drying
- Decreases permeability and improves longevity.
- Seventhly, resistant to blasts, seismic activity, and fire.

Drawbacks:

Several drawbacks of GPC are enumerated below.

- Requires careful management due to the involvement of sodium hydroxide, which may pose risks to human safety.
- Restricted to the utilization of precast units.
- Absence of consistency

FLY ASH –

Due to its economic and environmental advantages, fly ash usage has become crucial for civil engineering (Ravina and Mehta, 1986; Matkovi'c, 1990). The amount of free lime in the ash limits how much cement FA can replace. In addition to its chemical makeup, FA's phase composition, glassy phase content, coal or lignite burning temperature, specific surface area (SSA), etc. all affect its reactivity (Matkovi'c, 1990). According to Tillman et al. (2012), FA is a pozzolanic substance. The term "pozzolanic" describes substances that, while having little to no cementing action on their own, will create insoluble cementitious compounds when exposed to lime and water (Montgomery et al., 1981).

A byproduct of coal-fired power stations, FA, or pulverized fuel ash, is added to cement and concrete as a mineral. A typical coal-burning generating station configuration is depicted in Fig. 1. When pulverized coal is forced into the furnace's burning zone, its combustible components—primarily carbon, hydrogen, and oxygen—ignite at a temperature of around 1500 °C (2700 °F). At this temperature, non-combustible minerals such as quartz, calcite, gypsum, pyrite, feldspar, clay minerals, and others melt into tiny liquid droplets. Small spherical glassy particles are formed when the flue gasses from the burning zone quickly cool the droplets they carry. Solid particles are extracted from flue gasses using mechanical and electrical precipitators or baghouses. The ash particles that "fly" away from the furnace with the flue gasses are referred to as FA (Thomas, 2013). The type of coal utilized, the burning conditions, the collection technique, and other factors all affect the characteristics of FA (McCarthy and Dyer, 2019). Although the usage of FA as a pozzolanic element and its reaction potentials were first identified in early 1914, a significant study on the use of FA in concrete was first published in the US in 1937 (McCarthy and Dyer, 2019; Halstead). According to earlier research conducted in the 1980s, substituting FA for concrete can greatly enhance its mechanical and durability qualities (Montgomery et al., 1981), just as FA can enhance the paste's microstructure (Filho et al., 2013). FA has historically been added to concrete at quantities ranging from 15 to 25% by mass of the cementitious material component, depending on the application, FA qualities, specification restrictions, geographic location, and climate (Thomas, 2007). Rarely, it was reported that concrete containing up to 80% FA has been effectively put (Marceau et al., 2002). According to ASTM, there are two classes of FAs

used in concrete: class F and class C. A byproduct of burning bituminous coal is the class F FA. Class F FA has a low calcium level but a high iron, silica, and alumina content. It's a glassy material that needs to be activated with either lime or cement. Class C FA is produced by burning lignite and sub-bituminous coal. Compared to class F FA, it has a higher calcium content. Concrete with class C FA gains strength considerably faster than that with class F FA (McCarthy and Dyer, 2019; Marceau et al., 2002). In addition to being economical, FA improves workability, strength, and drying shrinkage in both fresh and hardened concrete. Additionally, the storage and disposal of FA, an industrial by-product, is resolved by using it in concrete (Atis, 2003).

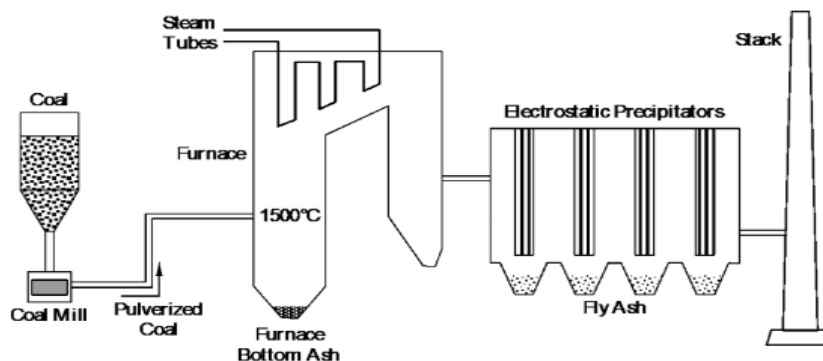


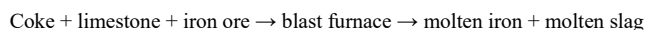
Fig. 1. A schematic diagram of a coal-fired electrical generating station (Thomas, 2013).

2

GGBS - A by-product of the production of iron and steel, ground granulated blast furnace slag (GGBS) is a finely ground cementitious substance. It can partially replace Ordinary Portland Cement (OPC) and is frequently used as a supplemental cementitious material (SCM) in concrete. The molten slag produced in a blast furnace during the production of iron is used to make GGBS. Granulated blast furnace slag is a glassy, granular substance that is created when this molten slag is quickly cooled, typically by water. GGBS is created by drying and finely grinding this material. High-performance concrete, durable concrete, mass concrete, underground structures, marine structures, and geopolymer concrete are among the applications where GGBS is very helpful.

Iron ore, limestone, and coke are fed into a blast furnace to produce iron. Molten slag is created when impurities in the iron ore mix with the fluxing materials at high temperatures.

The fundamental procedure is:



After being removed from the molten iron, the molten slag is quickly quenched with water. A structure that is primarily amorphous or glassy is produced by rapid cooling, which inhibits crystallization.

