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Experimental Research on Geo Polymer Concrete using Nano Technology

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Abstract:

After water, one of the material used most often in the infrastructure and construction industries is concrete, cement is vital material in concrete, but the major environmental issue arises by the liberation of Carbon di-oxide (CO_2) gas, alternate cementitious materials utilization in concrete could be beneficial. Geo polymer concrete (GPC) is emerged as innovative development, that produced by cementitious materials that not only enables the reduction of carbon footprint but also enhances the properties of concrete considerably. The mechanical and long-lasting qualities of concrete buildings are also essential to more over concrete technology's sustainability to reduce the quantity of raw materials needed. Nanotechnology is currently having a big impact on the construction industry. Nanoparticles have an impact on the properties of geo-polymers and may be used to create GPC, and mortar that is based on fly ash rather than cement. The features of geo-polymer mortars are significantly altered when nanomaterials like carbon nanotubes (CNT), graphite, Nano silica, and other substances are added. Nano Titanium di-oxide (TiO_2) functions as a photo-catalyst once it is added. Nano silica and other nanomaterials have shown promise as possible sources of antibacterial characteristics. This area of research has looked at the effects of various nanomaterials on the properties of geo-polymer mortars and concretes.

Keywords: Nanomaterials, Nanotechnology, Fly Ash, Geo-polymer Concrete, Nano Silica.

1. Introduction

Concrete is one of the types of building materials that are used in construction nowadays, and it makes up the bulk of the time that concrete is used. Throughout the course of human history, lime has served as the principal binder used in the manufacturing of concrete. It is well known that the manufacture of OPC presents a number of difficult challenges. All of this raises a whole new question: other than concrete, are there any other materials that can be employed that are reliable and even more resistant to wear and tear than the material that is now being utilised? The solution is a substance that goes by the term geo-polymer concrete and is a kind of material. The application of geo-polymer technology in the concrete industry as an alternative binder to Portland cement is a sector that has a great deal of potential for future growth. This field is expected to see significant development in the near future. This is because geo-polymer technology can be used in a variety of applications. At no stage in the manufacturing process is Portland cement required in any way, shape, or form in order to create geo-polymer. Instead, raw materials that are already abundant in alumina and silica in their natural forms are used in the production of geo-polymers. When it comes to using fly ash as a source material, the kind of fly ash that has a low calcium level (ASTM Class F) is chosen over the type of fly ash that has a high calcium content (ASTM Class C). It is likely that the creation of geo-polymer concrete will provide a solution to the conundrum of how to produce concrete in a manner that is less detrimental to the natural world and more supportive of the practise of sustainable development. It has an incredibly small impact on the ecosystem of the area that is directly next to it. The phrase "nanomaterial concrete" refers to a brand-new kind of concrete that is formed from components that have grain sizes that are on the nanoscale. This sort of concrete was given the name "nanomaterial concrete." These materials, in their natural state, have a texture that may be described as exceedingly fine. The use of these materials results in increases not only in the early-age strength of cemented cement paste but also in the quantity of CH crystals generated by nanomaterials. The production of nanoparticles included a number of different varieties. Nano silica (NS) is an innovative pozzolan that was developed as a one-of-a-kind solution with the intention of enhancing the microstructure and stability of cement that incorporates nanomaterial. Nano-silica is a relatively new pozzolan. In comparison to conventional cementitious materials, nanomaterials showed early ageing, enhanced hydration properties, decreased porosity, and increased water absorption.

2. Objective

This paper primarily reports on the effect that nano-sized silica has on geo-polymer concrete, which is the topic of this examination. The major features that are considered are the object's compressive strength as well as its durability.

3. Experimental Methodology

3.1 Materials

3.1.1 Fly Ash

The fly ash taken in the experimental study was of the class F type as shown in Figure 1, and had a relatively low calcium content. This was determined by analysing the results of the experiment. The researchers were able to arrive at this conclusion as a result of the results of the inquiry. The fly ash that has been granted the designation of Class F has a significant amount of pozzolanic activity and a lime content of less than 10 percent. In addition, this particular kind of fly ash has been designated as belonging to the Class F category. The Table 1 contains information that can be used to learn about the chemical

components that were present in the fly ash that was used in the research project that is presently being carried out.

