

## **Correlation between Compressive Strength and Split Tensile Strength of GGBS and MK Based Geopolymer Concrete using Regression Analysis**

<sup>1</sup>B. Sarath Chandra Kumar, <sup>2</sup>Sadasivan Karuppusamy, <sup>3</sup>K. Ramesh

<sup>1</sup>Associate Professor, Department of Civil Engineering, K L University,  
Guntur, Andhra Pradesh, India.

<sup>2</sup>Assistant Professor, Department of Statistics, Eritrea Institute of Technology,  
Mai Nefhi, Eritrea.

<sup>3</sup>Professor and Head, Department of Civil Engineering, P. V. P. Siddhartha  
Institute of Technology, Kanuru, Vijayawada, Andhra Pradesh, India.

Email: sarath.9b@gmail.com, ksmudt@gmail.com,  
kookutlaramesh@yahoo.co.in

Corresponding Author: B. Sarath Chandra Kumar  
Email: sarath.9b@gmail.com

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### **Abstract**

*In this study, the compressive strength and split tensile strength were performed on totally 264 laboratory made Geopolymer Concrete cubes and 264 laboratory made Geopolymer Concrete cylinders. Regression analysis using R software was carried out. A simple relationship was determined and correlated between compressive strength and split tensile strength. The concrete cubes were prepared with various mix proportions that yield cube crushing strength within the range of 20 to 60 Mpa.*

**Keywords :** Compressive Strength, Split Tensile Strength, GGBS, Metakaoline, Regression Analysis

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### **I. Introduction**

The construction industry forms an important role of the Indian economy. Utilization of the industrial by-products in the construction industry becomes an important route for construction cost reduction and safe disposal of the industrial wastes [IX]. In this regard, direct use of GGBS and flyash with alkali activation to produce geopolymer cements are used to manufacture special concretes for construction [XV], [XIV]. The internal energy which is used for the manufacture geopolymer cements are very less than the Ordinary Portland cement based concrete

(OPCs), which is directly effected on the greenhouse gases [XIV]. In some severe environmental conditions where OPCs are not so durable and the development of new and alternative concrete like geopolymer concrete is in need.

As we know that the production of cement gives more pollution to the environment and in the other hand depletion of natural resources is also happening. In the last 4 decades requirement and production of cement around the globe are increasing due to rapid growth in population. As the demand for electricity increases, the electricity produced from thermal power plants also increases. Simultaneously the waste i. e. Fly ash production increases, which may cause more disposal and environmental problems [XII].

As the constructions increase the utilization of concrete increases in which Ordinary Portland Cement (OPC) is used as a primary binder. As a civil engineer we very much knew about the problems related to environmental issues in the production of cement. The amount of carbon dioxide releases into the atmosphere is equal to the production of cement and also it is well known that the energy required for the production of cement is high which consumes more fossil fuels [XII], [VII]. When the cement is partially replaced in the presence of water and cured at ambient temperature, fly ash reacts with the calcium hydroxide during the hydration process to form the C-S-H gel. The development and application of high volume fly ash in concrete, which enabled the replacement of cement up to 60% by mass of concrete [XII].

The extensive research works carried out for several years to corroborate the potential of geopolymer concrete as a potential construction material [I], [II], [V], [XIII], [XIV], [XV], [XVIII]. The development of alternative concretes like geopolymer concrete is of great relevance to India, where large quantities of industrial wastes are being generated by the industries [I]. The use of geopolymer concrete is slowly increasing, especially for chemical resistant structures in industries and research is going to extend the variety of applications. In fact, a considerable amount of experimental work has been already carried out in Australia, US and Spain. Several investigators have proposed suitable source materials for geopolymer concrete production, their processing, mix design, mechanical properties, and durability aspects [III], [VI], [XIX], [XX].

This paper considers geopolymer concrete cubes and cylinders with different percentages of GGBS and Metakaolin produced by ambient temperature curing. A total of eleven combinations of GGBS and Metakaline mixes was tested for 28 days and 56 days [XVII].

### **Research Significance**

Some methodology adopted for a mathematical model was taken into account for developing the regression analysis to predict 28 days and 56 days compressive and splitting tensile strengths of GPC, which may serve as the useful tools in the civil engineering optimization problems such as optimization of concrete mixtures. In certain applications toughness property is needed. Experimental data were statistically analyzed for developing mathematical models

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considering more influencing factors which are not considered by the earl researchers,  
and also the models were verified for its performance/ suitability [XVI].

