BAUXITE TAILINGS BASED GEOPOLYMER CONCRETE REINFORCED WITH GRAPHENE OXIDE

Our country is developing with various growing infrastructures due to this there is a high rate of cement demand. The cement industry produces cement that releases an equal amount of CO_2 into the air which causes various serious environmental issues like airborne pollution, gases, and CO_2 emission. This leads to the necessity to bring forth alternative binders to decrease carbon dioxide emissions and carbon footprint. Geo-polymer concrete is an eco-friendly material that is an alternative for conventional concrete. The present study is proposed to address the problem of disposal issues of Bauxite Tailing, a solid waste from alumina production. Studies reveals that bauxite tailing is a suitable Geo-polymer precursor due to its high basicity and high aluminum content. Also, its high sodium content supports faster dissolution in geo-polymer concrete. Though it is a good precursor for the manufacture of Geo-polymer concrete, it is observed that there is a need for a supplement to support the strength increase beyond a threshold. It is expected to overcome this strength drop by introducing a Nano additive called 'Graphene Oxide' with the Geo-polymer concrete which is also expected to improve the durability, microstructural and thermal properties along with the mechanical properties

FIELD OF INVENTION

The present invention relates to the development of Geo-polymer concrete. More Particularly, the present invention relates to Geo-polymer concrete with bauxite tailings as a precursor with optimum proportions with fly ash and Ground Granulated Blast-Furnace Slag GGBS. More particularly, the present invention relates to incorporating the nanomaterial Graphene oxide with optimum proportion in bauxite-based Geopolymer concrete at ambient temperature exhibits enhancement of mechanical, durability, and thermal properties.

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BACKGROUND OF THE INVENTION AND PRIOR ART

Various studies have been carried out with Geo-polymer concrete by predominantly using Fly ash, Ground Granulated Blast-furnace Slag (GGBS) and Metakaolin as precursors. Some studies were performed with bauxite tailing replaced along with Fly-ash or GGBS under ambient and heat curing conditions. Bauxite Tailings is a suitable Geo-polymer precursor due to its high basicity and high aluminum content. When Bauxite Tailings are replaced along with Fly-ash desired strength and high percentage of Bauxite Tailings replacement was not achievable under ambient curing. From various other studies, it is perceived that when the concept of nanotechnology is introduced in the study of concrete for construction, due to the particle size of the nanomaterials which are less than 100 nm has verified that there is better improvement seen in the properties of the concrete in both fresh and hardened state (*Li et.al., 2017)*. Due to the high surface area to volume ratio of 'Graphene Oxide' can accelerate the rate of chemical reaction in geopolymer concrete *(Shao et.al., 2021)*. The exceptional laminar structure and high surface functions of the Graphene Oxide supports effectively to enhance the mechanical, microstructure and thermal properties of the geopolymer concrete under ambient curing (*Liu et.al., 2020*). Bauxite based Geo-polymer when reinforced with small quantity of Graphene Oxide can therefore exhibit enhancement of mechanical, durability properties and aids in energy conservation.

In the review of published patents regarding the Bauxite Tailings and GGBS in Geo-polymer, **Indian Patent (App.No. 202141007336)** describes the usage of red mud (Bauxite Tailings) and foundry waste anf GGBS has a trenary blend to produce bricks **China Patent (App.No. CN201410160376.9A)** describes about the usage of Bauxite Tailings in the replacement of GGBS alone in the Geo-polymer concrete, **United States Patent (App.No. US15/612,677)** describes the usage of Bauxite Tailings and Fly ash Class C and Class F in the geo-polymer concrete.

Another **China Patent (App.No. CN202010201147.2A)** describes about the incorporation of nano material Graphene oxide and Metakaolin based Geo-polymer concrete. In an extensive search of patents on Geo-polymer concrete prepared with 'Bauxite Tailings incorporated with the nanomaterial Graphene Oxide' for enhancing mechanical, durability and behavior at elevated temperatures, no invention is been found and there is a need for enabling usage of the industrial solid waste by-product (Bauxite tailings) in Geo-polymer concrete efficiently and for its possible real-time executions.

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OBJECT OF THE INVENTION:

A primary object of the present disclosure is to provide a Geopolymer concrete with optimum content of Bauxite tailing with fly ash and GGBS without compromising strength and durability under ambient curing.