Figure 1. Fly ash

Table 1. Chemical composition of fly ash

Oxide	Percentage	Standard value by IS 3812
Silica	55	SiO2 > 35%
Alumina	22	Al2O3 22 Total > 70%
Iron	5	
Calcium	5-7	-
Magnesium	3	< 5%
Loss of Ignition	2	< 12 %

3.1.2. Aggregate

The present study makes use of coarse aggregates (CA) with diameters of 20mm and 10mm, as well as fine aggregate (FA) acquired from a source in the neighbourhood; these aggregates have the characteristics that are the focus of the investigation, properties were listed in Table 2.

Table 2. Properties of Aggregate

Properties	Coarse aggregate		Fine aggregate
	CA-I	CA-II	FA (Sand)
Specific gravity	2.65	2.64	2.58
Fineness modulus	7.12	5.92	2.97

3.1.3 Alkaline Liquid

The role that is played by alkaline solutions in the process of geo-polymerization is not only the most significant but also the one that has the most far-reaching repercussions. This is because it is the part that is played by alkaline solutions. In this particular set of tests, we have decided to make use of a mixture of solutions that include varying concentrations of sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH). The concentrations of these solutions range from 8M to 16 M.The following are the concentrations that will be used for each solution: 8M, 12M, and 16 M, respectively. In order for the pellets of sodium hydroxide to be capable of being used in the process of producing a NaOH solution in the laboratory, they first needed to be dissolved in water. Only after that would it be possible to make use of them. Because of this fact, it was possible to find a solution to the difficulty that we were having. Because the polymerization process creates a significant amount of heat during the mixing of Na_2SiO_3 with NaOH solution, mixed for 24 hours. This was a prerequisite for the procedure. Because of this, the heat that was generated as a side effect of the polymerization process was able to be controlled and managed.

3.1.4 Sodium Hydroxide (NaOH)

There are two different forms of sodium hydroxide that may be acquired in commercial quantities. These forms include flakes and pellets. The concentration of the sodium hydroxide solution, which is measured in terms of molarity, may be used in order to calculate the mass of the solid for each of the different molarities as shown in Table 3, and its properties were listed in Table 4.

Table 3. Mass of NaOH for 97% Purity

Molarity	Mass of NaOH Solids (gm)
8	260
10	314
12	361
14	404
16	444

Table 4. Properties of NaOH

Property	Value
Mass	40 gm/mol
Density	2.1 gm/cm^3
Specific gravity	2.1

3.1.5 Sodium Silicate (Na_2SiO_3)

When it comes to geo-polymerization, the alkaline liquid that is used most of the time is a combination of NaOH or potassium hydroxide (KOH) with either Na_2SiO_3 as shown in figure 2 or potassium silicate (K_2SiO_3). This mixture may also include silicates of either sodium or potassium. This is carried out in order to get the effects of the geo-polymerization that are required. In some instances, it could be preferable to use a combination of potassium silicate and sodium silicate rather than either one of them alone. On the other hand, this is not the accepted procedure. There are further applications that may be improved by the use of a combination of Na_2SiO_3 or K_2SiO_3 rather than either one of them alone. Potassium silicate is another material that sees extremely little usage, even though it is a chemical that may be found in certain foods but has very few additional applications. The properties are given in the table 5.

Table 5. Na_2SiO_3

Property	Value
Specific Gravity	1.718
Na_2O	19.6%
SiO_2	35.8%
Solid Weight	55%
Water Weight	45%