### **Statistical Analysis for Strength Prediction**

The strengthening of concrete is a complex process involving many external factors. A number of improved prediction techniques have been proposed by including empirical or computational modeling, statistical techniques. Many attempts have been made for modeling this process through the use of computational techniques such as finite element analysis. While, a number of research efforts have concentrated on using multivariable regression models to improve the accuracy of predictions. Statistical models have the attraction that once fitted they can be used to perform predictions much more quickly than other modeling techniques, and are correspondingly simpler to implement in software. A part of its speed, statistical modeling has the advantage over other techniques that it is mathematically rigorous and can be used to define confidence interval for the predictions. This is especially true when comparing statistical modeling with other models. Statistical analysis can also provide insight into the key factors influencing 28 days compressive strength through regression analysis. For these reasons, statistical analysis was chosen to be a technique for strength prediction of this paper [VIII], [XV].

## **II. Experimental Study**

### **Materials**

The geopolymer concrete was obtained by mixing different combinations of GGBS, Metakaolin, fine aggregates, coarse aggregates and alkaline activator solution (AAS). GGBS (ground granulated blast furnace slag) from JSW Cements conforming to IS 12089 were used. River sand available in Vijayawada was used as fine aggregates. They were tested as per IS 2386. In this investigation, locally available granite crushed stone aggregates of maximum size 10mm and down was used and characterization tests were carried out as per IS 2386. Potable water was used for the OPC and distilled water was used for the geopolymer concretes.

The alkaline activator solution (AAS) used in geopolymer concrete mixes was a combination of sodium silicate solution ( $\text{SiO}_2/\text{Na}_2\text{O}=2.5$ ), sodium hydroxide pellets and distilled water. The role of AAS is to dissolve the reactive portion of source materials Si and Al present in GGBS and Metakaolin provide a highly alkaline liquid medium for condensation polymerization reaction. The sodium hydroxide was taken in the form of flakes of approximately 2.5 mm in size. The sodium hydroxide (NaOH) solution with required concentration was prepared by dissolving the computed amount of sodium hydroxide flakes in distilled water.

The NaOH solution and sodium silicate solution were prepared separately and mixed together at the time of casting. Since a lot of heat is generated when sodium hydroxide flakes react with water, the sodium hydroxide solution was prepared 24 hours before casting. It should be noted here that it is essential to achieve the desired degree of workability of the geopolymer concrete, concrete mix amount of superplasticiser is added in geopolymer concrete. However, excess water can result in

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the formation of pore network, which could be the source of low strength and low durability [XVII].

**Table 1.** Mix proportions of geopolymer concrete

Materials Used	Cementitious Materials	Fine Aggregate	Coarse Aggregate	Sodium Hydroxide	Sodium Silicate	Superplastiser
Quantity of Materials in kg/m <sup>3</sup>	414	660	1136	53	133	8.28

**Table 2.** Combinations of GGBS and Metakaolin

Mix ID	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11
Metkaolin (%)	100	90	80	70	60	50	40	30	20	10	0
GGBS (%)	0	10	20	30	40	50	60	70	80	90	100

### Mix Proportions

Unlike Ordinary Portland cement concretes, geopolymer concretes are a new class of construction materials and therefore no standard mix design approaches are available for geopolymer concretes. While Rangan and Hardjito have presented certain guidelines for fly ash based geopolymer concretes, some of the trials carried out using these procedures indicated that the workability and strength characteristics of such mixes were not satisfactory. Such a thing is possible because geopolymer concrete involves more constituents in its binder (viz., GGBS, Metakaolin, sodium silicate, sodium hydroxide and water), whose interactions and final structure and chemical composition are strongly dependent on the source of the materials and their production process [IV].

Therefore, the chemistry and microstructure of geopolymer concrete is more complex and is still a matter of research, whereas the chemistry of cement and its structure and chemical composition are well established due to extensive research carried out over more than a century. While the strength of cement concrete is known to be well related to its water cement ratio, such a simplistic formulation may not hold good for geopolymer concretes. Therefore, the formulation of the geopolymer concrete mixtures was done by trial and error basis. Numerous trial mixes were cast and tested for compressive strength at the end of 28 days. The primary objective of performing the trial and error procedure was to obtain a range of compressive strength at the end of 28 days. The proportions and composition of GPS and AAS were so decided that the test specimens cast were demoulded after 24 hours of in mould curing and the required strength could be realized. In order to compare the

results of tests conducted using geopolymer concrete, additional conventional concrete mixes, prepared with OPC and designed as per IS 10262 - 2009 The details of the mix proportions are given in Table 1. The combinations of the geopolymer concrete mixes are shown in Table 2.