Steps in manufacturing –

- Production of molten slag: During the production of iron, slag is created as a byproduct.
- Quick cooling/granulation: Water is used to quickly cool the molten slag.
- Drying: To get rid of extra moisture, the granulated slag is dried.
- Grinding: To create a fine powder, the dried granulated slag is processed in an appropriate grinding mill.
- Storage: The final GGBS is transported and kept in silos for usage in concrete and cement.

GGBS is especially crucial for geopolymer and alkali-activated concrete. GGBS and other aluminosilicate materials can be used as key precursors in geopolymer systems, in contrast to traditional concrete. For instance:



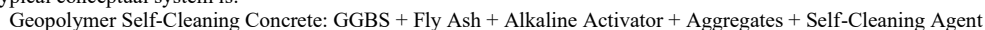
Typical alkaline activators consist of: NaOH, or sodium hydroxide

Fly ash typically adds substantial amounts of silica and alumina, whereas sodium silicate (Na_2SiO_3) GGBS contributes significant amounts of calcium.

This combination can offer:

- Quicker development of strength
- Better early-life strength in comparison to systems with high fly ash
- The microstructure is dense.
- Less Portland cement is needed

An example of a typical conceptual system is:



GGBS mostly contributes to the geopolymer/alkali-activated binder system, but if the self-cleaning mechanism is based on a photocatalyst like titanium dioxide (TiO_2), the photocatalyst is in charge of photocatalytic processes under appropriate light conditions.

Self-Cleaning Concrete - As the name suggests, self-cleaning or photocatalytic concrete is reasonably priced. Some of us may believe that it is impossible, but the name suggests revolutionary thoughts. However, it is currently practicable; many other nations continue to use concrete because of its amazing positive outcomes. We can create new innovations in the broad field of concrete construction. We can improve the anti-aging of concrete and create a beautiful atmosphere with this concrete cleaning method. But in order to lessen health problems, this kind of concrete creates indoor air purification. It is possible to gradually lessen breathing issues. We can take action to achieve this self-purifying/cleaning technology to purify the concrete utilizing photocatalyst, however protecting concrete never raises awareness among consumers. The best filters for concrete are photocatalysts, which produce favorable reactivity over the material. The reaction over the cement is neutral; it may be removed by spraying water, which won't damage the cement or change its binding qualities. The possibility for cleaner air is one of the astounding environmental benefits of clean buildings.

Photo catalyst - Numerous substances function as photocatalysts. A few studies that have been conducted to look into the impact of photocatalyst in cementitious materials demonstrate this. The performance of the cement characteristics is enhanced by the use of nanoparticles as a photocatalyst. When added to cement, nanoparticles can either replace a portion of the cement or serve as an additive in cement paste. These widely dispersed

nanoparticles serve as fillers in the void, accelerating the rate of hydration and increasing their propensity to clump together during mixing. The most often utilized nanoparticles in cement products are carbon nanotubes, silicon oxide (SiO₂), zinc oxide (ZnO), titania or titanium dioxide (TiO₂), and aluminum oxide (Al₂O₃). According to research, the mechanical characteristics of the goods were affected when nano-silica was added to the cement paste. According to a few studies, the addition of TiO₂ nanoparticles is primarily carried out with photocatalytic activity because of its high catalytic activity and chemical stability. The resistance of nano-TiO₂-containing concrete to chloride penetration is greater than that of nano-SiO₂-containing concrete. This is because the content of nanoparticles causes the pore structure to become more refined while the chloride penetration decreases. The addition of nano-TiO₂ improves the production of geopolymer and results in a compact microstructure with fewer cracks. By adding more nano-TiO₂ to the modified cement, the compressive strength can be increased. Several researches have been conducted on the incorporation of TiO₂ into concrete specimens. The photo catalyst, Titanium dioxide (TiO₂) is a naturally occurring compound that can decompose gaseous pollutants in the presence of sunlight. Nano titanium (nano-TiO₂) are reported that can improve the mechanical properties and durability properties of concrete. ZnO exhibits a better efficiency in photocatalytic degradation of some reactive dyes in aqueous solution and it can also improve the mechanical properties and durability properties.

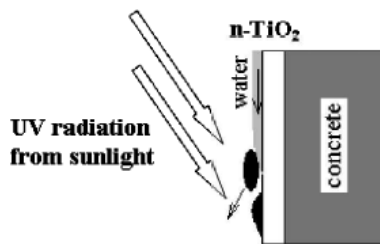


Figure - Self-cleaning effect of n- TiO₂ at concrete surface

Geo Polymer Concrete –

One type of inorganic polymer is geopolymer. In order to create binders, Joseph Davidovits (1978) suggested using an alkaline liquid to react with silicon (Si) and aluminum (Al) as source materials of geological origin or with by-product materials like fly ash and rice husk ash. These binders were given the label "geo polymer" since the chemical reaction occurring in this instance is a polymerization process and the precursors are of geological origin. As carbon emissions and the ensuing global warming have become the world's top concerns, geopolymer concrete is becoming more and more important. One tone of carbon dioxide is released during the manufacturing of one tone of cement. By offering carbon credits, many nations are encouraging the use of fly ash as a construction material. This will not only lower carbon dioxide emissions and cement output, but it will also encourage the use of fly ash waste, which is a huge global disposal issue. Nearly every state in India has thermal power facilities, hence fly ash is widely available. The soluble alkali metals that make up the alkaline liquids are often based on potassium or sodium. Combining sodium hydroxide (NaOH) or potassium hydroxide (KOH) with sodium silicate or potassium silicate is the most popular alkaline liquid utilized in geopolymerization. Sodium hydroxide and sodium silicates are inexpensive and readily accessible alkaline solutions. Heat-cured low-calcium fly ash-based geopolymer concrete is the focus of this paper. As a source material, low-calcium fly ash (ASTM Class F) is favored over high-calcium fly ash (ASTM Class C).