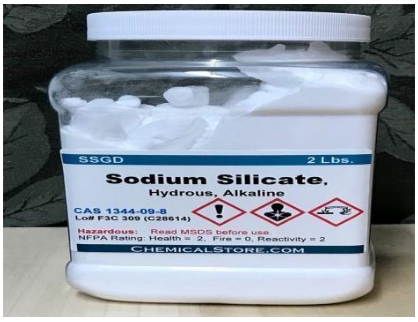

Figure 2. Sodium Silicate

3.1.6 Nano Silica

When activating alumina-silicate precursors like FA, one of the most essential things to keep in mind is the composition of the activator solution that is being used in the process. This is because the composition of the activator solution directly affects the outcome of the process. This is because the activator solution is one of the most significant components that has the capacity to impact the structural and mechanical performance of an activated material. The reason for this is due to the fact that the activator solution is one of the most essential components. The type of alkaline salt that is used in an alkali activator (which is typically silicate or hydroxide), the way in which the alkaline component is added (as a solution or in a solid state), and the dosage of the alkaline component, which is typically expressed as molar ratios taking into consideration the overall composition of the raw material, are the three most important aspects of an alkali activator. Additionally, it has been shown that the alkali cation that is provided by the alkaline solution has an effect on the early phases of binder synthesis and, as a result of this impact, on the mechanical performance of the items that are ultimately generated. This finding was made possible by the fact that an alkaline solution was used. In order to provide evidence of this impact, a test subject consisting of an alkaline solution was used. This finding was made possible due to the fact that alkaline solutions are, in and of themselves, alkaline. This is because alkaline solutions release alkali ions into the environment in which they are present, which is the cause of this phenomenon. Alternate activators created from modified nano-silica were used throughout each and every step of the production procedure. As a direct consequence of this, the geo-polymers were able to maintain a high level of mechanical strength while simultaneously maintaining a low level of permeability. On the other hand, the mechanical strengths of these binders are comparable to the mechanical strengths of binders that were created from the same fly ash by adding sodium silicate activators that are commercially available for purchase. These binders were made using the same raw materials as the source material. When compared to the level of responsiveness exhibited by other binders, the level of responsiveness displayed by these binders is much lower. When compared with the case of commercial silicate activators, the water demand and porosity of the samples that were formed using the nano-silica-based activators are much lower. This is because nano-silica activators (figure 3) are composed of nanoparticles that are very small. This is due to the fact that nano-silica activators are constructed out of nanoparticles, which are very minute. This is because, in comparison to silicate, nano-silica has a larger surface area per unit of water, which explains why we get this result. This gap may be due to the somewhat delayed release of silica from the solid nano-silica particles, which continue to stay in suspension in the solution throughout the early stages of the reaction and then release silica later on in the course of the reaction. In other words, the solid nano-silica particles release silica at a later point in the course of the reaction. To put it another way, throughout the first phases of the reaction, the solid nano-silica particles maintain their state of suspension inside the solution. To put it another way, the nano-silica particles do not ever come out of their state of suspension inside the solution at any time over the course of the reaction; to say it another way, they remain suspended throughout the whole process. When NS was added to the formulation, the amount of time required for geo-polymers to reach their optimum hardness was drastically cut down, which led to significant cost savings. This was the result of the NS speeding up the procedure, which was the cause of the situation. The accelerated rate at which the reaction was taking place was a direct consequence of the increased activity of the nanoparticles, which had the effect of hastening the rate at which the reaction was taking place. When there was a greater proportion of solids to liquids in the mixture, the process of setting needed less time. On the other hand, when there was a smaller percentage of solids to liquids, the procedure took longer. The increase in the proportion of solids to liquids in the combination was directly responsible for the time savings that resulted from this. According to the findings of the MIP analysis, the specimens that had 1% micro silica added to them were much denser than the other specimens. This was one of the findings of the study. The inquiry turned up this information as one of its conclusions. It has been concluded, on the basis of these data, that there is a possibility that nanotechnology geo-polymers may find applications in the future. This has been shown by the fact that there is a chance of it happening. The continuation of research and technological advancement will lead to an increase in the number of nanoparticles that are produced, which will, in turn, lead to an increase in the utilisation of nanomaterials in geo-polymers. The properties of nano silica are mentioned in table 6.

Table 6. Properties of Nano silica

Property	**Value**
Surface Area (gm/m^2)	over
Average Particle Size (nm)	12
Loss of Ignition	< 1.0
pH	3.4 – 4.7
Silica (%)	> 99.8