### **Mix Design of Geopolymer Concrete**

In the design of geopolymer concrete, coarse and fine aggregates together were taken as 75% of entire mixture by mass. This value is similar to that used in OPC concrete in which it will be in the range of 75% to 80% of the entire mixture by mass. Fine aggregate was taken as 30.8% of the total aggregates. From the past literatures, it is clear that the average density of Cementitious materials based geopolymer concrete is similar to that of OPC concrete ( $2400\text{kg/m}^3$ ) [XXI]. Knowing the density of concrete, the combined mass of alkaline liquid and cementitious materials can be arrived. By assuming the ratios of alkaline liquid to cementations materials as 0.45, mass of metakaolin and mass of alkaline liquid was found out. To obtain mass of sodium hydroxide and sodium silicate solutions, the ratio of the sodium silicate solution to the sodium hydroxide solution was fixed as 2.5. Extra water (other than the water used for the preparation of alkaline solutions) used respectively to achieve workable concrete [IX], [XI], [XVII]. Sodium hydroxide of 8 Molar and 10 Molar concentration is used in the present study.

### **Preparation of specimens**

Prior to cast, the inner walls of moulds were coated with lubricating oil to prevent adhesion with the hardening concrete. The concrete was placed in the moulds in three layers of equal thickness and each layer was vibrated until the concrete was thoroughly compacted. Specimens were demoulded after 24 hrs [IV]. The specimens were cured for a period of 28 days and 56 Days in ambient condition. After curing, the test specimens were tested for compressive strength and Split Tensile Strtength.

### **Data Analysis**

Linear nonlinear regression analysis was conducted using R software to study the correlation between compressive strength and split tensile strength.

## **III. Results and Discussions**

### **Compressive Strength Test**

The most common test to find the characteristic properties of geopolymer concrete are compressive strength. The compressive strength test was done on 150 mm X 150 mm X 150 mm cube GPC specimens at 3, 7, 28 and 56 days of curing.



Fig 1. Casted Moulds of GPC



Fig 2. Ambient Curing of GPC

The cube compressive strength results for GPC with GGBS and MK varying between 0% to 100% at 3, 7, 28 and 56 days are presented in Table 3.

**Table- 3:** Compressive Strength of 8 Molar and 10 Molar GPC

Mix ID	8 Molar Compressive Strength (MPa)				10 Molar Compressive Strength (MPa)			
	3 days	7days	28 days	56 Days	3 days	7days	28 days	56 days
M1	6.01	8.68	13.17	15.16	17.1	17.86	19.645	20.56
M2	9.46	12.83	16.36	18.24	21.07	22.16	24.065	25.84
M3	12.03	15.08	20.32	22.86	22.455	23.47	25.14	26.65
M4	14.77	20.56	24.13	26.84	25.65	26.955	28.355	30.02
M5	19.17	22.02	26.01	28.72	26.81	27.32	30.515	31.56
M6	19.76	28.27	29.67	31.54	31.23	34.12	35.23	37.24
M7	24.96	30.98	33.84	33.26	33.67	35.61	38.34	40.01
M8	30.51	33.06	38.50	40.85	41.23	43.75	47.35	51.56
M9	31.68	37.55	40.22	42.46	43.65	45.07	49.94	53.04
M10	33.75	38.42	42.68	44.84	50.32	52.32	55.5	59.65
M11	40.50	45.31	48.04	51.65	52.12	53.8	60.03	63.54

### Split Tensile Strength Test

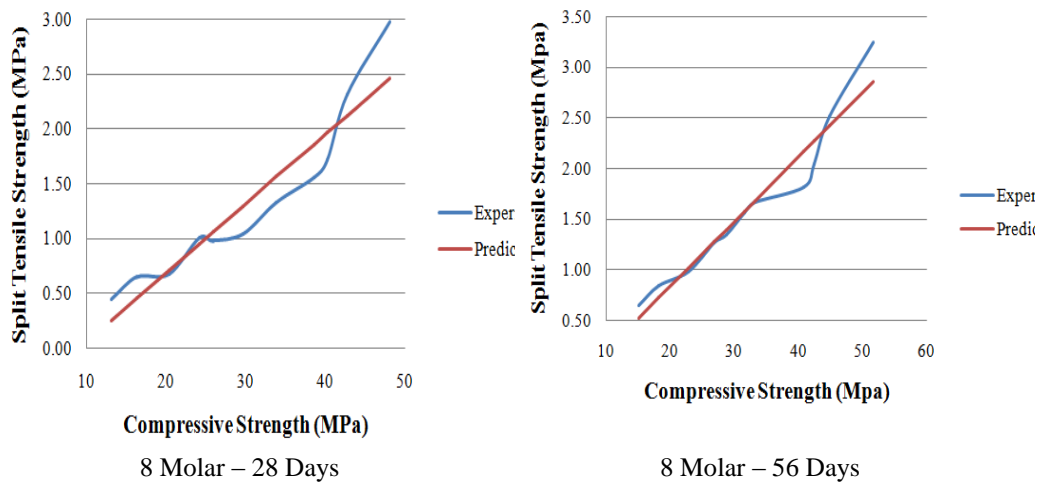
The split tensile strength test is an indirect test used to find the tensile strength of cylindrical specimens. Tensile strength tests were done on 300 mm long and 150 mm diameter cylinder concrete specimens at 3, 7, 28 and 56 days of curing as per the procedure specified in IS: 5816 - 1999. Figure 5.16 shows the experimental setup for tensile strength. Cylinder specimens were tested on 2000 kN CTM and the maximum load applied to the specimen were then recorded. For every batch average