Another object of the present disclosure is to improve the strength of Bauxite based Geopolymer concrete with an optimum dosage of Graphene oxide.

Another object of the present disclosure is to provide Bauxite based Geopolymer concrete reinforced with Graphene oxide enhancing the performance of concrete at elevated temperatures.

SUMMARY OF THE INVENTION:

The following presents a simplified summary of the disclosure in order to provide a basic understanding to the reader. This portion explains the overview of the invention.

The present invention belongs to the field of the construction industry, in particular to the preparation of concrete without cement.

The present invention eliminates the need of heat curing of Geopolymer concrete which is a limitation when fly ash is used as a precursor.

One preferred embodiment of the present invention contemplates precursor ingredients for Geopolymer concrete such as Fly ash, GGBS, and Bauxite tailings.

Another preferred embodiment of the present invention contemplates the 'Bauxite Tailing' and 'Graphene Oxide' at an optimum proportion at which the maximum performance is obtained.

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Various percentages of combinations from 0% to 50% of Bauxite Tailing are replaced with Fly Ash and GGBS to prepare geopolymer concrete with various concentrations of alkaline activator solution, the strength, microstructure at elevated temperatures and durability characteristics of these proportions are recorded and analyzed to arrive at the optimum mix.

Signature of Applicant: F.S. Frieda
Name: (F.S. FRIEDA)

Signature of Applicant: Greeshma. S
Name: (S. GREESHMA)

To,
The Controller of Patents
The Patent Office, at Chennai

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BAUXITE TAILINGS BASED GEOPOLYMER CONCRETE REINFORCED WITH GRAPHENE OXIDE

Abstract:

The present invention is proposed to address the problem of disposal issues of Bauxite Tailing, solid waste from alumina production. Literature study reveals that bauxite tailing is a suitable Geo-polymer precursor due to its high basicity and high aluminium content. Also, its high sodium content supports faster dissolution in geo-polymer concrete. The properties of the Geo-polymer concrete with the addition of bauxite tailings under ambient curing is expected to be improved by introducing a Nano additive called 'Graphene Oxide' along with the bauxite based Geo-polymer concrete which is can also improve the durability, microstructural and thermal properties along with the mechanical properties. It is proposed to study the Mechanical Properties in terms of Compressive Strength, Tensile Strength and Flexural Strength. The Durability Properties in terms of water absorption, Sulphate resistance, Rapid chloride penetration test, water permeability & Acid Resistance are also proposed to be carried out. It is also proposed to study the Microstructure Characterization and behaviour of Geo-polymer concrete Thermal Properties (mass loss, thermal deformation, thermal conductivity) for the geo-polymer concrete prepared with bauxite tailing as precursor added with Graphene oxide Nano additive. Cost Analysis will also be performed to understand the practical applicability of the proposed combinations. The scope of the project work covers the precursor GGBS and Fly ash replacement by bauxite tailings from 0% - 50% by volume and graphene oxide addition by 0.01%-0.4% variation. A mortar study will be performed to arrive at the optimum molarity of NaOH with an alkaline environment of Na2SiO3/NaOH as 2.5.

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FORM 2

THE PATENTS ACT, 1970

(39 of 1970)

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THE PATENTS RULES, 2003

COMPLETE SPECIFICATION

(See section 10 and rule 13)

1. TITLE OF THE INVENTION

A PROCESS FOR MAKING BAUXITE TAILINGS-BASED GEOPOLYMER CONCRETE REINFORCED WITH A NANO ADDITIVE MATERIAL

2. APPLICANT(S):

a) **F.S. Frieda**

b) An Indian National

c) Anna University, Sardar Patel Road, Chennai, Tamil Nadu, India 600025.

a) **Dr. S. Greeshma**

b) An Indian National

c) Anna University, Sardar Patel Road, Chennai, Tamil Nadu, India 600025.

3. PREAMBLE TO THE DESCRIPTION

The following specification particularly describes the invention and the manner in which it is to be performed.

FIELD OF THE INVENTION:

The present invention relates to the field of sustainable construction materials. More particularly, the present invention relates to a process for making bauxite tailings-based geopolymer concrete reinforced with a nano additive material.