Figure 3. Nano Silica

Nano silver-silica modified geo-polymer mortar

Stimulation with alkali solutions and temperature curing between 40 and 75 degrees Celsius are often required for the geo-polymeric reaction to take place successfully. This is done in order to get outcomes in a hardened state of GPC, are comparable to those achieved by using conventional concrete. The strength development of geo-polymer that is cured under the room temperature and is based on fly ash has been the subject of a number of experiments, all of which have demonstrated that there is potential for improvement in this area. After being allowed to cure at room temperature for a period of 28 days, geo-polymer mortar with 6% nano silica will exhibit a discernible increase in both its mechanical strength and its durability. This improvement may be detected when the mortar is examined for its mechanical properties. Depending on the specific materials that were used to make the combination, the freshly mixed concrete or mortar might have a pH ranging anywhere from 10 to 12, depending on the range of values. As a direct result of this and the very high alkalinity, it does not let any bacteria grow inside it, which is one of the consequences of this. Despite this, this very high pH will gradually decrease on its own as more time passes. When the pH of the concrete or mortar falls to a level lower than 9.0, the surface of the concrete will begin to experience bacterial attack or deposition. This will continue until the pH is brought back up to a level higher than 9.0. When the pH of the concrete or mortar drops below 9.0, you will see this kind of result. In addition to capillaries, micro and macro cracks, and other defects, bio-deterioration is what causes the concrete to get damaged. Bio-deterioration is caused by the presence of microbial colonies on the surface of the concrete. According to the findings of a number of studies, the use of silver nanoparticles at low concentrations has the potential to be used as an antibacterial agent. This was found by observing the effects of the agent on bacteria. It has been shown that a low-calcium fly ash-based silica-modified geo-polymer mortar that is allowed to cure at room temperature has nearly the same levels of strength and durability while displaying significantly improved antibacterial qualities. Antibacterial characteristics may be found in standard cement mortar, silica-modified geo-polymer mortar, and silver-silica-modified geo-polymer mortar; however, the antibacterial properties of silver-silica-modified geo-polymer mortar are superior to those of typical cement mortar. Because of their positive charge, the silver nanoparticles in the liquid growth medium have the potential to electrostatically attract the negatively charged bacterial cell walls. This is because the bacterial cell walls themselves are negatively charged. The liquid has these nanoparticles all throughout it. The presence of a tiny number of silver ions, or NPs, that have been oxidised may also be responsible for electrostatic attachment to the bacterial membrane. This results in a loss in the osmotic stability of the cell, which is then followed by the leakage of intracellular contents as a consequence of the cell spilling its contents as a result of the cell losing its osmotic stability (Figure 4).

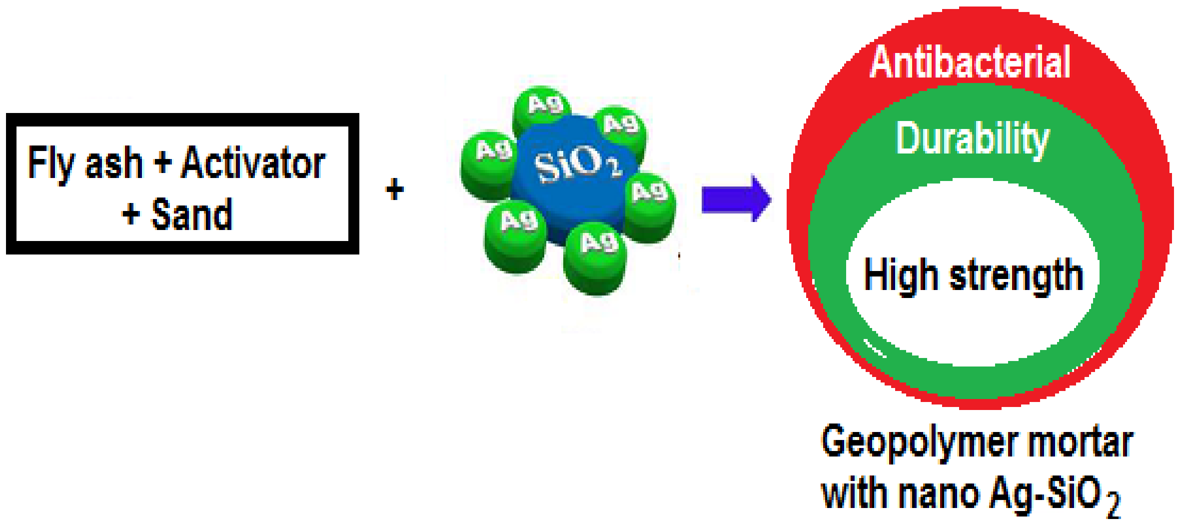

Figure 4. The amalgamation of Nano silica and mortar

3.2 Design procedure for geo-polymer concrete

This particular design for a concrete mix as mentioned in the table 7 was chosen from among the many trial mixes that were carried out and will now be put to use for the purposes of experimentation.