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of the three values are taken for getting accurate results. The split tensile strength results for GPC with GGBS and MK varying between 0% to 100% at 3, 7, 28 and 56 days are presented in Table 4.

**Table- 4:**Split Tensile Strength 8 Molar and 10 Molar GPC

Mix ID	8 Molar Split Tensile Strength (MPa)				10 Molar Split Tensile Strength (MPa)			
	3 days	7days	28 days	56 Days	3 days	7days	28 days	56 Days
M1	0.31	0.33	0.44	0.65	0.43	0.45	0.60	0.65
M2	0.41	0.59	0.65	0.84	0.56	0.79	0.88	0.96
M3	0.62	0.63	0.68	0.98	0.75	0.82	0.87	0.98
M4	0.73	0.93	1.01	1.26	0.80	0.90	1.00	1.09
M5	0.69	0.75	0.98	1.34	0.82	0.84	0.86	1.01
M6	0.78	0.94	1.04	1.56	0.98	1.29	1.41	1.54
M7	1.12	1.28	1.33	1.66	1.60	1.71	1.77	1.86
M8	1.01	1.48	1.55	1.81	1.47	1.65	1.71	1.94
M9	1.33	1.66	1.71	2.04	1.52	1.56	1.61	1.75
M10	1.56	2.07	2.31	2.51	1.86	2.46	2.71	2.96
M11	2.15	2.65	2.97	3.24	3.00	3.31	3.43	4.54

From the Table 3 and Table 4, it is found that the split tensile strength of GPC with GGBS is more when tested at 28 days and 56 days. But due to presence of MK with GGBS in the geopolymer concrete there is a gradual decrease in split tensile strength. It is also observed that the strength of the concrete increases with the increase in the concentration of NaOH. The relationship between cube compressive strength and split tensile was found out using regression analysis and is shown in Figure 3 to Figure 5



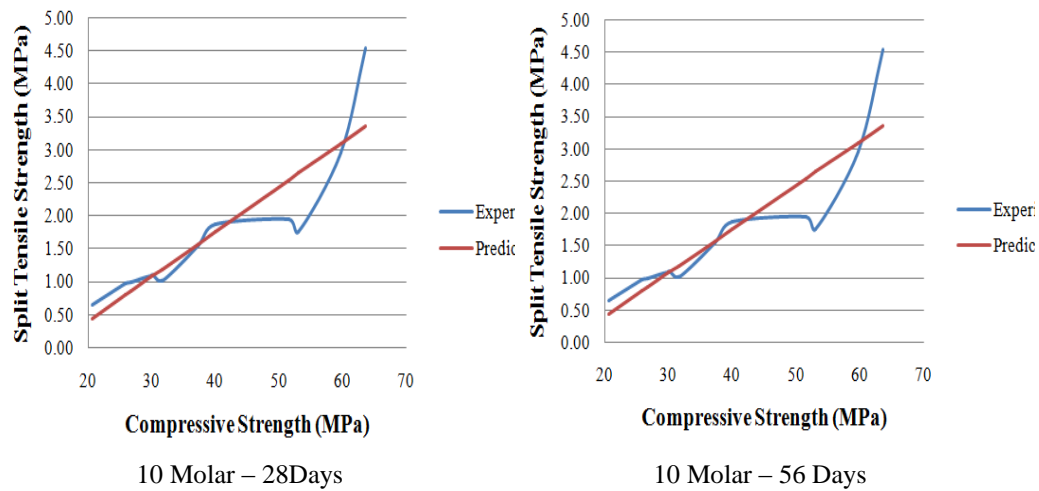


Fig 3. Relationship between Cube Compressive Strength and Split Tensile Strength 8 Molar and 10 Molar GPC for Linear Regression Analysis – 28 Days and 56 Days

