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PREDICTING THE STRENGTH OF GGBS BASED GEOPOLYMER CONCRETE BY USING SOFT COMPUTING TECHNIQUES

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ABSTRACT

The use of secondary binding materials is well accepted because of the several improvements in concrete composites, the overall economy of the structures, and environmental preservation. Blast furnace slag is a non-metallic product consisting essentially of glass containing silicates and alumino-silicate of lime, which is developed simultaneously with iron in a blast furnace or electric pig iron furnace. Granulated slag is obtained by further processing of the molten slag by rapid chilling or quenching with water or steam and air. This project presents the investigation of the compressive strength of geopolymer concrete. Ground Granulated Blast Furnace Slag (GGBS) is partially incorporated in a mathematical model developed based on the Soft Computing Techniques (Regression Analysis) concept for predicting the compressive strength of concrete with GGBS. The strength of concrete was estimated by the Regression Analysis and also compared with the laboratory test results. The study established that Regression Analysis technique is effective for predicting the strength of GGBS with the cement concrete depending upon their mix proportions. The application of this technique makes the possibility for the desired strength. Therefore, the use of GGBS as a pozzolanic component should be given priority from technical, economic, and environmental considerations.

Keywords: GGBS; Compression Strength; Regression Analysis; Geopolymer Concrete; Molarity.

INTRODUCTION

Geopolymer concrete is environmentally friendly, and therefore the materials used are renewable. Cement is employed within the construction material to rapidly increasing demandday by day. Professor J. Davidovits In French was formed in 1970 to characterize the range of materials within the geopolymer inorganic molecules. It doesn't use traditional concrete in geopolymer concrete to get around 2.8 billion a lot of greenhouse gases on its drug. Increasing concrete urbanization as a component of binder content. To cause pollution to supply the temperature of 1 ton of greenhouse gas and cement. The environmental impact is to sustain theassembly of cement .

Cement industries are accountable for reducing the greenhouse gas emission of the geopolymerconcrete seven percent. Increasing day-to-day urbanization of energy demand production. In economics, it's more of a foothold for the development industries. The iron waste matter that'sproduced within the industry in ground granulated furnace slag. For that the price and safe disposal of the art fact, there's two concrete wastes. For construction material, this is often fantastic in several years for geopolymer concrete. Alkali activator combining the geopolymerconcrete with hydroxide (or) sodium hydroxide and water glass (or) alkali-silica. to provide high universal strength, the alkali solution may be a factor affecting the mechanical strength. The geopolymer concrete was supported to test the ground granulated blast furnace slag. it's very high for the expansion rate is reflect by the speed of concrete production. it's anoversized amount of non-renewable resources of the globe to utilize the concrete. In geopolymer concretewaste materials just like the fly ash, silica fume etc. are less pollution to boost the concrete. It reduces the carbonic acid gas release from produces the standard cement. it's utilizing the commercial wastage by-product of the fabric to causes the carbonic acid gas emission in a verybinding material and its atmosphere causes the cement and aggregates.

In 1998 Davidovits proposed a geopolymer technology as an alternative to the Ordinary Portland cement (OPC) binder which is majorly being used in construction industries. Geopolymer are chain of mineral molecules linked with covalent bonds. In this technology, thematerial which is rich in silica (Si) and alumina (Al) is reacted with high alkaline solution by the process of repolymerization for the production of binding silicate should be rich in silicon(Si) and aluminium (Al). They could be by-product materials such as fly ash, silica fume, slag,rice-husk ash, red mud, etc. Geopolymers are also unique in comparison to otheraluminosilicate materials (e.g. aluminosilicate gels, glasses, and zeolites). Geopolymerisation is higher than in aluminosilicate gel or zeolite synthesis.[36] In 1998 Davidov its proposed a geopolymer technology as an alternative to the OrdinaryPortland cement (OPC) binder which is majorly being used in construction industries.