- It has been determined that the solution of sodium hydroxide should be mixed with sodium silicate at a ratio of 2.5.
- The curing process required twenty-four hours in the oven at a temperature of sixty degrees Celsius.
- For mixtures with a molar concentration of 8M, the ratio of water to geo-polymer solids (W/GPS) is 0.27, whereas the ratio for mixtures with a molar concentration of 12M is 0.26, and the ratio for mixtures with a molar concentration of 16M is 0.25.

Table 7. Quantity in Kg/m^3

Material	Quantity
Mix	G30
Alkaline Liquid/ Fly Ash	0.45
Fly Ash	380.689
NaOH	48.945
Na_2SiO_3	122.364
FA	554.4
CA	776.1 (20mm)
	518.7 (10mm)
Water	38.0

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Chemical Admixture	3.8

When nano-silica (NS) and steel fibre (SF) are used together, the flexural properties of the material might potentially see a considerable improvement.

- Each batch of self-compacting geoplymer concrete (SCGC) had its viscosity adjusted in such a way that it maintained the same level of VS2/VF2 throughout its whole life. Those mixtures that did include NS in the studies that were carried out were proven to have a greater degree of cohesiveness than those mixtures that did not contain NS in the experiments that were carried out. When compared to the combinations that did not include NS, this was the finding that was made.
- The use of nano-silica in combination with steel fibres did not have a negative impact on the compressive strength of SCGC (self-compacting geo-polymer) specimens.
- In order to get a more in-depth understanding of the circumstances, a statistical analysis was performed on the amount of influence that SF and NS had on the features of SCGC (self-compacting geo-polymer). In order to get a deeper comprehension of the existing condition of events, this step was taken.

3.3 Experimental Investigation

Compression Strength

Tests of compressive strength and durability were carried out on a G30 grade of concrete to determine their respective findings. The experiments were carried out with varied molar concentrations (8 M, 12 M, and 16 M), as shown in figure 5 as well as varying percentages of natural silica (0 percent, 0.5 percent, 1 percent, and 1.5 percent).

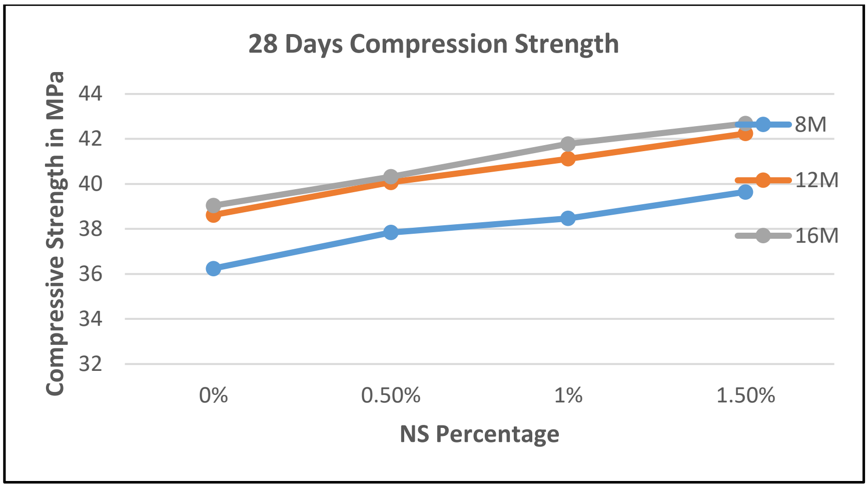

Figure 5. 28 days Compressive Strength

It has been shown that an increase in the proportion of NS leads to a rise in the compressive strength of the material. On the other hand, it has been proven that there is not a substantial difference in the compressive strength between 12 M and 16 M. This is something that has been shown to be the case.

Durability

During the durability test, every single concrete cube was given a period totaling 28 days to cure before being immersed in a salt chloride solution that contained 3.5% NaCl (sea water) for lengths of time totaling both 28 and 56 days (figure 6 and figure 7). This was done in order to compare how well the cubes held up under the conditions of the test. This action was carried out not once, but twice. During our analysis, we not only took into consideration the percentage decrease in weight but also the percentage reduction in the compressive strength of the material.