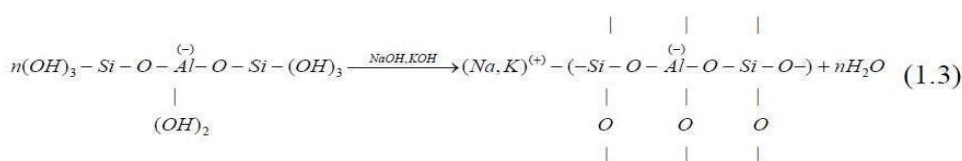
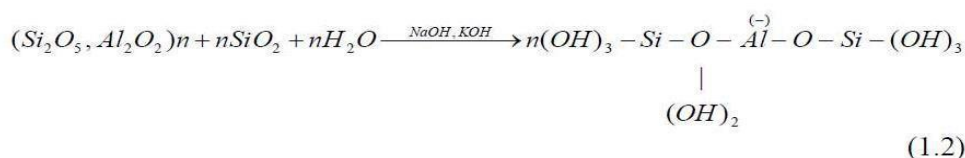
Geo polymerisation

The fast chemical reaction between Si-Al minerals and alkaline liquids causes the geopolymerization process, which results in the formation of a three-dimensional polymeric chain and ring structure made up of Si-O-Al-O links (Davidovits 1994).



where z is 1, 2, 3, or even higher, up to 32; n is the degree of polymerization or poly condensation; M is the alkaline element or cation, such as potassium, sodium, or calcium; the symbol indicates the presence of a link.

Equations 1.2 and 1.3 (Van Jaarsveld et al. 1999; Davidovits 1994) show how geopolymer material often forms:



The chemical reaction between Si-Al minerals and alkaline liquids consists of the following stages (Glukhovskiy 1959; Davidovits 1994; Xu & van Deventer 2000):

- Destruction of Si and Al atoms from the source material through the multifaceted action of hydroxide ions.
- Coagulation and condensation of precursor ions into monomers.
- Poly condensation/polymerisation of monomers into polymeric crystalline structures.

Nevertheless, the above three processes can overlap each other and occur simultaneously. Thus, it is hard to separate and assess one by one individually (Palomo et al. 1999). Subsequently, the following three fundamental forms of geo polymer occurs (Davidovits 1994):

- Poly-sialate, which contains [-Si-O-Al-O-] as the reoccurring element.
- Poly-sialate-siloxo, which contains [-Si-O-Al-O-Si-O-] as the reoccurring element.
- Poly-sialate-disiloxo, which contains [-Si-O-Al-O-Si-O-Si-O-] as the reoccurring element. Sialate is an abbreviation of silicon-oxo-aluminate.

The Equation 1.3 denotes the liberation of water throughout the formation of geo polymers. The expulsion of water from the geopolymer paste during the curing and drying phases creates discontinuous nano-pores within the paste matrix. This procedure improves the efficacy of geo polymers. Consequently, the water solely enhances workability since it does not participate in a chemical reaction (unlike the hydration of cement). The use of geo-polymeric materials is dictated by their chemical structure, where an atomic ratio of Si:Al of 1,2,3 establishes a highly rigid 3D network, but a Si:Al ratio beyond 15 imparts a polymeric nature to the geo-polymeric material. Ultimately, the polymerization process undergoes a rapid chemical reaction in an alkaline milieu on Si:Al minerals, resulting in the formation of a three-dimensional polymeric chain and ring structure comprised of Si - Al - O bonds (Davidovits 1999).

2. OBJECTIVES OF THE STUDY

This research facilitates the analysis of heavily polluted areas in India and evaluates the relationship between pollutant levels. Furthermore, it identifies areas where photocatalytic concrete infrastructure can demonstrate optimal efficacy according to the trial results. To elucidate the impact of environmental factors, especially temperature, on the photocatalytic degradation of pollutants to establish a relationship between photocatalytic efficiency and seasonal climate. The amount of by-product or waste substitution significantly influenced the characteristics of concrete. Waste resources possess considerable potential for the production of eco-friendly concrete. This research aims to ascertain the characteristics of concrete by including supplemental cementitious materials such as GGBS and Fly Ash as substitutes for cement in the concrete mix.

The incorporation of titanium dioxide into concrete has shown efficacy in degrading pollutants, including nitrogen oxides, upon exposure to sunlight. This photocatalytic mechanism efficiently eliminates surface impurities from concrete, resulting in a cleaner and more sustainable ecosystem. The findings of this research indicate that using extra cementitious materials and titanium dioxide in concrete can contribute to more environmentally friendly concrete and enhanced sustainability, along with financial advantages. Additional investigation and advancement in this area may result in the widespread adoption of geo polymer self-cleaning concrete as a means to enhance the longevity and upkeep of infrastructure.

Following objectives are considered in this study –

- To examine ecological sustainability.
- To determine the appropriate blend ratio for geopolymer concrete.
- To examine the application of TiO₂ as a sustainable material.
- Due to the elevated cost of TiO₂, our research incorporates a minimal quantity of additive in the standard concrete.
- To do experimental evaluations on the durability of various concrete grades.
- To evaluate the economic viability of traditional concrete against geopolymer concrete.
- To evaluate the appropriateness of these materials for higher-grade concrete.
- To undertake longevity assessments on high-performance concrete.
- To examine the techniques for mitigating air pollution.
- To diminish the occurrence of patch formations.
- To maintain the youthfulness of concrete.