BACKGROUND OF THE INVENTION:

Various studies have been carried out on Geo-polymer concrete by predominantly using Fly ash, Ground Granulated Blast-furnace Slag (GGBS), and Metakaolin as precursors. Some studies were performed with bauxite tailing replaced along with Fly-ash or GGBS under ambient and curing conditions. Bauxite Tailings are a suitable Geo-polymer precursor due to its high basicity and high aluminium content. When Bauxite Tailings are replaced along with Fly-ash desired strength was not achievable under ambient curing with higher percentage of Bauxite Tailings replacement. From various other studies, it is perceived that when the concept of nanotechnology is introduced in the production of concrete for construction, it has verified that there is better improvement seen in the properties of the concrete in both fresh and hardened state due to the particle size of the nanomaterials which are less than 100 nm (*Li et.al., 2017)*. The high surface area to volume ratio of Graphene Oxide can accelerate the rate of chemical reaction in geopolymer concrete *(Shao et.al., 2021)*. The exceptional laminar structure and high surface functions of the Graphene Oxide support effectively enhance the mechanical, microstructure, and thermal properties of the geopolymer concrete under ambient curing (*Liu et.al., 2020*).

Indian patented document number: 202141007336 discloses a method of Manufacture of Red Mud and Waste Foundry Sand Based Sustainable Bricks characterized in that and comprising: mixing 80wt% of Red mud and 10wt% of Waste foundry sand to obtain a mixture, wherein the Red Mud is a solid waste produced from the aluminum industry, wherein the waste foundry sand is primarily silica coated with a thin film of burnt carbon and dust; blending the obtained mixture with 10wt% of binder and a stabilizer at ambient temperature to obtain a blend, wherein the binder is Ground granulated blast furnace slag (GGBS), wherein the stabilizer is selected from Geo-polymer solution, 8M alkaline solution or Lime solution; and pouring the blend into a block making machine for casting to form said bricks.

Chinese patented document number: CN201410160376 discloses a method for producing a geopolymer binding material by red mud and the geopolymer binding material. The method

comprises the following steps: (1), the red mud is evenly mixed with hydroxide of alkali metal or carbonate, and 3 to 5 mol of alkali metal is contained in the hydroxide of alkali metal or the carbonate, which is added into the red mud per kilogram; (2), the mixture is calcined for 1 to 3 hours at the temperature of 700˚C to 900˚C, and a heat-alkali activated red mud is obtained after cooling; (3), the activated red mud is mixed with granulated blast-furnace slag powder according to the mass ratio of (1.5:1):(4:1). When being used, the geopolymer binding material produced according to the method is evenly mixed with water with the mass ratio of 60 percent to 70 percent so as to achieve maintenance formation. According to the invention, waste material red mud produced by using Bayer processes when used as a precursor largely is environmentally friendly and low in cost. The geopolymer binding material can be directly added with water to stir during the use, alkaline boosters such as water glass and the like are not required to be added, curing and compaction or dried formation are not required, the use is convenient, and the adaptability is good.

However, the above-mentioned documents and other conventional method fails to address the problems of the need for heat curing of geopolymer concrete, the problem of disposal issues of Bauxite Tailing which is a solid waste from alumina production, increased amount of emission of CO_2 by the conventional concrete into the air, poor thermal and mechanical properties etc.

Therefore, there is still a need for a solution that can provide an improved method for obtaining a geopolymer concrete that has the capability to overcome the drawbacks of the prior art and can provide a solution for the problem of disposal issues of Bauxite Tailing, solid waste from alumina production.

OBJECT OF THE INVENTION:

The primary objective of the present invention is to disclose a process for making bauxite tailings-based geopolymer concrete reinforced with a nano additive material.

Another objective of the present invention is to disclose a process that eliminates the need for heat curing of Geopolymer concrete which is a limitation when fly ash is used as a precursor.

Another objective of the present invention is to disclose a geopolymer concrete which is an eco-friendly material that is an alternative to conventional concrete.

Still another objective of the present invention is to disclose a geopolymer concrete which reduces the release of CO_2 into the environment.

Yet another objective of the present invention is to disclose a geopolymer concrete which addresses the problem of disposal issues of Bauxite Tailing, solid waste from alumina production.

Yet another objective of the present invention is to disclose a geopolymer concrete reinforced with graphene oxide which aims towards improving the durability, microstructural and thermal properties along with the mechanical properties.

