An Experimental Investigation on Rheology and Strength Properties of Self Compacting Geo-Polymer Concrete by using EXCEL, MATLAB and PYTHON

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Abstract - *Concrete is the second most-consumed material in the world after water. As the demand for concrete as a construction material increases, so the demand for Portland cement also increases proportionally. On the other hand, the climate change due to global warming, environmental protection had become a major concern. This is because of the emission of greenhouse gases like CO_2 by human activities. Of all the greenhouse gases, CO_2 contributes about 65% of global warming. The Cement industry is also responsible for the emission of CO_2 into the atmosphere due to the high production of tones of Portland cement which in turn releases tones of CO_2. The environment must be protected by preventing the dumping of waste products in an uncontrolled manner. Several efforts are made to overcome this issue. So, some of these include the utilization of supplementary cementing materials like fly ash, silica fume, granulated blast furnace slag, rice husk ash, grass hay, and meta-kaolin, and also the alternative binders to Portland cement. In this manner, the consumption of Self-compacting Geopolymer concrete may reduce some effects on the environment in the cement industry. In terms of global warming, the technology of Self-compacting Geopolymer concrete could significantly reduce the emission of CO_2 into the atmosphere. This report presents the analysis and experimental results of properties of Self-compacting Geopolymer concrete for grade 40 using Excel, MATLAB, and Python Script.*

***Key Words*: Self-compacting Geopolymer Concrete, Fly-ash, Quartz powder, Excel, MATLAB, Python**

1.INTRODUCTION

The term 'Geo-Polymer' was coined by Davidovits in 1978. It describes a family of mineral binders with same chemical composition to zeolites but differ in amorphous microstructure. Source materials and alkaline liquids are the two main constituents of Geo-polymer concrete. The source material should be rich in Silicon and Aluminum. In this Geo-polymer concrete, the source material used is fly-ash. The process of polymerization is the chemical reaction that takes place in this case. Unlike Ordinary Portland Pozzolanic cements, Geo-polymer concrete do not form Calcium-silicate hydrates for matrix formation and strength, but utilize the poly-condensation reaction of silica and alumina. The Geo-Polymer paste binds the coarse aggregates, fine aggregates and other unreacted materials together to form the Geo-polymer concrete. The manufacture of Self compacting Geo-polymer concrete is carried out by using concrete technology procedures. Aggregates occupy the largest volume in Self compacting Geo-polymer concrete about 75-80% same as in the Portland cement. The silicon and alumina in the fly ash are activated by sodium hydroxide and sodium silicate solutions to form Geo-Polymer paste in the process of binding.

2. MATERIALS USED

In the preparation of Self-Compacting Geo-polymer concrete, the materials used are Fly ash, Quartz powder, Sodium Hydroxide (NaOH), Sodium Silicate (Na_2SO_3) and potassium silicate. In addition to these, Hooked end steel fibers and Cem-fil anti-crack alkaline resistant glass fibers are added to provide resistance to cracking, to enhance strength and durability properties of concrete, to resist plastic shrinkage cracks and to resist acid attack.

Fig 1: Hooked end steel fibers

Fig 2: Cem-fil anti-crack alkaline resistant glass fibers

3. MIX-PROPORTIONS OF SELF-COMPACTING GEOPOLYMER CONCRETE

Table 1: Mix proportions of Self compacting Geo-polymer concrete

Mix	Fly ash	Quartz Powder	Quartz sand (kg/m^3)	Coarse aggregate	Sodium silicate solution	Sodium hydroxide solution	SP %of powder content	Extra water	Fibers % of fiber content	
	(kg/m^3)	(Kg/m^3)		(kg/m^3)	(kg/m^3)	(kg/m^3)			Steel	Glass
SCGPC 1	500	0	925	805	125	50	2	12%	-	-
SCGPC 2	450	50	925	805	125	50	2	12%	2	-
SCGPC 3	400	100	925	805	125	50	2	12%	1.75	0.25
SCGPC 4	350	150	925	805	125	50	2	12%	1.50	0.5
SCGPC 5	300	200	925	805	125	50	2	12%	1.25	0.75
SCGPC 6	250	250	925	805	125	50	2	12%	1.00	1.00
SCGPC 7	200	300	925	805	125	50	2	12%	0.75	1.25