3. Methodology -

Mix Proportions – Different mix proportions have been prepared in the laboratory for the experimental program as tabulated below:

MIX	CEMENTIOUS MATERIALS			SELF CLEANING MATERIAL
	CEMENT PPC (53 GRADE)	Fly Ash	GGBS	TiO ₂
GPC M1	100%	-		0%
GPC M2	50%	40%	10%	3%
GPC M3	50%	30%	20%	3%
GPC M4	50%	25%	25%	3%
GPC M5	50%	20%	30%	3%
GPC M6	50%	10%	40%	3%

Properties of Cementitious Materials – The alkali activation of fly ashes is a chemical process by which the glassy component of these powdered materials is transformed into very well-compacted cement. Activated fly ash enhances the strength and durability of concrete at an early age, as well as its corrosion resistance. The fly ash and GGBS is activated using a variety of processes, including mechanical (physical), thermal, and chemical activation.

Properties of Fly Ash, GGBS & Cement –

S.No.	Chemical Composition %	GGBS	Fly Ash	Cement
1	SiO ₂	34.6	56.86	20.87
2	Al ₂ O ₃	12.7	23.51	4.35
3	Fe ₂ O ₃	1.2	4.39	3.93
4	CaO	38.5	0.83	60.2
5	MgO	11.6	0.6	2.74
6	Na ₂ O	0.6	0.39	0.08
7	K ₂ O	0.7	1.4	0.23
8	Loss of Ignition	-	10.68	2.19
9	SO ₃	-	-	2.71
PHYSICAL PROPERTIES				
1	Density (g/cm ³)	1.25	2.26	3.14
2	Particle Size (µm)	10.81	32.5	14.73
3	Specific Gravity	2.9	2.2	3.15
4	pH Value	9.1	8.5	13

Tests Conducted on Cement –

CEMENT	Fly Ash	GGBS	Titanium Di Oxide TiO ₂	NORMAL CONSISTENCY IN %	INITIAL SETTING TIME IN MIN	FINAL SETTING TIME IN MIN	Compressive Strength at 28 Days
100%	-			36	35	560	55.6
50%	40%	10%	3%	30	30	510	53.2
50%	30%	20%	3%	33	36	475	52.6
50%	25%	25%	3%	35	40	460	51.25
50%	20%	30%	3%	38	35	510	52.2
50%	10%	40%	3%	40	35	535	50.8

Mix proportion for M25 grade of Concrete -

Cement	Water	FA	CA
420	197	585	1097
1	0.47	1.39	2.61

Mix proportion for M30 grade of Concrete –

Cement	Water	FA	CA
447	197	578	1084
1	0.44	1.29	2.42

Tests on specimens

The examination of concrete samples is crucial for regulating and verifying concrete quality. All the samples produced underwent examination to investigate the impact of substituting a portion of cement with phosphor gypsum and fine aggregate with thermosetting polymers on both workability and strength. Consequently, the experimental study conducted was categorized into three primary sections. The subsequent items are as follows:

1. Study on workability

- Slump test

2. Study on strength

- Compressive strength test
- Splitting tensile strength test
- Flexural strength test
- Durability Test
- Water Absorption Test