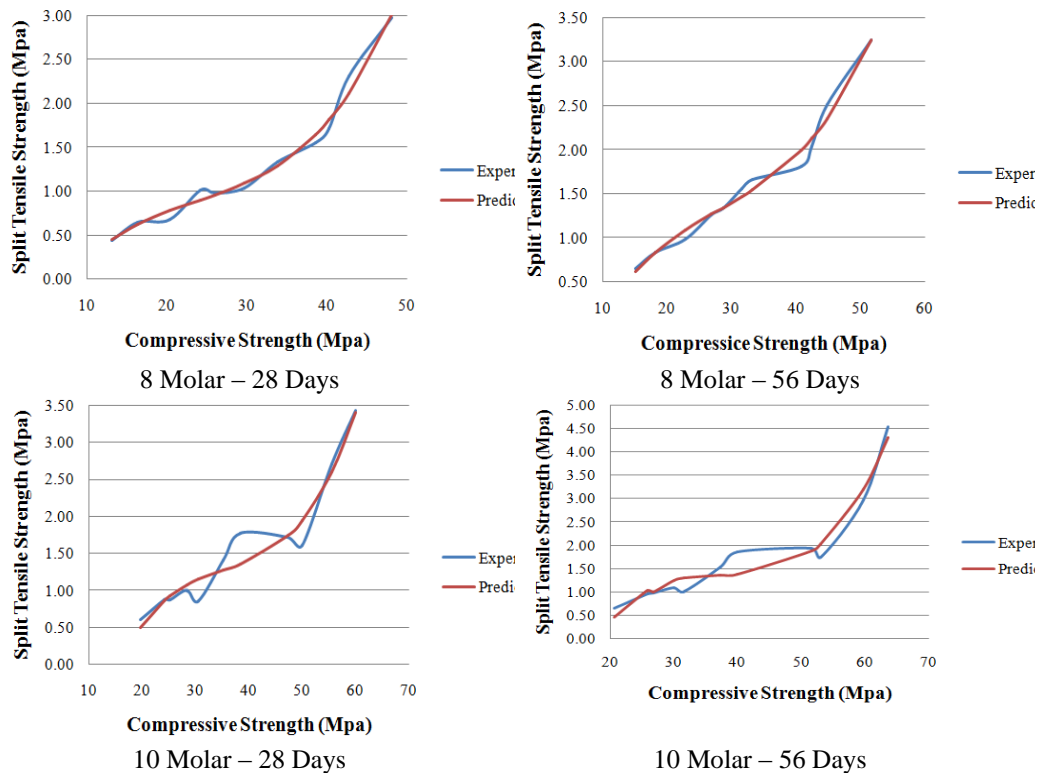


Fig 4. Relationship between Cube Compressive Strength and Split Tensile Strength 8 Molar and 10 Molar GPC for Quadratic Regression Analysis – 28 Days and 56 Days