Geopolymer are chain of mineral molecules linked with covalent bonds. In this technology, thematerial which is rich in silica (Si) and alumina (Al) is reacted with high alkaline solution by the process of repolymerization for the production of binding material. The alkaline solution act as activator for Geopolymerization which involves fast chemical reaction under highly alkaline condition on Si-Ai minerals that results in a three-dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds. The main significance of geopolymer technology lays preliminary in its ability to produce high performance binder from materials such as fly- ash or GGBS which

are rich in Silica and Alumina content. The use of Geopolymer mortar inready mix designs are increasing, also its applications in precast connections using acceleratedcuring is observed. Geopolymer mortar is emerging as environment friendly construction material for sustainable development as there are number of benefits linked with it. Geopolymer mortar not only reduces the Co2 release from OPC and utilizes industrial waste by products such as fly ash, ground granulated blast furnace slag etc. effectively. As a source material which are activated by alkaline solution act as binder. Co2 emission to the atmospherecaused by cement and aggregate industries can be reduced by 80% with the help of geopolymertechnology. Hence it can be said that the geopolymer mortar shows considerable promise for the application in mortar industry as an alternative binder to OPC and is relatively new area forresearch that can leads to use of geopolymer environmentally friendly mortar eventually.

SOFT COMPUTING

Soft computing is defined as a group of computational techniques based on artificial intelligence (human like decision) and natural selection that provides quick and cost effective solution to very complex problems for which analytical (hardcomputing) formulations do notression analysis is a set of statistical methods used for the estimation of relationships between a dependent variable and one or more independent variables. It can be utilized to assessthe strength of the relationship between variables and for modeling the future relationship between them. This also involves some errors in the prediction of the appropriate model. The errors include R-Squared, RMSE, MAPE.

ERRORS IN REGRESSION ANALYSIS WHICH ARE TO BE NEGLECTED

1. R-Squared
2. Root Mean Square Error (RMSE)
3. Mean Absolute Percentage Error (MAPE)

Impotance of the Geopolymer Concrete

Producing one ton of cement requires about 2 ton of raw materials (shale and limestone) and releases 0.87 ton (H" 1 ton) of CO2, about 3 kg of Nitrogen Oxide (NOx), an air contaminant that contributes to ground level smog and 0.4 kg of PM10 (particulate matter of size 10 µm), an air borne particulate matter that is harmful to the respiratory tract when inhaled. The globalrelease of CO2 from all sources is estimated at 23 billion tons a year and the Portland cement production accounts for about 7% of total CO2 emissions. The cement industry has been making significant progress in reducing CO2 emissions through improvements in process technology and enhancements in process efficiency, but further improvements are limited because CO2 production is inherent to the basic process of calcinations of limestone. Mining of limestone has impact on land-use patterns, local water regimes and ambient air quality and thus remains as one of the principal reasons for the high environmental impact of the industry.Dust emissions during cement manufacturing have long been accepted as one of the main issuesfacing the industry. The industry handles millions of tons of dry material. Even if 0.1 percent 8 of this is lost to the atmosphere, it can cause havoc environmentally. Fugitive emissions are therefore a huge problem, compounded by the fact that there is neither an economic incentivenor regulatory pressure to prevent emissions. The cement industry does not fit the contemporary picture of a sustainable industry because it uses raw materials and energy that are non-renewable; extracts its raw materials by mining and manufactures a product that cannotbe recycled. Through waste management, by utilizing the waste by-products from thermal power plants, fertilizer units and steel factories, energy used in the production can be considerably reduced. This cuts energy bills, raw material costs as well as green house gas emissions. In the process, it can turn abundantly available wastes, such as fly ash and slag intovaluable products, such as geopolymer concretes. 'Geopolymer cement concretes' (GPCC) are Inorganic polymer composites, which are prospective concretes with the potential to form a substantial element of an environmentally sustainable construction by replacing/supplementingthe conventional concretes. GPCC have high strength, with good resistance to chloridepenetration, acid attack, etc. These are commonly formed by alkali activation of industrial aluminosilicate waste materials such as FA and GGBS, and have a very small Greenhouse footprint when compared to traditional concretes.

Objective and Scope of Study

The present study has been undertaken with the following objectives:

1. To make a concrete without using cement (i.e. Geopolymer concrete).
2. To evaluate the different strength properties of geopolymer concrete mixture of GGBS and fly ash replaced in percentage to cement.
3. To investigate the compressive strength of geopolymer concrete by using Ground Granulated Blast Furnace Slag (GGBS) and partially incorporate in a mathematical modeldeveloped based on the Soft Computing

(Regression Analysis) concept for predicting the compressive strength.

METHODOLOGY

The following methodology was used in the present experimental study.The main components involved in the methodology are:

1. Material acquisition.
2. Preparation of sodium hydroxide solution.
3. Preparation of concrete cubes.
4. Ambient curing.
5. Determination of Compressive Strength.