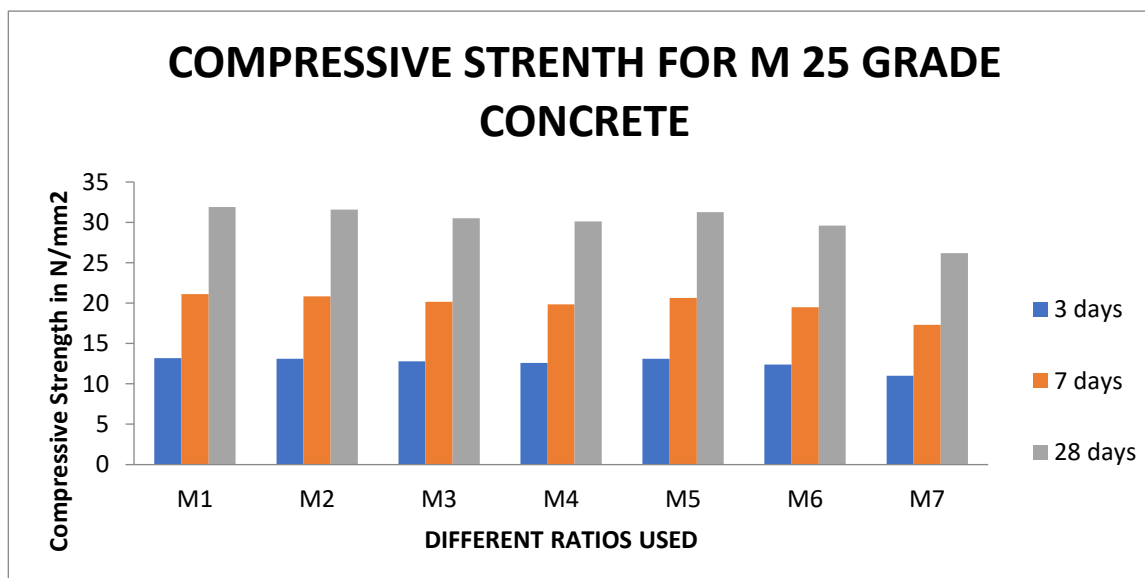
4. Results –

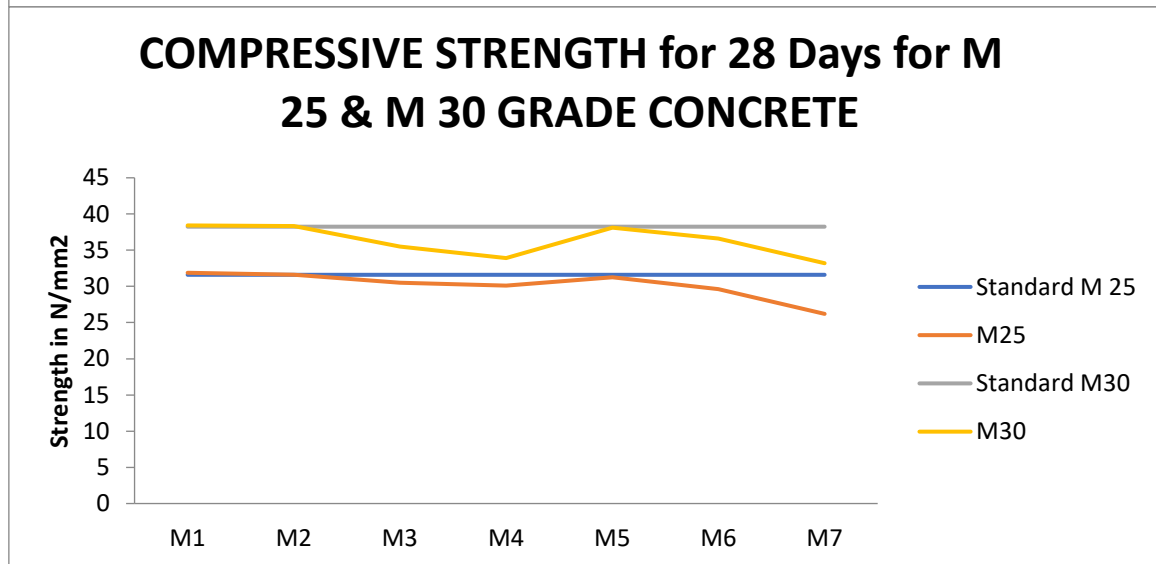
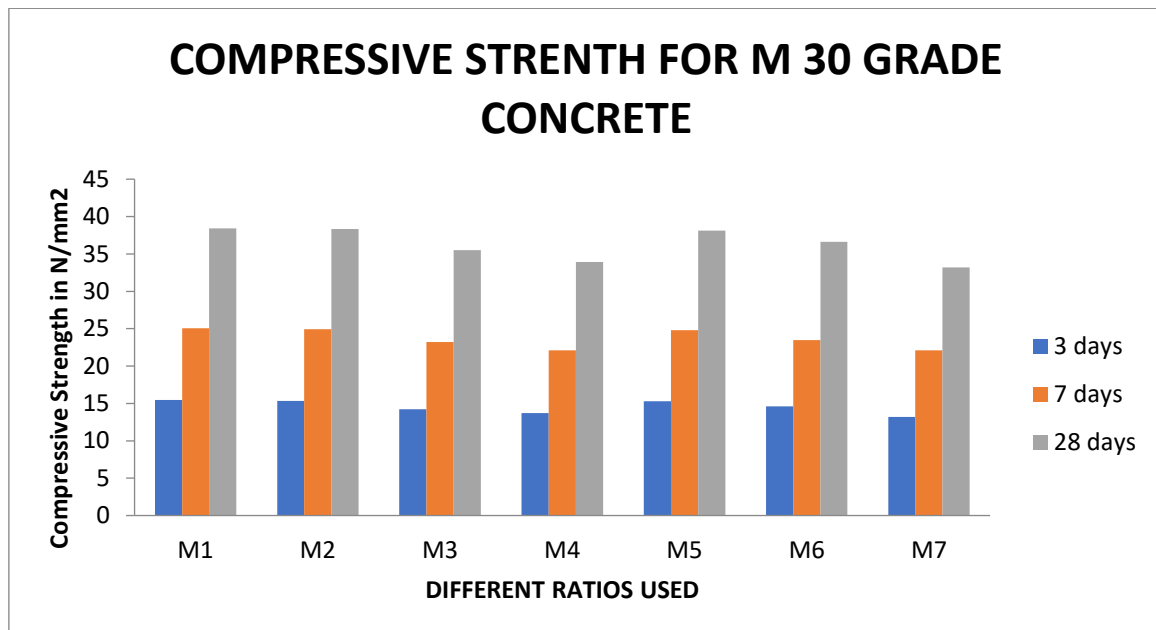
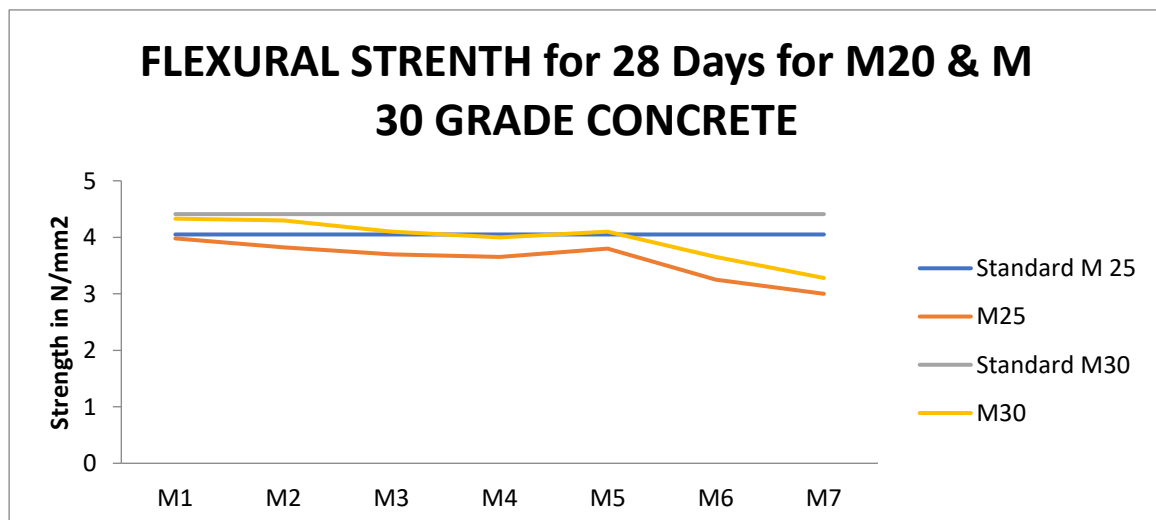
Workability Test Results: The results from the observations collected from the test have been calculated and tabulated below:

MIX PROPORTIONS	VALUE OF SLUMP IN mm.	
	M30	M25
GPC M1	90	100
GPC M2	110	110
GPC M3	110	120
GPC M4	105	115
GPC M5	95	100
GPC M6	90	100

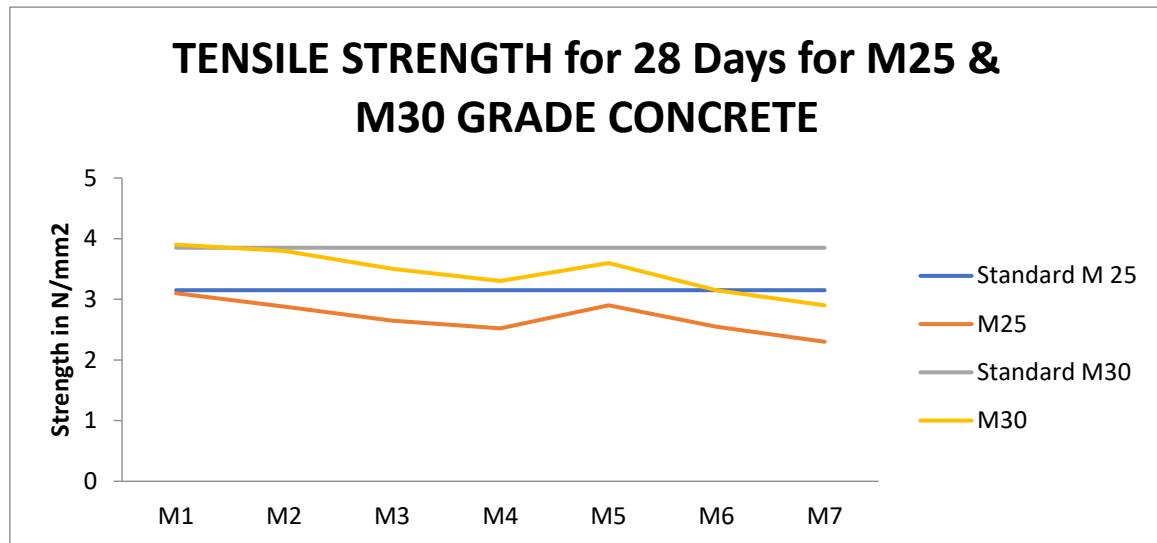
Results of Workability of Concrete by Slump Cone Test**4.2 Compressive Strength Test Results**

For M 25 Grade of Concrete



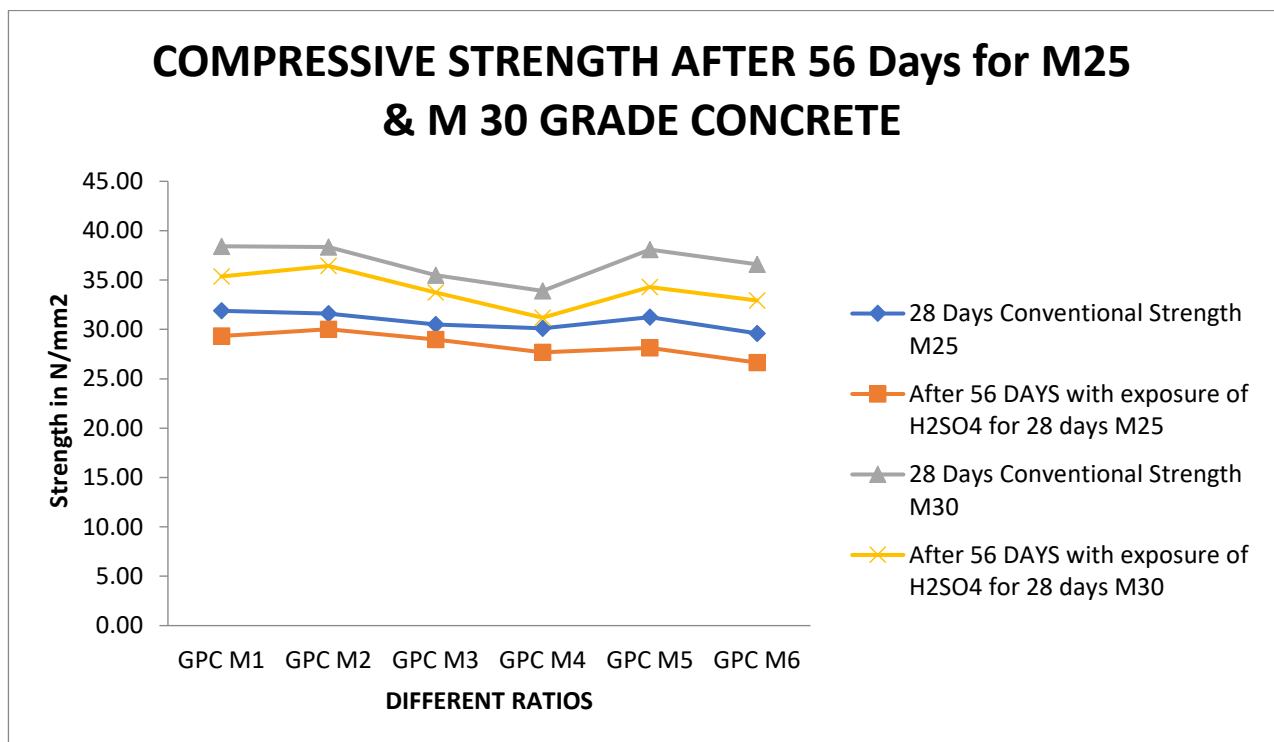
For M 30 Grade of Concrete**4.2 Flexural Strength Test Results**