4. FRESH PROPERTIES

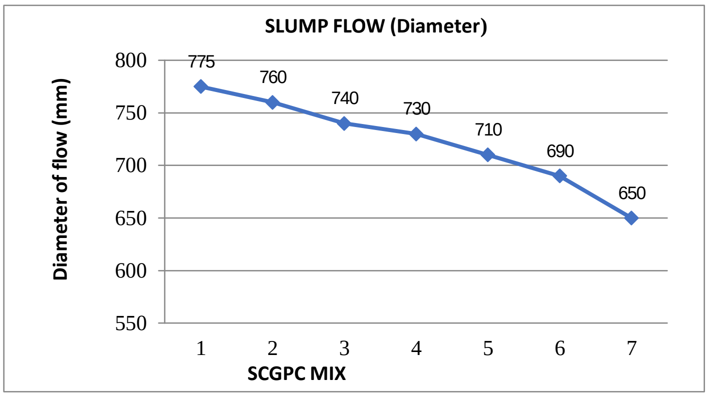

Chart 1: Deviation of slump flow for SCGPC

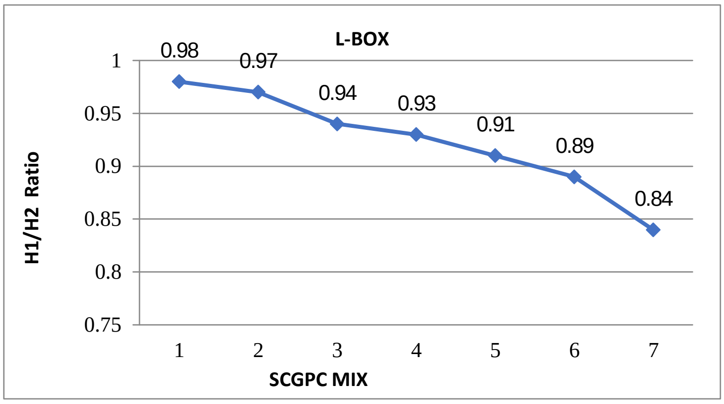

Chart 2: Deviation of L-Box for SCGPC

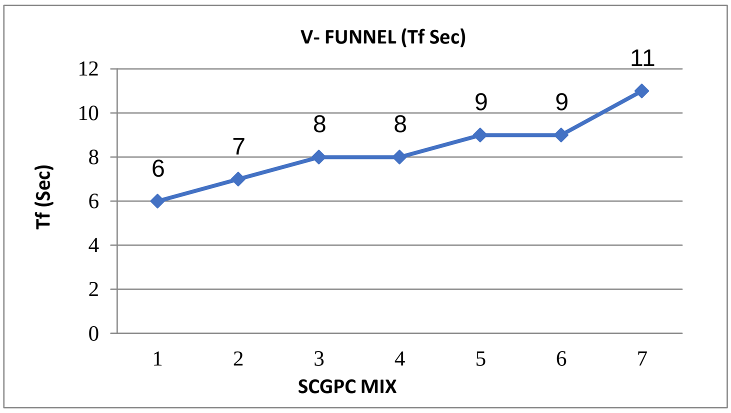

Chart 3: Deviation of V-Funnel T_f minutes for SCGPC

5. HARDENED PROPERTIES

The hardened properties such as compressive strength, flexural strength and split-tensile strength are determined. The results of the compressive strength on 150mm cube specimens at the age of 7 days and 28 days are mentioned in Table 3.