Material Acquisition:

GGBS – an industrial by-product material from the steel industry was used to learn the lucrative results. Industrial stainless steel waste material is also used to understand its beneficialeffects. Similar to potassium hydroxide and potassium silicate, the alkaline activator solution chosen for this experimental study was sodium hydroxide and sodium silicate. The sodium hydroxide concentration identified in this analysis was taken as 2 Molarity, 4 Molarity, 6 Molarity, 8 Molarity, and 10 Molarity. From the previous literature review, a mix of geopolymer concrete design was done. And mix design of ordinary Portland cement was doneas per IS 10262.

Ground Granulated Blast-furnace Slag

Ordinary portland cement - Cement is made by heating calcareous (calcium carbonate)calcareous products in a kiln with small amounts (like clay). The resulting hard material, knownas 'clinker' is then ground into a powder by a small amount of gypsum to make the cement form, the most widely used. This concrete is known as Ordinary Portland Cement.

Fine aggregate(River Sand) - River sand is rounded particle sand taken from the banks of rivers. This is also used forplastering as sea bed sand is unavailable in landlocked regions.

River Sand

Coarse aggregates - The material retained on 4.75 mm sieve is called as coarse aggregate. In this test we use theaggregate which is passing through 12.5 mm sieve and retained on 10 mm sieve.

Coarse aggregates

Preparation of Sodium Hydroxide Solution(NaOH)

1. It is an inorganic compound which is highly soluble in water.8 and 10 M were includedin this experiment.
2. The solution is made 24 hours ahead of time for the casting.
3. The sodium hydroxide with 97-98% purity, in flake or pellet form, is commercially available.
4. The solids must be dissolved in water to make a solution with the required concentration.

The concentration of sodium hydroxide solution can vary in the range between 8 Molar and 10 Molar;however, 8 Molar solution is adequatefor most applications. The mass of NaOH solids in a solution vary depending on the concentration of the solution. For instance, NaOH solution with a concentration of 8 Molar consists of 8×40 = 320grams of NaOH solids per litre of the solution, here 40 is the molecular weight NaOH.

SODIUM SILICATE (Na_2SiO_3)

1. Sodium silicate is known as a water glass. It is available in both solution and gel formin markets.
2. The ratio of Na2SiO3 is 24 hours before casting and mix its pellets. It includes waterwith 36 hours is used.
3. The sodium silicate solution A53 with SiO2-to-Na2O ratio by mass of approximately2, i.e., SiO2 =

29.4%, Na2O = 14.7%, and water = 55.9% by mass, is generally used.

Preparation of Concrete Cubes:

- The standard size of cube is 150mmx150mmx150mm is to be used for the concrete testing.

- All the ingredients of the concrete are added likewise to make a fresh concrete mix.
- The concrete mix should be placed in the form of layers into the concrete cube and tamping of 25 times for each layer is necessary for the proper settling of the concrete in the cube without voids.

Ambient Curing:

The cubes filled with concrete should be left for 24 hours and then the cubes(concrete)should be removed from the moulds.The removed concrete cubes should be kept in the open atmosphere till the time period of testing.(7days,14days,28days).The curing of the concrete with the help of atmosphere is known as Ambient Curing. This curing entirely depends on the climatic characteristics like temperature, naturallight, moisture and air.

Determination of Compressive Strength of Concrete:

The cubes after getting cured for certain period of specific time, they are placed under Compressive Testing Machine(CTM) for checking their strength at different curing time periods.The cube dimensions like area should be entered in the CTM and then the load is appliedgradually on the cube. The point of fracture or point of breaking of the concrete cube is noted and the readingsof the compressive testing machine are noted and forwarded for the further proceedings.

Experimental Investigation

- **Alkaline Activator**

The second-most portion in geopolymer concrete was the alkaline activator. This activator's main purpose is to react with the GGBS and make it a binder, in which GGBS or fly ash can not act as binders without this activator solution. The source materials such as slag, fly ash, metakaolin etc. contain a rich quantity of silicon and aluminium and now the alkaline solutioncan react with silicon and aluminium to form as a binder. The alkaline activator solutions havetypically been based mainly on potassium or sodium. The widely used alkaline activators in geopolymerization are potassium hydroxide or sodium hydroxide, and potassium silicate or sodium silicate. For this analysis, sodium silicate and sodium hydroxide were mixed into the alkaline activator solution.Distilled water was used to dilute the flakes for the preparation of the sodium hydroxide solution.And one day before casting, this alkaline activator solution wasprepared, since the NaOH solution emits a lot of heat when diluting sodium hydroxide flakes.