Other objects and advantages of the present invention will become apparent from the following description taken in connection with the accompanying drawings, wherein, by way of illustration and example, the aspects of the present invention are disclosed.

SUMMARY OF THE INVENTION:

In accordance with the main embodiment of the present invention, a process for making bauxite tailings-based geopolymer concrete reinforced with a nano additive material. Bauxite Tailings-based Geo-polymer when reinforced with a small quantity of Graphene Oxide which is a nanomaterial can exhibit enhancement of mechanical, and durability properties and aid in energy conservation. The process of the present invention involves easy and simple steps. The disclosed process provides bauxite tailings-based geopolymer concrete reinforced with graphene oxide. In the first step of the said process: binder materials selected which will be used in the process of making the geopolymer oxide. The binder materials include bauxite tailing and ground granulated blast furnace slag (GGBS). In the second step of the said process: alkaline activators are selected so as to develop binding properties when mixed with the binding materials. To create an alkaline activator solution, which is subsequently combined with the combination of the binder materials, the alkaline activators were prepared using sodium hydroxide and sodium silicate. In the third step of the said process: a nano additive material is used in the process of making bauxite tailings-based geopolymer concrete. The said nano material is Graphene oxide. The said nano material is added to improve the durability, microstructural and thermal properties along with the mechanical properties of the said geopolymer concrete. In the fourth step of the said process: the binding materials which are bauxite tailing and ground granulated blast furnace slag (GGBS) are taken with the percentage weight of 40% and 60% respectively. The binding materials are then mixed well for 5 minutes. The GGBS has a specific gravity of 2.90 and has a fineness modulus of 390 m^2/kg. In the fifth step of the said process: the said alkaline activator solution is prepared using sodium silicate in the form of a solution with 14.2% of Na_2O, 31.12% of SiO_2 and 54.68% of H_2O and sodium

hydroxide in the form of flaxes with 99% purity. The sodium hydroxide solution of 4M is prepared 24 hours prior to the casting and mixed with a sodium silicate solution wherein the ratio between the said sodium silicate and sodium hydroxide is 2.5. In the sixth step of the process: the prepared alkaline activator solution is added into the mixture of the said binder materials and mixed well. In the seventh step of the process: 0.1% of the nano additive material is added to the mixture of the binder materials and the alkaline activator solution. The said nano material is synthesized by hummers modified method, and obtained in powder form with length of 5-10µm, thickness of 0.8-2nm, number of layers 1-3, surface area of 200m^2/g, and bulk density of 0.121g/cc. Further, the dispersion of Graphene oxide is obtained with a concentration of 0.5g/100 ml in deionized water which is then sonicated using a probe sonicator for 30 minutes, and is sonicated again for 15 minutes before adding to the mixture of the alkaline activator solution and the binder material mixture. In the eighth step of the said process: after adding the nano additive material into the mixture of the binder materials and the alkaline activator solution, the mixture is mixed well and then collected in a separate container as the obtain mixture is ready to be used in the construction of any kind of structure. In the ninth step of the said process: the obtained mixture is then poured into the cube moulds or any shape of the mould. In the tenth step of the said process: the poured mixture is compacted with the help of table vibrators. In the eleventh step of the said process: the compacted cube moulds are de-moulded after 24 hours and are kept under ambient temperature of 25º C to 30º C. In the final step of the said process: the nanomaterial reinforced bauxite tailings based geopolymer concrete cube is tested after 28 days for its compressive strength and test results shows improved strength of 47.5MPa. This novel mix deign also has improved durability, microstructural and thermal properties along with mechanical properties and can be efficiently used for constructing a structure without heat curing. Other objects and advantages of the present invention will become apparent from the following description taken in connection with the accompanying drawings, wherein, by way of illustration and example, the aspects of the present invention are disclosed.

DETAILED DESCRIPTION:

The following description describes various features and functions of the disclosed device and methods with reference to the accompanying figures. In the figures, similar symbols identify similar components, unless context dictates otherwise. The illustrative aspects described herein are not meant to be limiting. It may be readily understood that certain aspects of the disclosed

system, method and apparatus can be arranged and combined in a wide variety of different configurations, all of which are contemplated herein.

These and other features and advantages of the present invention may be incorporated into certain embodiments of the invention and will become more fully apparent from the following description and claims or may be learned by the practice of the invention as set forth hereinafter.