5.1 Compressive Strength

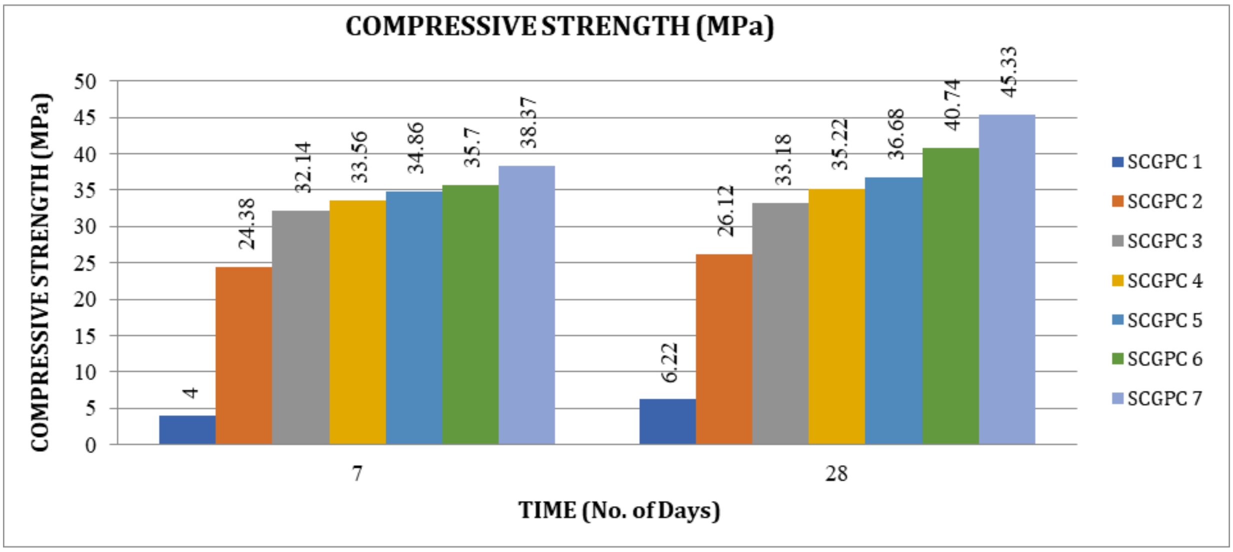

Chart 4: Compressive strength of SCGPC mixes

5.2 Split Tensile Strength

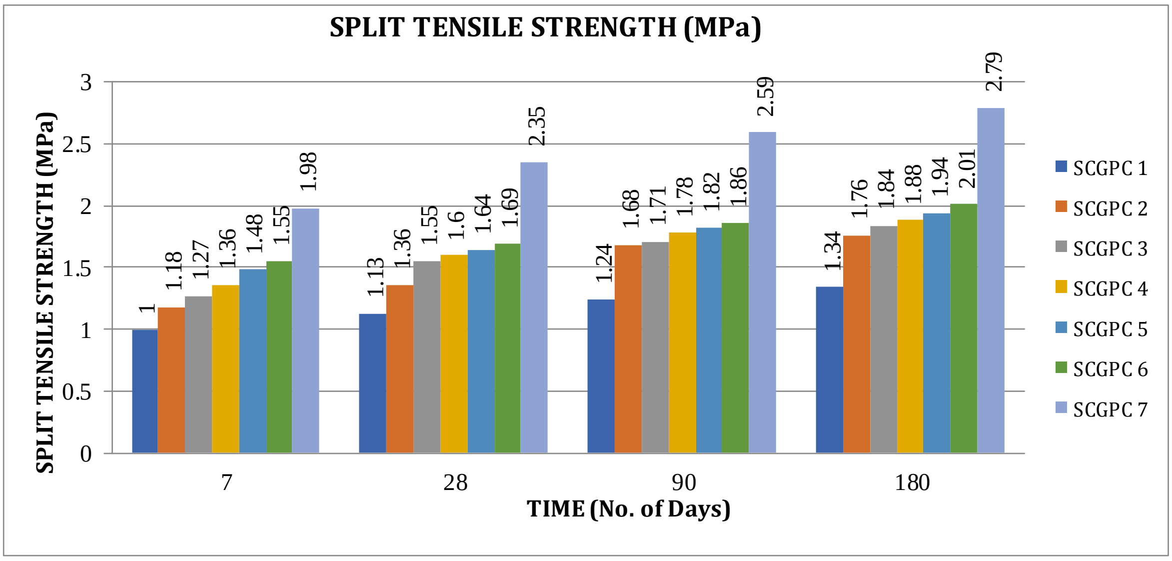

Chart 5: The split tensile strength for SCGPC mixes.