Sodium Hydroxide Flakes

Sodium Silicate

Mix Design of Geopolymer Concrete

The nature of the geopolymer concrete mix was not clearly defined as specified. And becauseof this, a mixing method of geopolymer concrete from earlier literature was found to be similarto conventional concrete, which was about 2400 kg / m3, for geopolymer concrete made withGGBS. The overall combined aggregate percentage was 75 per cent of the total geopolymer concrete mass, which was close to standard Portland concrete. And the percentage of the fines from the total amounts was 37 per cent. In this experimental investigation, the actual gross aggregate size was 20 mm and 10 mm, and the sum of 20 mm was 60 per cent from the coarseaggregate figure, while the remainder was 10 mm. With the use of 10 mm aggregates, the voidsin the concrete should be filled with 20 mm aggregates. The GGBS and alkaline activator solution of combined weight were calculated from this as the density of geopolymer concrete were known. And the ratio of alkaline liquid and cement content has also been expected to be0.45, and the GGBS amount has been calculated nowand the alkaline activator solution quantityhas been calculated. Geopolymerisation starts after the addition of the alkaline activator solution.The concentrations in this experimental analysis were 8 molarities, 10 molars,

12 molars, 14 molars and 16 molars in sodium hydroxide for thealkaline activator solution. Of allmolarities, the ratio of sodium hydroxide to sodium silicate was 1:2.5. Likewise, 320 grams ofNaOH have dissented to one litre of distilled water for one molar concentration of sodium hydroxide, 10 molars (10 M) were dissolved 400 g of NaOH and 12 molars (12 M) were solved480 g of NaOH for one litre of distilled water and 14 molars (14 M) 560 g of NaOH for one specific molar concentration. The dissolving is to be done and eventually the dissolving in a litre of distilled water for 16 Molars (16 M) is 640 grams of NaOH. Table 4.31 shows the mixednature of geopolymer concrete.

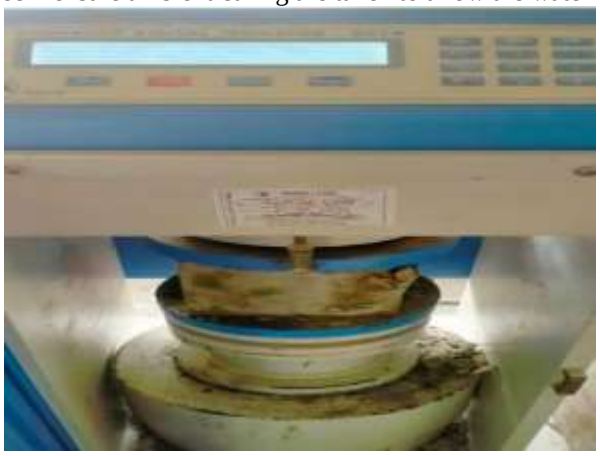
Mix Design

Materials	**Quantity kg/m^3**
GGBS	413.8
Fine Aggregates	660
Coarse Aggregates	1136
NaOH	53.2
Na2SiO3	133

Testing of specimens

a) Compressive Strength of Cubes Cured under Ambient Temperature

The concrete of strength to finding only one alternate method. Strength of the concrete specimen is determined the casting of a cube having dimensions of 0.15mx0.15mx0.15m. Aftercasting geopolymer concrete and normal concrete cubes they were left under curing conditionfor 3, 7, 14, 28, 56 and 90 days. The producer was followed as per IS 516: 1959.The cube sample is mounted in the test machine to centrally place the specimen at the bottom of the testing machine and to change the movable component to reach the top surface of the cube. Incube size of moulds, 0.15X0.15X0.15m was cast with the same molarity (i.e., 8Molarity, 10Molarity, 12Molarity, 14Molarity, 16Molarity) and normal concrete. After 1440mins the specimens are demould and subjected to ambient curing. After 3, 7, 28, 56, day the specimensare ambient curing are taken to allow the waterless and testing the machine.