4.3 Split Tensile Strength Test Results



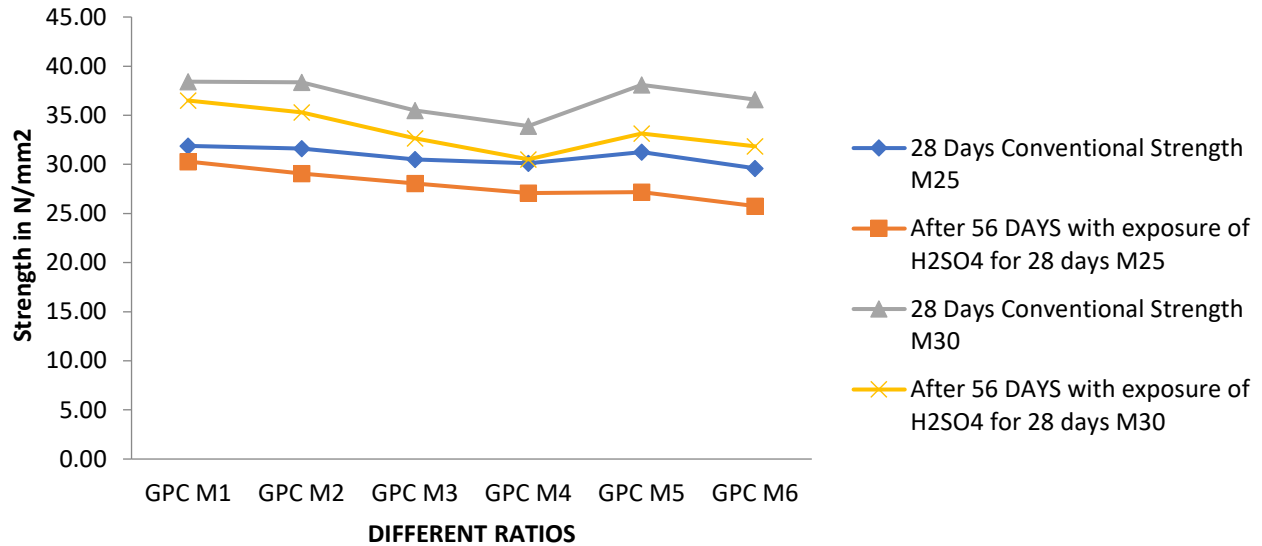
4.4 Durability Tests

Sulphuric Acid Attack Test



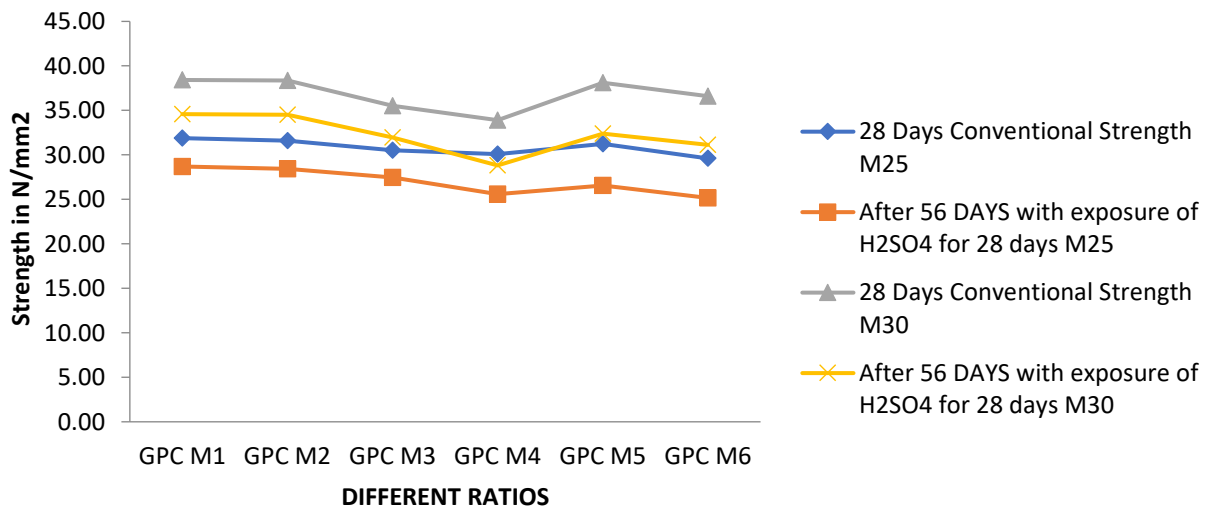
Alkalinity Test - Sodium Hydroxide Test

COMPRESSIVE STRENGTH AFTER 56 Days for M25 & M 30 GRADE CONCRETE



Sea Water Attack Test

COMPRESSIVE STRENGTH AFTER 56 Days for M25 & M 30 GRADE CONCRETE



Water Absorption Test: This test method is used to determine the rate of absorption of water by hydraulic cement concrete by measuring the increase in the mass of a specimen resulting from absorption of water as a function of time when only one surface of the specimen is exposed to water. Water absorption is measured by measuring the increase in mass as a percentage of dry mass. It can be seen that surface water absorption is higher than internal water absorption for all the specimens. This is due to the rapid loss of water at the cover concrete during curing. Water Absorption = $\frac{(M_2 - M_1)}{M_2} \times 100\%$. The samples are dried in hot air oven once at particular time and temperature and afterwards cooled in a desiccator.

5. Conclusion –

- The workability improved as the proportion of Fly Ash was increased by partially substituting cement up to 50%. Optimal workability was achieved with 40% cement substitution by fly ash and 10% GGBS.
- The compressive strength improved by as much as 5% with the ideal substitution of cement using fly ash and GGBS in comparison to the traditional mix.
- The typical mix exhibited a greater splitting tensile strength in the cylinder. The reduction in splitting tensile strength is as much as 5% compared to M1. The values discovered are below the normal thresholds.
- The flexural strength is observed to be superior in the usual mix M1. The reduction in the potency of the residual mix ratio indicates a significant decline of 7% compared to the standard mix.
- An increase in the proportion of fly ash and GGBS results in diminished durability in seawater, however it exhibits enhanced resistance to alkaline and acidic assaults.
- The self-cleaning characteristics are evaluated with a 5% concentration of TiO₂, yielding superior outcomes for this specific proportion. However, the increased utilization of TiO₂ renders the concrete financially impractical. In the production of green concrete, it is possible to match the cost of traditional concrete by substituting 100% of cement and fly ash, while incorporating a minor quantity of TiO₂ to enhance workability and strength, resulting in a lightweight concrete that is economically advantageous for environmental sustainability or challenging conditions.