5.3 Flexural strength

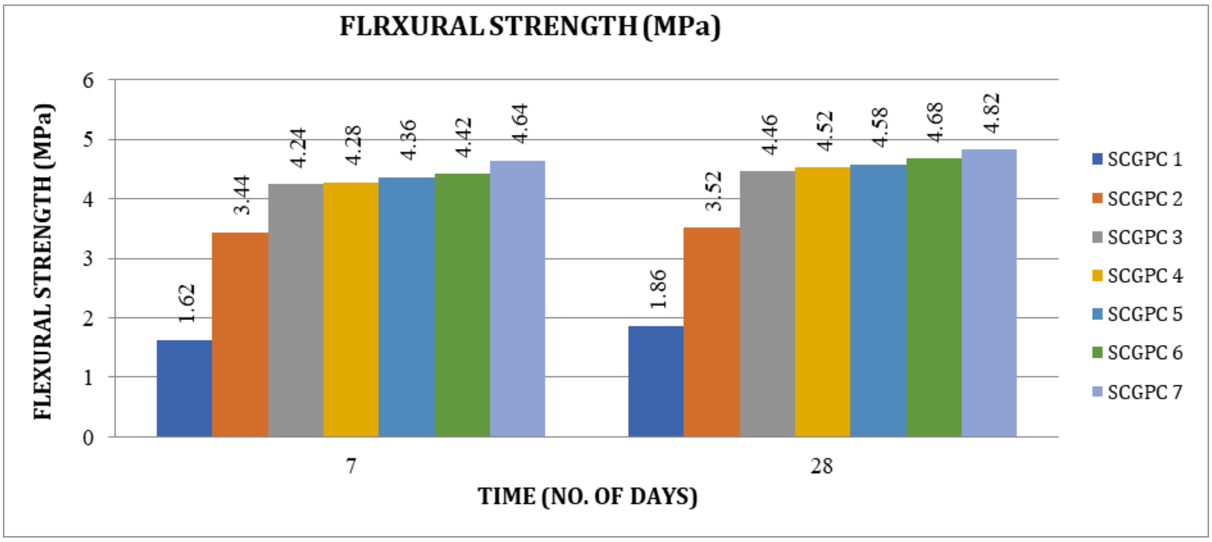

Chart 6: Flexural strength of GPC mixes

6. TEST RESULTS

6.1 Input Values for Linear Regression Analysis

Table 2: Input values of Compressive strength and Split Tensile strength for linear regression analysis

X (SPLIT TENSILE STRENGTH) IN MPa	Y (COMPRESSIVE STRENGTH) IN MPa
1.00	4.00
1.18	24.38
1.27	32.14
1.36	33.56
1.48	34.86
1.55	35.70
1.98	38.37
1.13	6.22
1.36	26.12
1.55	33.18
1.60	35.22

1.64	36.68
1.69	40.74
2.35	45.33
1.24	6.84
1.68	28.76
1.71	36.49
1.78	38.67
1.82	41.84
1.86	44.81
2.59	49.86
1.34	7.38
1.76	32.16
1.84	39.40
1.88	43.32
1.94	46.84
2.01	48.39
2.79	53.84

Table 3: Input values of Compressive strength and Flexural strength for linear regression analysis

X (FLEXURAL STRENGTH) IN MPa	Y (COMPRESSIVE STRENGTH) IN MPa
1.62	4.00
3.44	24.38
4.24	32.14
4.28	33.56
4.36	34.86

4.42	35.70
4.64	38.37
1.86	6.22
3.52	26.12
4.46	33.18
4.52	35.22
4.58	36.68
4.68	40.74
4.82	45.33
1.98	6.84
3.78	28.76
4.84	36.49
4.90	38.67
4.96	41.84
5.06	44.81
5.28	49.86
2.14	7.38
4.16	32.16
5.23	39.40
5.36	43.32
5.42	46.84
5.46	48.39
5.70	53.84

7. REGRESSION ANALYSIS

Regression analysis is considered as a statistical method that helps to analyze the relationship between two or more variables. There are several regression analysis methods and at their core, all examine the effect of one or more independent variables on a dependent variable.