Compressive Strength Test

b) Split Tensile Test of Cubes Cured under Ambient Temperature and Water Curing

It is finding a concrete strength to subject into the cylinder of a lateral compressive force. Therewas no direct method for knowing the Concrete tensile strength, for determining the tensile strength of geopolymer and normal concrete cylinders. The test specimens In a horizontal direction they were placed in the compressive force machine. In the size of 0.15m diameter and0.30m large cylinder were cast with the same molarity (i.e.,8Molarity, 10Molarity, 12Molarity,14Molarity, 16Molarity) and normal concrete. After 1440 mins the cylinder specimens are demolding

and subjected to ambient curing. After 3,7,,28,56 daysthe specimens are ambient curing is taken and allow the waterless and test machine to place the specimen horizontal. Theload was applied gradually until cylinder splits into two parts. The test was performed as per IS 5816: 1999.

Split Tensile Strength Test

Compressive Strength Test Results

The compressor power was performed on 3, 7, 14, 28, 56, 90 days on cement concrete molaritycube of M30 and M40 and M50. And as shown in Table they listed all the mixes.The results of the experiments increased geopolymer concrete compressive strength, and for 3, 7,, 28, 56 days the geopolymer concrete had a compressive strength higher than M40 concrete, as shownin Table . The compressive strength of geopolymer concrete for 3,7, 28, 56 days of testing was double the strength of grade M40 concrete, raising the strength of geopolymers produced with different molarities with an increase in compressive strength of geopolymer concrete in 8M and 10M – 0.017% for 3, 7, 28, 56 days. 10M and 12M –0.031% for 3, 7, 28, 56 days. 12M and 14M – 0.033% for 3, 7, 28, 56 days. 14M and 16M – 0.151% for 3, 7,, 28, 56 days. To compare the conventional concrete M40 strength is 0.015% for 3 to7 days, 0.28% for 7 to 28 days, 0.041% for 28 to 56 days, 0.059% And it can be inferred thatthe strength was also rising as the sodium hydroxide concentration rises and when geopolymerconcrete only displays higher strengths from 8 molarity compared to M40 grade concrete. Theoutcome was also shown in the bar-line format in table and for 3, 7, 14, 28, 56, respectively.

Test Results of Compressive Strength for 3, 7, 28 and 56 days

Mix ID	3 Days	7 Days	28 Days	56 Days
M1	30	35.6	61.67	70.89
M2	32.1	36.1	65.29	77.5
M3	34.14	36.7	68.34	80.18
M4	38.6	40.3	70.2	83.28
M5	40.8	42.78	73.82	85

Split Tensile Strength Test Results

Split tensile strength was done on the cylinders of 0.30m height and 0.15m diameter. On 3, 7,28, 56 days, on cement concrete cube of M30 and M40 and M40 on geopolymer concrete cubes of different molarities, the tensile strength was executed. And they listed allthe mixes asshown in Table 5.1. From the test results, the compressive strength of geopolymer concrete was improved and the tensile strength of geopolymer concrete was higher than M40 concrete for 3, 7, 14, 28, 56 and 90 days, these test results were shown in Table 5.7. For 3, 7, 28, 56 days of testing, the tensile strength of geopolymer made concrete was double the strength of M40 grade concrete and raises the strength of geopolymer produced with specific molarities Increased strength with an increase in compressive strength of geopolymer concrete. And it can be inferred that the strength was also rising as the sodium hydroxide concentration rises and when geopolymer concrete only displays higher strengths from 8 molarity compared to M40 grade concrete. The outcome was also shown in the bar- line format in table 5.1, 5.15, 5.16, 5.17, 5.18, 5.19 and 5.20 for 3, 7,28, 56days, respectively.

Test Results of Split Tensile Strength for 3, 7, 28, 56 days

Mix ID	3 Days	7 Days	28 Days	56 Days
M1	3.1	3.32	3.74	3.43
M2	3.75	3.84	4.05	4.12
M3	3.83	3.95	4.52	4.75
M4	3.94	4.6	4.65	4.82
M5	4.2	4.12	5.02	5.28

Flexural Strength Test Results

It is finding a concrete strength to subject into the prism beam of a lateral compressive force. The size of 0.15x0.15x0.70m was cast on 3, 7, 28, 56 days, on cement concrete cube of M30 and M40 and M40 on geopolymer concrete cubes of different molarities, the tensile strength was executed. And they listed all the mixes as shown in Table 5.1. From the test results,the flexural strength of geopolymer concrete was improved were higher than M40 concrete for3, 7, 28, 56 days, these test results were shown in Table 5.8. For 3, 7, 28, 56 days of testing, the flexural strength of geopolymer made concrete was double the strength of M40 grade concrete and raises the strength of geopolymer produced with specific molarities Increased strength with an increase in flexural strength of geopolymerconcrete. And it can be inferred that the strength was also rising as the sodium hydroxide concentration rises and whengeopolymer concrete only displays higher strengths from 8 molarity compared to M40 grade concrete.