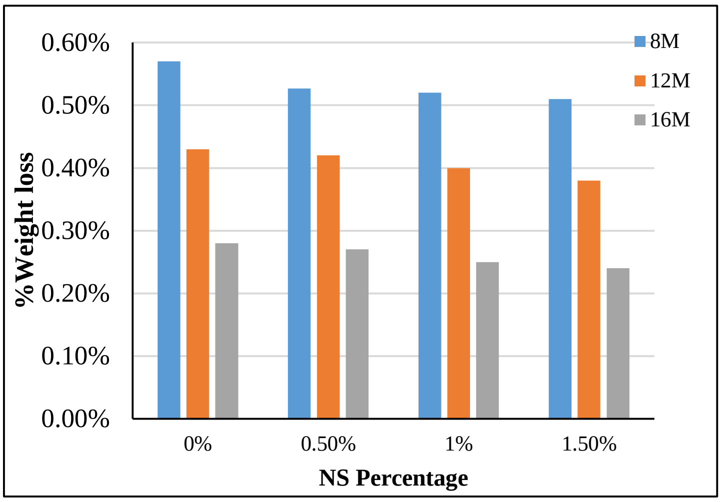

Figure 6. % Weight loss for 28 days

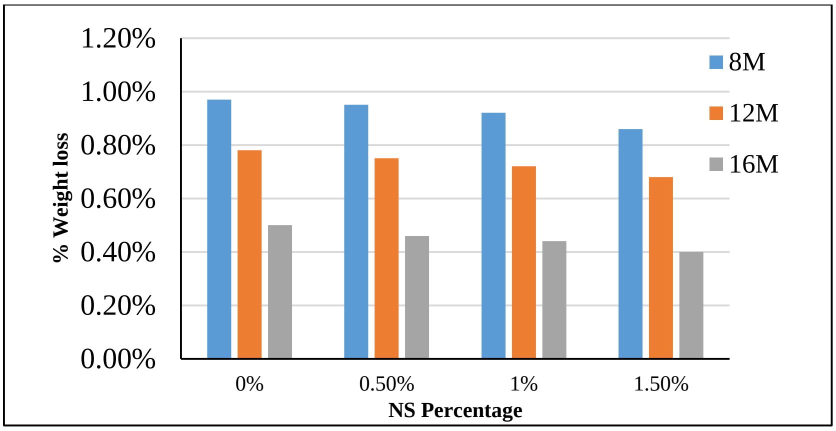

Figure 7. % Weight loss for 56 days

When the molarity of the solution is raised, there is a considerable decrease in the amount of weight that is lost when expressed as a percentage. On the other hand, increasing the quantity of NS results in a little reduction in the proportion of weight loss that takes place. The 8M group displayed the biggest percentage of weight decrease as a consequence of the weight loss that was shown to have taken place when compared to the 12M group and the 16M group. This was the result of the weight loss that was shown to have taken place.

The percentage of loss in compressive strength over a period of 28 and 56 days as mentioned in the graph figure 8 and figure 9 respectively reveals a slight diminish in the percentage of strength loss as long as the molarities were raised, and strength increment was noted by the content of nano-silica (NS) raised. This discovery is confirmed by the fact that an increase in molar concentration also resulted in a decrease in the percentage of loss in compressive strength. This finding was made possible because of this finding. The fact that the percentage of loss in compressive strength decreases with increasing molar concentration is proof that this is the case, and you should be able to see that this is the case from the statement that came before this one. It was found that the compressive strength of the 8M specimen had significantly decreased when compared to that of the 12M and 16M specimens. This was determined when the compressive strength of the 8M specimen was compared to that of the 12M and 16M specimens.