7.1 Regression Analysis Using EXCEL

7.1.1 Compressive Strength from Split Tensile Strength

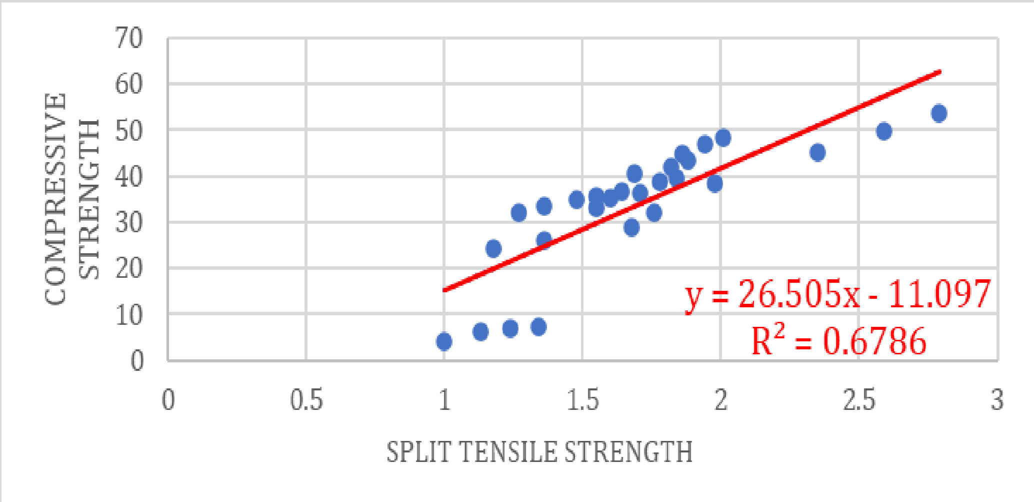

Chart 7: Split Tensile Strength vs Compressive Strength

Table 4: Actual and Predicted Compressive strength from Split Tensile strengths

ACTUAL COMPRESSIVE STRENGTH IN MPa	PREDICTED COMPRESSIVE STRENGTH IN MPa
4.00	15.41
24.38	20.18
32.14	22.56
33.56	24.95
34.86	28.13
35.70	29.99
38.37	41.38
6.22	18.85
26.12	24.95
33.18	29.99
35.22	31.31
36.68	32.37

40.74	33.70
45.33	51.19
6.84	21.77
28.76	33.43
36.49	34.23
38.67	36.08
41.84	37.14
44.81	38.20
49.86	57.55
7.38	24.42
32.16	35.55
39.40	37.67
43.32	38.73
46.84	40.32
48.39	42.18
53.84	62.85