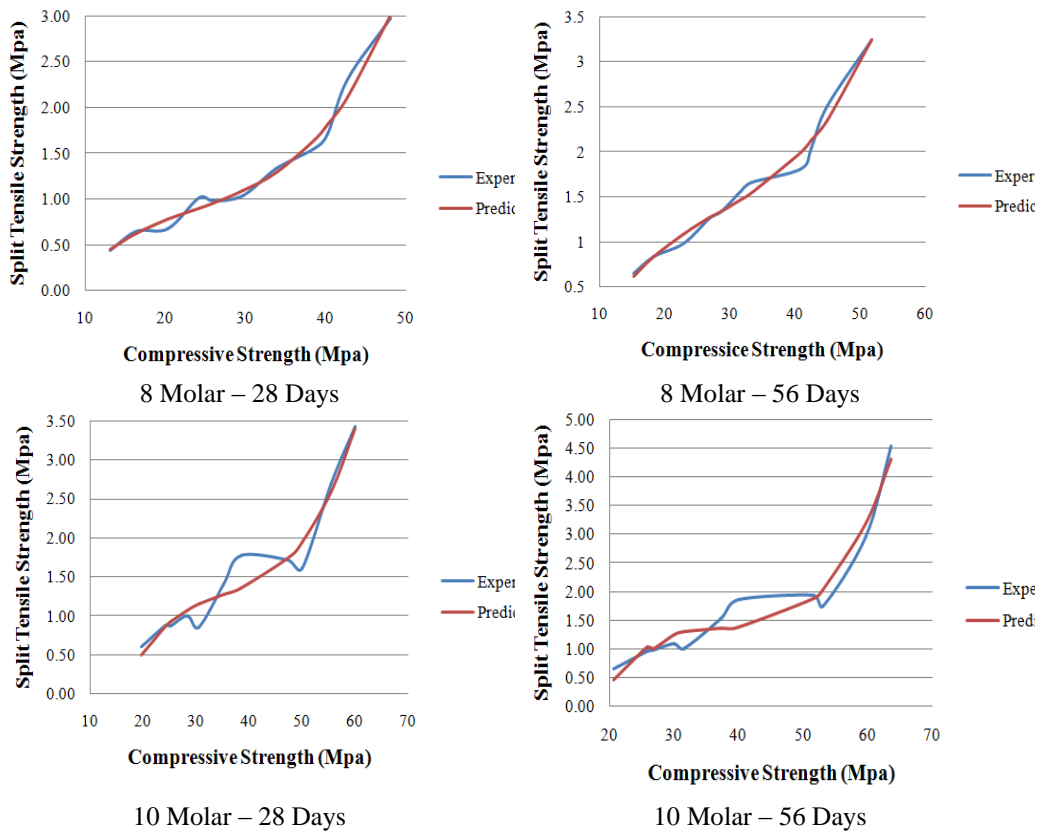


Fig 5. Relationship between Cube Compressive Strength and Split Tensile Strength 8 Molar and 10 Molar GPC for Cubic Regression Analysis – 28 Days and 56 Days

#### IV. Relationship between Cube Compressive Strength and Split Tensile Strength

The relationship between split tensile strength and compressive strength was obtained for 8M and 10M are as follows

##### 8 Molar

##### Linear Regression Analysis

$$f_t = -0.5827 + 0.0633 (f_{ck}) \quad (28^{\text{th}} \text{ day}) \quad (1)$$

$$f_t = -0.4423 + 0.0638 (f_{ck}) \quad (56^{\text{th}} \text{ day}) \quad (2)$$

### Quadratic Regression Analysis

$$f_t = 0.9724 - 0.0543 (f_{ck}) + 0.0019 (f_{ck})^2 \quad (28^{\text{th}} \text{ day}) \quad (3)$$

$$f_t = 0.6084 - 0.00078 (f_{ck}) + 0.0011 (f_{ck})^2 \quad (56^{\text{th}} \text{ day}) \quad (4)$$

### Cubic Regression Analysis

$$f_t = -1.194 + 0.2011 (f_{ck}) - 0.007123 (f_{ck})^2 + 0.000099 (f_{ck})^3 \quad (28^{\text{th}} \text{ day}) \quad (5)$$

$$f_t = -1.513 + 0.2187 (f_{ck}) - 0.0063 (f_{ck})^2 + 0.00007 (f_{ck})^3 \quad (56^{\text{th}} \text{ day}) \quad (6)$$

Where

$f_{ck}$  = Compressive strength in MPa

$f_t$  = Split tensile strength in MPa

From the above result, it is observed that for 8 Molar 28 days cured GPC the linear regression analysis performed adequately well, explaining 89% (R-Square= 0.8866) of the variation in the split tensile strength of the concrete in terms of cube compressive strength. The analysis is statistically significant at 0.0001 level (p-value=0.00002) and the variable compressive strength is also significant in the analysis at 0.0001 level (p-value=0.00002).

The quadratic regression analysis is also statistically significant at 0.0001 level (p-value=0.0000), explaining 96% (R-Square=0.9646) of variation in the split tensile strength of the concrete in terms of cube compressive strength. In this analysis, both the variables compressive strength and square of compressive strength are statistically significant at 0.10 levels allowing us to make reasonable results. Overall, this analysis shows satisfactory results since in most of the mixes the predicted values are closer to observed values as compared to linear regression analysis in predicting the split tensile strength in terms of cube compressive strength.

The cubic regression analysis also performed well in predicting the split tensile strength of the concrete in terms of cube compressive strength. This analysis is statistically significant at 0.0000 level (p-value=0.0000) explaining 98% (R-Square=0.9851) of variation in split tensile strength in the concrete in terms of cube compressive strength. The analysis predicts values reasonably well for all mixes unlike the other two analysis. The values indicate that the predicted values for split tensile strength is very close to observed values as compared to other two analysis.

From the above result, it is observed that for 8 Molar 56 days cured GPC the linear regression analysis performed adequately well, explaining 93% (R-Square= 0.9364) of the variation in the split tensile strength of the concrete in terms of cube compressive strength. The analysis is statistically significant at 0.0000 level (p-value=0.0000) and the variable cube compressive strength is also significant in the model at 0.0001 level (p-value=0.0000).