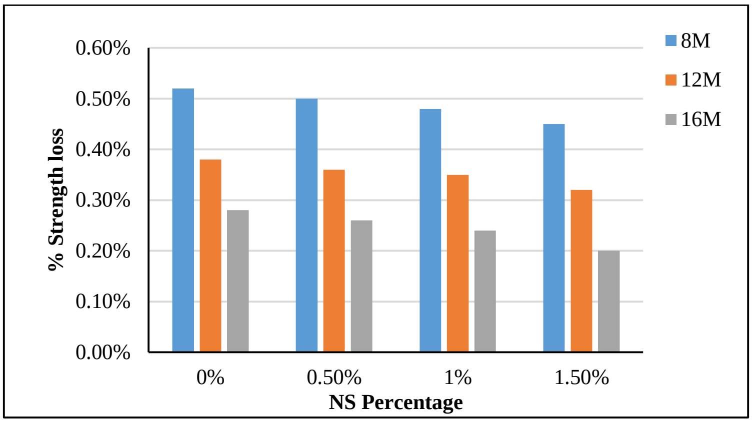

Figure 8. % loss of compressive strength 28 days

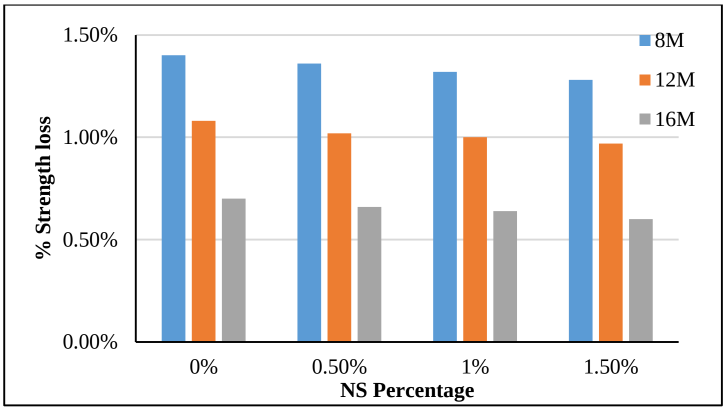

Figure 9. % loss of compressive strength for 56 days

4. Results

The important findings of the experimental study are as follows.

- According to the findings of an experiment, low calcium content of fly ash resulted compressive strength raised when a greater amount of nano-silica was used in the mixture. This was the case when the quantity of nano-silica used was increased. Testing demonstrated that this has a positive connection with the strength of the concrete, which indicates that it should be used.
- It has been discovered that the strength of GPC blends with 12M contained dosage of 1.5% NS is 1.2 times more than the strength of GPC specimens as contrasted with 8M contained 1.5% NS. This information can be found in the table that can be seen here. On the other hand, there is only a little improvement in the compressive strength of GPC specimens after 28 days, with 16M having 1.5% NS.

- Because it is conceivable for GPC samples produced with a concentration of 16M to produce unexpected and erroneous findings, it is advised that the attentiveness of NaOH used be maintained at a optimum of of 12 M. This is because it is possible for GPC samples to provide unexpected and erroneous results. This is due to the fact that it is possible for GPC samples obtained with a concentration of 16M to provide conclusions that were not anticipated and were incorrect.
- It was determined in the course of a laboratory study on the molar concentration of sodium hydroxide solution that a 16 M NaOH solution is more hazardous to handle than a 12 M solution. The research was carried out in order to better understand the relationship between the two variables. Additionally, the probability of solidification of alkaline activators was greater with a 16-M solution than it was with a 12-M solution. This was the case when comparing the two concentrations. During the lab study As a direct consequence of this, solutions of sodium hydroxide with a concentration of 12M are often suggested for use in the process of manufacturing geo-polymer concrete.
- When compared to one another, the strength of GPC that was made with a concentration of 12M is only marginally lower than the strength of geo-polymer concrete that was formed with a concentration of 16 M.
- During the durability test, the loss of weight that is caused by the chloride effect is decreased when the molarity of the solution rises, and there is also a little reduction as the percentage of nano-silica increases. Both of these factors contribute to a small overall reduction. These two elements work together to bring about an overall reduction in weight. These two effects, when used together, have the combined effect of reducing the pace of overall weight reduction.
- The surface of the test specimens showed no evidence of having been affected in any manner after being exposed to sodium chloride for up to 56 days. This was despite the fact that the surface had been exposed to sodium chloride.
- We say that a certain sort of geo-polymer concrete has "great resistance" when it offers a high level of protection against chloride attack after being heated to cure. This kind of protection can only be offered by geo-polymer concrete that has been heated. This illustrates that geo-polymer concrete may be used in a broad variety of situations, including those that involve the presence of salty water. Specifically, this demonstrates that geo-polymer concrete can be used in saltwater environments.
- There is evidence to suggest that nano-silica has an influence on the attributes of compressive strength and durability shown by geo-polymer concrete. These qualities may be seen as a result of using nano-silica. It has been shown that nano-silica has an effect on these characteristics.

5. Conclusions

The following are the conclusions made throughout the experiment.