Accordingly, those of ordinary skill in the art will recognize that various changes and modifications of the embodiments described herein can be made without departing from the scope of the invention. In addition, descriptions of well-known functions and constructions are omitted for clarity and conciseness.

The terms and words used in the following description and claims are not limited to the bibliographical meanings, but, are merely used to enable a clear and consistent understanding of the invention. Accordingly, it should be apparent to those skilled in the art that the following description of exemplary embodiments of the present invention are provided for illustration purpose only and not for the purpose of limiting the invention.

It is to be understood that the singular forms “a,” “an,” and “the” include plural referents unless the context clearly dictates otherwise.

It should be emphasized that the term “comprises/comprising” when used in this specification is taken to specify the presence of stated features, integers, steps or components but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.

In accordance with the present invention, a process for making bauxite tailings-based geopolymer concrete reinforced with a nano additive material is provided. The process is comprising the steps of: selecting, binder materials from bauxite tailing and ground granulated blast furnace slag (GGBS); selecting, alkaline activators which are sodium hydroxide and sodium silicate for preparing an alkaline activator solution; selecting, a nano additive material which is graphene oxide; mixing, the selected binder materials for 5 minutes; preparing, the said alkaline activator solution by adding pre-prepared 4M solution of sodium hydroxide in a sodium silicate solution wherein the ratio between the sodium silicate and sodium hydroxide is 2.5; adding, the said alkaline activator solution into the mixture of the said binder materials; adding, 0.1% of the said nano additive material to the above mixture of the binder materials

and the alkaline activator solution, and mixing well; obtaining, the concrete mixture; pouring, the obtained mixture into the cube moulds; compacting, the obtained mixture compacted by means of table vibrators; demoulding, the prepared cubes after 24 hours and keeping under ambient temperature of 25º C to 30º C; and testing, compressive strength of the obtained cube after 28 days and resulting in showing improved strength of 47.5MPa..The said nano material is Graphene oxide and is synthesized by hummers modified method, and obtained in powder form with length of 5-10µm, thickness of 0.8-2nm, number of layers 1-3, surface area of 200m^2/g, and bulk density of 0.121g/cm^3 and the dispersion of Graphene oxide is obtained with a concentration of 0.5g/100ml in deionized water which is then sonicated using a probe sonicator for 30 minutes, and is sonicated again for 15 minutes before adding to the mixture of the alkaline activator solution and the binder material mixture.

Further, the bauxite tailings was procured from Hindalco Industries Limited, Muri, Jharkhand having a Specific Gravity of 2.77. Fine Aggregate used in the present invention is river sand confirming to Zone II as per IS 383 with a specific gravity of 2.66, with a fineness of modulus of 2.83, and a bulk density of 1646 kg/m^3. Coarse Aggregate used in the present invention is with a maximum size of 12.5mm with a specific gravity of 2.76, a fineness of modulus of 6.26, and a bulk density of 1383 kg/m^3.

Physical and chemical properties of Graphene Oxide selected for making geopolymer concrete (%)

Type	**Particle Size (µm)**	**Bulk Density (g/cm^3)**	**Surface Area (m^2/g)**	**No of Layers**	**Thickness (nm)**	**Colour**	**Carbon %**	**Oxygen %**
Graphene Oxide	5-10	0.121	110-250	1-3	0.8-2	Black	70	30

Chemical composition of the precursors used in making geopolymer concrete:

Type	**SiO_2**	**Al_2O_3**	**CaO**	**Fe_2O_3**	**K_2O**	**MgO**	**TiO_2**	**Na_2O**	**P_2O_5**	**LOI***
GGBS	37.10	17.21	35.31	0.46	0.61	6.51	0.87	0.24	0.01	0.3
Bauxite Tailing	18.3	22.61	5.94	39.55	0.38	0.41	8.6	6.61	0.60	8.1

LOI (Loss of Ignition)

Density of the elements of the present invention used for making geopolymer concrete:

GGBS kg/m^3	**Bauxite Tailings kg/m^3**	**Coarse Aggregates kg/m^3**	**Fine Aggregates kg/m^3**	**NaOH kg/m^3**	**Na_2SiO_3 kg/m^3**
228.41	152.27	1293.6	554.4	48.95	122.36

We Claim:

1. A process for making bauxite tailings-based geopolymer concrete reinforced with a nano additive material, comprising the steps of:
    i. selecting, binder materials from bauxite tailing and ground granulated blast furnace slag (GGBS);
    ii. selecting, alkaline activators which are sodium hydroxide and sodium silicate for preparing an alkaline activator solution;
    iii. selecting, a nano additive material which is graphene oxide;
    iv. mixing, the selected binder materials for 5 minutes with a liquid to binder ratio of 0.45;
    v. preparing, the said alkaline activator solution by adding pre-prepared 4M solution of sodium hydroxide in a sodium silicate solution wherein the ratio between the sodium silicate and sodium hydroxide is 2.5;
    vi. adding, the said alkaline activator solution into the mixture of the said binder materials;
    vii. adding, 0.1% of the said nano additive material to the above mixture of the binder materials and the alkaline activator solution, and mixing well;
    viii. obtaining, the concrete mixture;
    ix. pouring, the obtained mixture into the cube moulds;
    x. compacting, the obtained mixture by means of table vibrator;
    xi. demoulding, the prepared cubes after 24 hours and keeping under ambient temperature of 25º C to 30º C; and
    xii. testing, compressive strength of the obtained cube after 28 days and resulting in showing improved strength of 47.5MPa.
2. The process for making bauxite tailings-based geopolymer concrete reinforced with a nano additive material as claimed in claim 1, wherein the percentage weight of the said binding materials i.e., bauxite tailing and ground granulated blast furnace slag (GGBS) is 40% and 60% respectively.
3. The process for making bauxite tailings-based geopolymer concrete reinforced with a nano additive material as claimed in claim 1, wherein the said nano material is Graphene oxide and is synthesized by hummers modified method, and obtained in powder form with length of 5-10µm, thickness of 0.8-2nm, number of layers 1-3, surface area of 200m^2/g, and bulk density of 0.121g/cm^3.

4. The process for making bauxite tailings-based geopolymer concrete reinforced with a nano additive material as claimed in claim 1, wherein the dispersion of Graphene oxide is obtained with a concentration of 0.5g/100ml in deionized water which is then sonicated using a probe sonicator for 30 minutes and is sonicated again for 15 minutes before adding to the mixture of the alkaline activator solution and the binder material mixture.
5. The process for making bauxite tailings-based geopolymer concrete reinforced with a nano additive material as claimed in claim 1, wherein the GGBS has a specific gravity of 2.90 and a fineness modulus of 390 m^2/kg.
6. The process for making bauxite tailings-based geopolymer concrete reinforced with a nano additive material as claimed in claim 1, wherein the said alkaline activator solution is prepared using sodium silicate in the form of a solution with 14.2% of Na_2O, 31.12% of SiO_2 and 54.68% of H_2O and sodium hydroxide in the form of flaxes with 99% purity.

Dated this 21st day of November 2022



Prateek Shrivastava
Indian Patent Agent
Registration No.: IN/PA-3334
of PNA Intellectual Property & Technology Attorneys
Attorneys for the Applicant

ABSTRACT:

A PROCESS FOR MAKING BAUXITE TAILINGS-BASED GEOPOLYMER CONCRETE REINFORCED WITH A NANO ADDITIVE MATERIAL

The present invention relates to a process for making bauxite tailings-based geopolymer concrete reinforced with a nano additive material. The said process comprising the steps of selecting, binder materials; selecting, alkaline activators; selecting, a nano additive material; mixing, the selected binder materials GGBS and Bauxite Tailings of 60% and 40% respectively for few minutes; preparing, the said alkaline activator solution by adding pre-prepared 4M solution of sodium hydroxide in a sodium silicate solution; adding, the said alkaline activator solution into the mixture of the said binder materials with a liquid to binder ratio of 0.45; adding, 0.1% of the said nano additive material to the above mixture after dispersing the Graphene oxide in deionized water; obtaining, the concrete mixture; pouring, the obtained mixture into the cube moulds; compacting, the obtained mixture by means of table vibrators; demoulding, the prepared cubes after 24 hours and keeping under ambient temperature of 25º C to 30º C; and testing, compressive strength of the obtained cube after 28 days and resulting in showing improved strength of 47.5MPa. The obtained geopolymer concrete has also improved durability, microstructural and thermal properties along with the mechanical properties.