Table-5.3 Test Results of Flexural Strength for 3, 7, 14, 28, 56 days

Mix ID	3 Days	7 Days	28 Days	56 Days
M1	4.1	5.46	6.2	6.14
M2	4.83	5.57	6.27	6.31
M3	5.22	5.65	6.32	6.53
M4	5.57	5.73	6.45	6.63
M5	5.73	5.88	6.54	6.74

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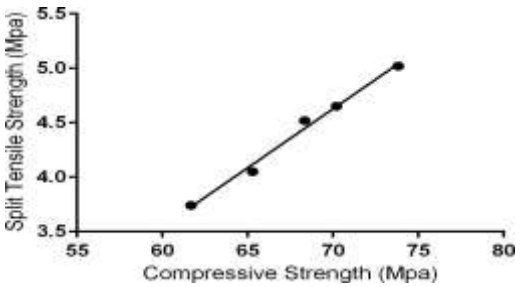
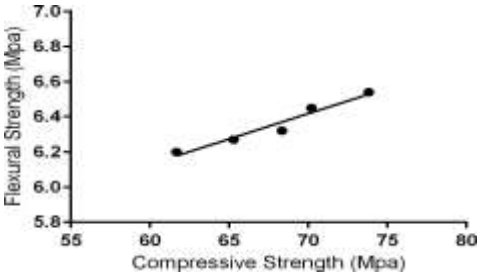
LINEAR, QUADRATIC AND CUBIC REGRESSIONAL EQUATIONS FORCURING PERIODS OF 28 DAYS

LINEAR REGRESSION TEST RESULTS GRAPHICAL REPRESENTATION 28 DAYS

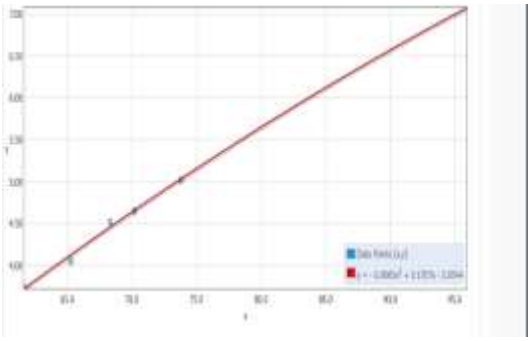


Regression Equation:
y = 0.02886*x + 4.398
R Square – 94.74

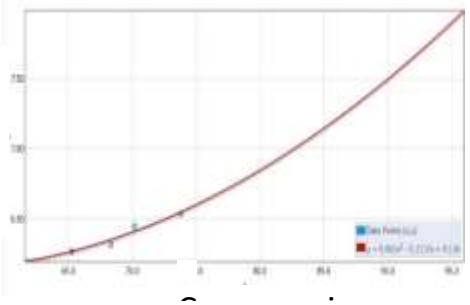


Regression Equation:
y= -0.1082*x – 2.948
R Square – 98.**98**

QUADRATIC REGRESSION TEST RESULTS GRAPHICAL REPRESENTATION 28 DAYS

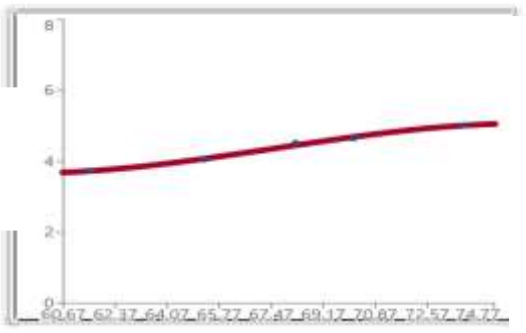


Regression Equation:
y = - 0.0005x^2 + 0.1707x - 5.0544
R Square – 97.9C

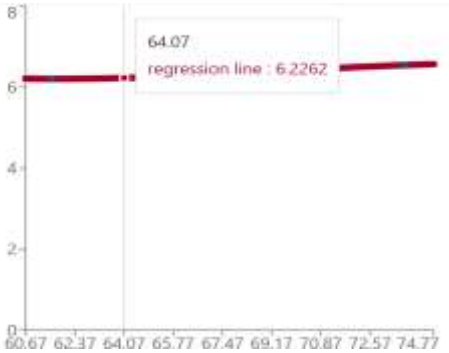


Regression Equation:
y = 0.001x^2 - 0.1117x + 9.136
R Square – 98.29

CUBIC REGRESSION TEST RESULTS GRAPHICAL REPRESENTATION 28 DAYS



Regression Equation:
y = 198.5204 - 8.8763x + 0.1332x^2 - 0.0007x^3
R Square = 99.43