- As a direct consequence of this, we arrived at the following findings and interpretations: Producing cement-free mortar and paste is one of the increasing research fields known as alkali-activated binders and geo-polymers. These are both terms for types of polymers. This area of inquiry is one of the burgeoning subfields of academic study, and the rate of research activity connected to it is gaining speed.
- The completion of this process will result in the manufacture of an alternate material to cement that will be obtained from industrial waste and activated by an alkaline solution. In many different contexts, one may substitute this substance for cement. It is possible to build a material out of geo-polymer

that does not require the use of cement and has performance levels that are equivalent to those of materials that are based on cement.

- The performance levels of the geo-polymer-based material may be equal to those of the cement-based material. The growth of strength during geo-polymerization is one of the primary tasks of the process of heat curing, and it plays a significant role in this development. This is due to the fact that having strong muscles is one of the most crucial duties.
- There is a correlation between a rise in temperature and an acceleration in the pace of geo-polymerization. This acceleration tends to occur in a way that is directly proportionate to the temperature increase.
- The investigation leads one to the conclusion that the inclusion of nanoparticles into geo-polymer mortar or concrete, such as nano silica, has substantial potential to be employed as an effective construction material in the context of civil engineering field applications. This conclusion may be reached as a direct result of the findings of the study. This is the realisation that one attains as a consequence of doing the investigation. This conclusion was arrived at as a direct consequence of the findings of the research. The antibacterial properties of nano silver-modified geo-polymer mortars were discovered by researchers.
- Because Portland cement is no longer used, CO_2 liberation is quiet lowered. This is one of the many positive environmental impacts that have resulted from this change. Because of this, there has been a proportional decrease in the amount of pollution that is present in the natural environment. This is because of the effects that this has had. GPC is a better option for the environment since it has lower CO_2 emissions than OPC, which makes it a more environmentally conscious product.
- Geo-polymer concrete is better for the environment; it has the potential to replace regular concrete made with Portland cement, significant high early strength can be seen in GPC, it can used in the precast structures. Geo-polymer concrete is better for the environment.
- This is a very cost-effective product called geo-polymer concrete, and the reason for this is because it makes use of waste from industrial processes. Because it is a factor that adds to the total cost of the material, the cost of geo-polymer concrete might be affected by this component as well.
- Incorporating additional components, such as silica with nanoscale dimensions, into GPC has the potential to improve the characteristics of the material. This is especially true in the case of nanoscale silica.

References

1. Davidovits J1994 Properties of geopolymer cements Proceedings of First International Conference on AlkalineCements and Concretes SRIBM Kiev Ukraine **1** pp 131-149.
2. Hardijito D, Wallah S E, Sumajouw D M J, Rangan B V 2004 On the development of fly ash based geopolymer concrete ACIMater J **101** pp 467—472.
3. Ammar Motorwala, Vineet Shah, RavishankarKammula, PraveenaNannapaneni, D B Raijiwala 2013 Alkali Activated Fly –ash Based Geopolymer Concrete IJEAT **3** pp 159-166.
4. A Maria Rajesh, M Adams Joe, Roy Mammen, 2014 Study of the Strength Geopolymer Concrete with Alkaline Solution of Varying Molarity IOSR Journal of Engineering **4** pp 19-24.
5. M Saafi, K Andrew, P K Tang, D McGhon, S Taylor, M Rahman, S Yang, X Zhou, 2013 Constr Build Mater **49** pp 46-55.
6. C Lamuta, S.Candamano, F Crea, and L Pagnotta, 2016 Mater Des **107** pp 57-64.

7. M F Nuruddin, A Kusbiantoro, S Qazi, M S Darmawan, N A Husin, 2011 Development of Geopolymer Concrete with Different Curing Conditions The Journal for Technology andScience **22** pp 24-28.
8. V Bhikshma, M Koti Reddy and T Srinivas Rao 2012 An Experimental Investigation onProperties of Geopolymer Concrete (No Cement Concrete) Asian Journal of Civil Engineering **13** pp 841-853.
9. V Bhaskar Desai and A Sathyam 2014 Basic Properties of Artificial Lightweight Aggregate by Using Industrial by Product (Fly Ash) IJCIET **5** 2014 pp 65 – 72
10. Mahroo Falah, Kenneth J D MacKenzie 2015 Ceramics International **41** pp13702–13708
11. D Hardjito, B V Rangan 2005 Development and Properties of Low-calcium Fly Ash based Geopolymer Concrete Research Report GC1, Curtin University of Technology, Australia.