The quadratic regression analysis is also statistically significant at 0.0001 level (p-value=0.0000), explaining 96% (R-Square=0.9671) of variation in the split tensile strength of the concrete in terms of cube compressive strength. In this analysis, the variable cube compressive strength is not statistically significant while the square of compressive strength is statistically significant at 0.05 level (p-value = 0.0258) in the analysis. Overall, this analysis shows satisfactory results since in most of the mixes the predicted values are closer to observed values as compared to linear regression analysis in predicting the split tensile strength in terms of cube compressive strength.

The cubic regression analysis also performed well in predicting the split tensile strength of the concrete cube in terms of compressive strength. This analysis is statistically significant at 0.0000 level (p-value=0.0000) explaining 98% (R-Square=0.9821) of variation in split tensile strength in the concrete in terms of cube compressive strength and the variables in the model are significant at 0.10 level. The analysis predicts values reasonably well like quadratic analysis and provides us with better results as compared to other.

## **10 Molar**

### **Linear Regression Analysis**

$$f_t = -0.6884 + 0.0589 (f_{ck}) \quad (28^{\text{th}} \text{ day}) \quad (7)$$

$$f_t = -0.9605 + 0.0679 (f_{ck}) \quad (56^{\text{th}} \text{ day}) \quad (8)$$

### **Quadratic Regression Analysis**

$$f_t = 1.1666 - 0.0457 (f_{ck}) + 0.0013 (f_{ck})^2 \quad (28^{\text{th}} \text{ day}) \quad (9)$$

$$f_t = 2.210 - 0.1010 (f_{ck}) + 0.0019 (f_{ck})^2 \quad (56^{\text{th}} \text{ day}) \quad (10)$$

### **Cubic Regression Analysis**

$$f_t = -4.151 + 0.4133 (f_{ck}) - 0.0110 (f_{ck})^2 + 0.0001 (f_{ck})^3 \quad (28^{\text{th}} \text{ day}) \quad (11)$$

$$f_t = -7.575 + 0.701 (f_{ck}) - 0.018 (f_{ck})^2 + 0.0002 (f_{ck})^3 \quad (56^{\text{th}} \text{ day}) \quad (12)$$

Where

$f_{ck}$  = Compressive strength in MPa

$f_t$  = Split tensile strength in MPa

From the above result, it is observed that for 10 Molar 28 days cured GPC the linear regression analysis performed adequately well, explaining 85% (R-Square= 0.8586) of the variation in the split tensile strength of the concrete in terms of cube compressive strength. The analysis is statistically significant at 0.0001 level (p-value=0.00004) and the variable cube compressive strength is also significant in the analysis at 0.0001 level (p-value=0.00004). The prediction using this analysis is reasonably well in all the mixes.

The quadratic regression analysis is also statistically significant at 0.0001 level (p-value=0.00008), explaining 90% (R-Square=0.9048) of variation in the split tensile strength of the concrete in terms of cube compressive strength. As compared to other

two analysis, the cubic regression analysis performed well in predicting the split tensile strength of the concrete in terms of cube compressive strength. This analysis is statistically significant at 0.0001 level (p-value=0.00009) explaining 94% (R-Square=0.9442) of variation in split tensile strength in the concrete in terms of cube compressive strength.

From the above result, it is observed that for 10 Molar 56 days cured GPC the linear regression analysis performed adequately well, explaining 79% (R-Square= 0.7874) of the variation in the split tensile strength of the concrete in terms of cube compressive strength. The analysis is statistically significant at 0.001 level (p-value=0.0003) and the variable cube compressive strength is also significant in the analysis at 0.001 level (p-value=0.0003).

The quadratic regression analysis is also statistically significant at 0.001 level (p-value=0.0003), explaining 86% (R-Square=0.8662) of variation in the split tensile strength of the concrete in terms of cube compressive strength.

As compared to other two models, the cubic regression analysis performed well in predicting the split tensile strength of the concrete in terms of cube compressive strength. This analysis is statistically significant at 0.0001 level (p-value=0.00006) explaining 95% (R-Square=0.9513) of variation in split tensile strength in the concrete in terms of cube compressive strength. The analysis predicts values reasonably well for mixes in the higher end and the lower end.

Finally, to decide on a analysis among linear, quadratic and cubic models we have carried out the residual analysis of the models. The residual analysis on the cubic model for 10 molar 28 days showed a better fit to the data as compared to linear and quadratic analysis.