Regression Equation:
y = 75.3697 - 3.0552x + 0.0445x^2 - 0.0002x^3
R Square = 97.2

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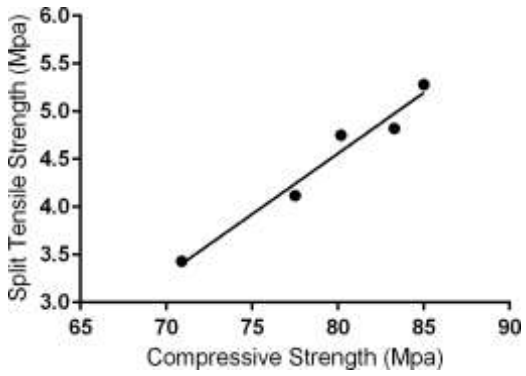
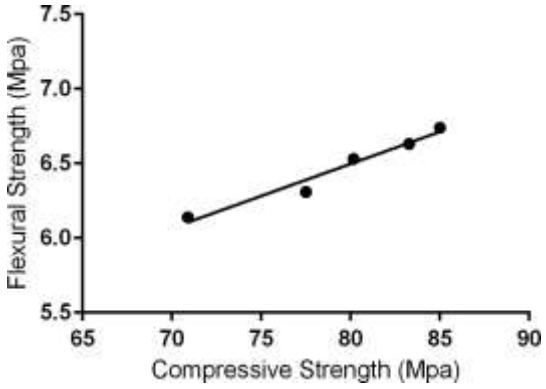
LINEAR REGRESSION TEST RESULTS GRAPHICAL REPRESENTATION 56 DAYS



Regression Equation:

y = 0.1270*x - 5.601

R square – 96.34



Regression Equation:

y = 0.04301*x + 3.057

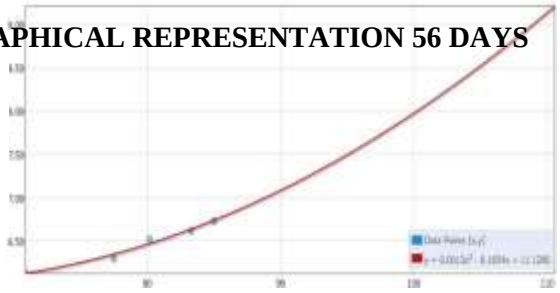
R square – 96.19

C ULTS GRAPHICAL REPRESENTATION 56 DAYS

Regression Equation:

$y = 0.0009x^2 - 0.0072x - 0.4025$

R Square = 98.1

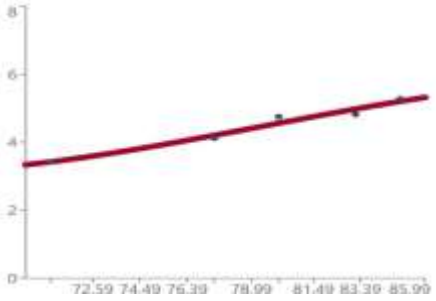


Regression Equation:

$y = 0.0013x^2 – 0.1654x + 11.1296$

R Square = 98.94

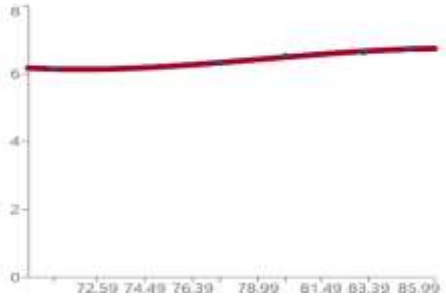
CUBIC REGRESSION TEST RESULTS GRAPHICAL REPRESENTATION 56 DAYS



Regression Equation:

$y = 99.6078 - 3.8667x + 0.0504x^2 - 0.0002x^3$

R Square = 96.45



Regression Equation:

$y = 197.3683 - 7.3526x + 0.0936x^2 - 0.0004x^3$

R Square = 98.72

CONCLUSION

Experimental study on geopolymer concrete and normal concrete to concluded that:

1. The compressive strength of geopolymer concrete is an increase in 8M and 10M – 0.017%for 3, 7, 28 and 56 days. 10M and 12M – 0.031% for 3, 7, 28, 56 days. 12M and14M – 0.033% for 3, 7, 28 and 56 days. 14M and 16M – 0.151% for 3, 7, 28 and 56 days.
2. The split tensile strength of geopolymer concrete is an increase in 8M and 10M - 0.003%for 3, 7, 28 and 56 days. 10M and 12M – 0.005% for 3, 7, 28 and 56 days. 12M and 14M – 0.006% for 3, 7, 28 and 56 days. 14M and 16M – 0.007% for 3, 7, 28 and 56 days.
3. The flexural strength of geopolymer concrete is an increase in 8M and 10M - 0.0016%for 3, 7, 28 and 56 days. 10M and 12M – 0.0016% for 3, 7, 28, 56 days. 12M and 14M – 0.0018% for 3, 7, 28 and 56 days. 14M and 16M – 0.0023% for 3,7, 28 and 56 days.
4. The geopolymer concrete made of GGBS is economical as the GGBS is the by-product(Bi product) of the steel industry.
5. There is a significant improvement in the compressive strength of geopolymer concretebeyond 28 days and 56 days for because of the void filling ability of GGBS. A similarpattern is also observed for split tensile strength.
6. The flexural strength of geopolymer concrete with an increase in the molarity of alkaliactivator.
7. The analysis, among linear, quadratic and cubic models was carried out. The residual analysis on the cubic model showed a better fit to the data as compared to linear and quadratic analysis.
8. As we are using GGBS in place of cement, the liberation of carbon dioxide can be avoided.
9. Also the use of GGBS may be economical and its fineness is productive.

SCOPE FOR FUTURE WORK

Considering the above conclusions in regard to the work presented in this thesis, the authorwould like to suggest the following extensions to this work as future scope.

1. Investigation may carry out to study the influence of GGBS with the different molarityof NaOH.
2. Investigation may carry out to study the influence of GGBS for pre-stressed concrete,fibre reinforced concrete and in precast elements.
3. This study could be extended for members subjected to dynamic loads and impactloads.

REFERENCES

[1] Yaswanth Kuppusamy, Revathy Jayaseelan, Gajalakshmi Pandulu, Veerappan Sathish Kumar, Gunasekaran Murali, Saurav Dixit, and Nikolai Ivanovich Vatin, 2022, Artificial Neural Network with a Cross-Validation Technique to Predict the Material Design of Eco-Friendly Engineered Geopolymer Composites, MDPI, Volume no.15, Article no.3443

[2] Kamal Upreti and Manvendra Verma, 2022, Prediction of Compressive Strength of Geopolymer Concrete using Artificial Neural Network, Journal of Engineering Research and Application, Volume 1, pp. 24-32

[3] Stephen Adeyemi Alabi and Jeffrey Mahachi,2022, Utilizing Artificial Neural Network andMultiple Linear Regression to Model the Compressive Strength of Recycled Geopolymer Concrete, International Journal Of Integrated Engineering VOL. 14 NO.4, pp no.43-56

[4] Yi Xuan Tang, Yeong Huei Lee, Mugahed Amran, Roman Fediuk, Nikolai Vatin, AhmadBeng Hong Kueh and Yee Yong Lee, 2022, Sustainability, Vol no.14, Article 5214.

[5] Hemn Unis Ahmed, Azad Mohammed and Ahmed Salih Mohammed, 2022, "Soft computing models to predict the compressive strength of GGBS/FA- geopolymer concrete"Journal: PLOS ONE. Vol. 17, No.5.

[6] Yong Zou, Chao Zheng, Abdullah Mossa Alzahrani , Waqas Ahmad , Ayaz Ahmad, Abdeliazim Mustafa Mohamed , Rana Khallaf and Samia Elattar, Evaluation of Artificial Intelligence Methods to Estimate the Compressive Strength of Geopolymers, Article 271, pp no.01-23.

[7] Mohsin Ali Khan, Adeel Zafar, Furqan Farooq, Muhammad Faisal Javed, Rayed Alyousef, Hisham Alabduljabbar, and M.Ijaz Khan, May 2021, Geopolymer Concrete Compressive Strength via Artificial Neural Network, Adaptive Neuro Fuzzy Interface System, and GeneExpression Programming With K-Fold Cross Validation, Frontiers in Materials, Volume 8, Article 621163.