The ideal proportion for fly ash can reach 70%, while GGBS can be utilized up to 30% for cement substitution, accompanied by 2% of TiO₂, yielding favorable outcomes. The strength values of this form of concrete exceed the usual compressive strength, making it prudent to utilize this green concrete in environmentally friendly applications, provided that the target strength is attained on-site through controlled methods. The aforementioned test outcomes were achieved without the incorporation of any additives. The design mix is determined by the ratio of the design mix.

6. REFERENCES -

- [1] Arafa Awadalla, Muhammad Fauzi Mohd Zain, Abdul Amir H. Kadhum and Zeinab Abdalla “Titanium dioxide as photocatalysis to create self-cleaning concrete and improve indoor air quality” (Nov 2011).
- [2] Adnan mujkanović “Self-cleaning concrete – a construction material for building cleaner world” (september 2016).
- [3] Siti Norsaffirah Zailan Norsuria Mahmed Mohd Mustafa Al Bakri Abdullah, Andrei Victor Sandu “Self-cleaning geopolymer concrete- review” (2016)
- [4] Mark Garger Evan Marohn “The use of titanium dioxide in concrete materials to filter smog pollution from air” (2018)
- [5] Abhijeet Shukla, Rao Faraz Waris, Mohd. Arhab, Syed Sajid Husain “A Review on Pollution Eating and Self- Cleaning Properties of Cementitious Materials” (March 2018).
- [6] T. Arun Kitcha, M. Dhanabal, V. Aravindan, S. Aravindh “Experimental Study of Photocatalytic Concrete using Titanium Dioxide” (April 2018).
- [7] T.Vignesh, A.Sumathi, K. Saravana Raja Mohan “Study on Self-Cleaning Concrete Using Nano-liquid TiO₂” (2018).
- [8] Dr.S.U. Kannan, Jebin Raj, Jerom Antony, Manoj, Mujahid “Study on the properties of self-cleaning concrete using titanium dioxide” (Aug 2018).
- [9] Anju raj “Behaviour of self-cleaning concrete by using various photocatalysts” (may 2019).
- [10] Ilker bekir topçu, erdi akkan, tayfun uygunoğlu, kardelen çalışkan “Self-Cleaning Concretes: an overview” (September 2020).
- [11] Hansaraj Dikkara, Varad Kaprea, Amey Diwana, Dr. S. K. Sekarb “Titanium Dioxide as a photocatalyst to create self-cleaning concrete” (2020).
- [12] Hritik S. Behare, Aditya N. Bhosale, Jeevan C. Kadale, Sagar B. Kale, Dinesh W. Gawatre “Investigation of Self Cleaning Concrete by Using Titanium Di-Oxide” (June 2021).
- [13] Azariy Lapidus, Evgenii Korolev, Dmitriy Topchiiy, Tatyana Kuzmina, Svetlana Shekhovtsova and Nikolai Shestakov “Self-Cleaning Cement-Based Building Materials” (2022).