**Table- 5:** Predicted values of 8 Molar 28 Days cured GPC for Split Tensile strength

Mix ID	Compressive Strength (MPa)	Split Tensile Strength (MPa)	Predicted Values for Split Tensile Strength		
			Linear Regression	Quadratic Regression	Cubic Regression
M1	13.17	0.44	0.2511	0.5938	0.4446
M2	16.36	0.65	0.4531	0.6033	0.6221
M3	20.32	0.68	0.7032	0.6698	0.7803
M4	24.13	1.01	0.9443	0.7913	0.9004
M5	26.01	0.98	1.0636	0.8722	0.9583
M6	29.67	1.04	1.2951	1.0685	1.0866
M7	33.84	1.33	1.5592	1.3558	1.2903
M8	38.50	1.55	1.8544	1.7568	1.6413
M9	40.22	1.71	1.9633	1.9259	1.8151
M10	42.68	2.31	2.1187	2.1874	2.1138
M11	48.04	2.97	2.4580	2.8392	3.0113

**Table- 6:** Predicted values of 8 Molar 56 Days cured GPC for Split Tensile strength

Mix ID	Compressive Strength (MPa)	Split Tensile Strength (MPa)	Predicted Values for Split Tensile Strength		
			Linear Regression	Quadratic Regression	Cubic Regression
M1	15.16	0.65	0.5256	0.7395	0.6186
M2	18.24	0.84	0.7222	0.8271	0.8378
M3	22.86	0.98	1.0172	0.9971	1.0917
M4	26.84	1.26	1.2713	1.1807	1.2678
M5	28.72	1.34	1.3913	1.2794	1.3458
M6	31.54	1.56	1.5713	1.4418	1.4652
M7	33.26	1.66	1.6811	1.5493	1.5430
M8	40.85	1.81	2.1657	2.1006	1.9962
M9	42.46	2.04	2.2685	2.2336	2.1273
M10	44.84	2.51	2.4205	2.4405	2.3516
M11	51.65	3.24	2.8552	3.1005	3.2449

**Table- 7:** Predicted values of 10 Molar 28 Days cured GPC for Split Tensile strength

Mix ID	Compressive Strength (MPa)	Split Tensile Strength (MPa)	Predicted Values for Split Tensile Strength		
			Linear Regression	Quadratic Regression	Cubic Regression
M1	19.65	0.60	0.4694	0.7750	0.5047
M2	24.07	0.88	0.7300	0.8267	0.8633
M3	25.14	0.87	0.7933	0.8470	0.9276
M4	28.36	1.00	0.9828	0.9259	1.0790
M5	30.52	0.86	1.1101	0.9942	1.1540
M6	35.23	1.41	1.3880	1.1858	1.2770
M7	38.34	1.77	1.5713	1.3442	1.3526
M8	47.35	1.71	2.1024	1.9465	1.7380
M9	49.94	1.61	2.2550	2.1591	1.9403
M10	55.50	2.71	2.5828	2.6751	2.5930
M11	60.03	3.43	2.8498	3.1555	3.4054

**Table- 8:** Predicted values of 10 Molar 56 Days cured GPC for Split Tensile strength

Mix ID	Compressive Strength (MPa)	Split Tensile Strength (MPa)	Predicted Values for Split Tensile Strength		
			Linear Regression	Quadratic Regression	Cubic Regression
M1	20.56	0.65	0.4352	0.9761	0.4550
M2	25.84	0.96	0.7936	0.9312	1.0320
M3	26.65	0.98	0.8486	0.9342	1.0082
M4	30.02	1.09	1.0773	0.9745	1.2519
M5	31.56	1.01	1.1818	1.0080	1.2960
M6	37.24	1.54	1.5674	1.2134	1.3630
M7	40.01	1.86	1.7554	1.3602	1.3792
M8	51.56	1.94	2.5394	2.3020	1.8702
M9	53.04	1.75	2.6399	2.4611	2.0322
M10	59.65	2.96	3.0886	3.2784	3.2017
M11	63.54	4.54	3.3527	3.8408	4.3105

## V. Conclusion

The correlation among the compressive strength and split tensile strength values obtained on laboratory made geopolymer concrete has been established. The following principal conclusions have been drawn:

- I. There is a significant improvement in the compressive strength of geopolymer concrete GGBS replaced with MK beyond 28 days and 56 days for 8 Molar and 10 Molar because of the void filling ability of MK and GGBS. A similar pattern is also observed for split tensile strength.
- II. There is a significant improvement in the compressive strength, split tensile strength and flexural strength of geopolymer concrete with an increase in the molarity of alkali activator.
- III. 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.

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