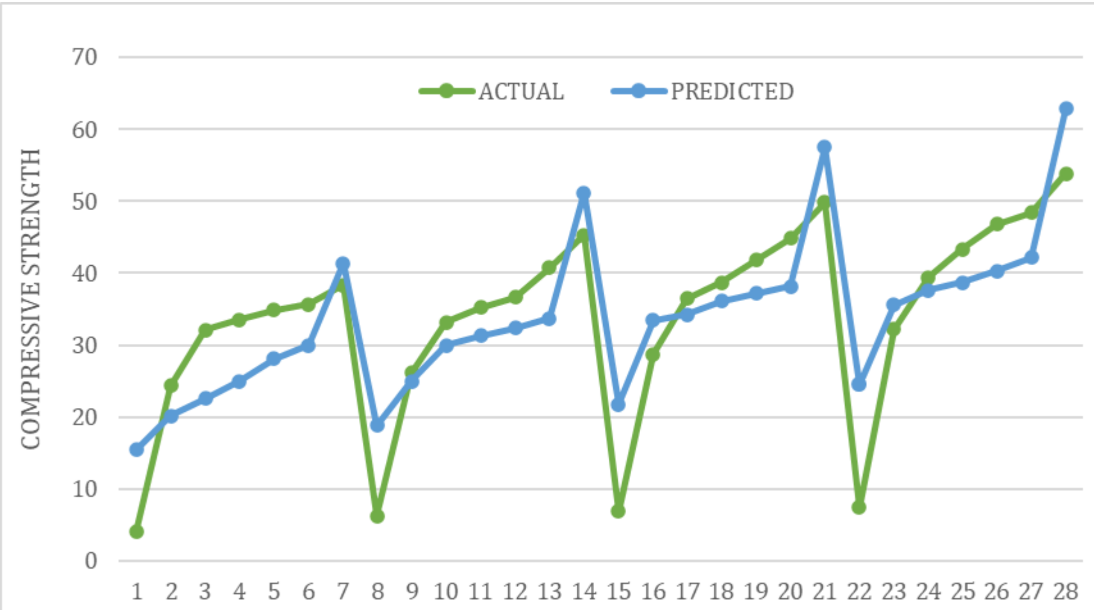

Chart 8: Actual vs Predicted Compressive strengths from Split Tensile strengths

7.1.2 Compressive Strength from Flexural Strength

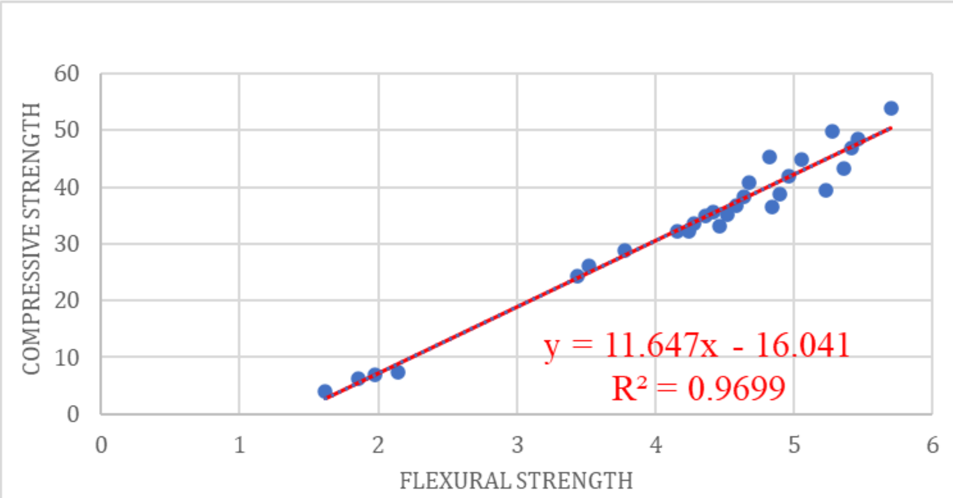

Chart 9: Flexure Strength vs Compressive Strength

Table 5: Actual and Predicted Compressive Strengths from Flexural Strengths

ACTUAL COMPRESSIVE STRENGTH IN MPa	PREDICTED COMPRESSIVE STRENGTH IN MPa
4.00	2.83
24.38	24.02
32.14	33.34
33.56	33.81
34.86	34.74
35.70	35.44
38.37	38.00
6.22	5.62
26.12	24.96
33.18	35.90
35.22	36.60
36.68	37.30

40.74	38.47
45.33	40.10
6.84	7.02
28.76	27.98
36.49	40.33
38.67	41.03
41.84	41.73
44.81	42.89
49.86	45.46
7.38	8.88
32.16	32.41
39.40	44.87
43.32	46.39
46.84	47.09
48.39	47.55
53.84	50.35

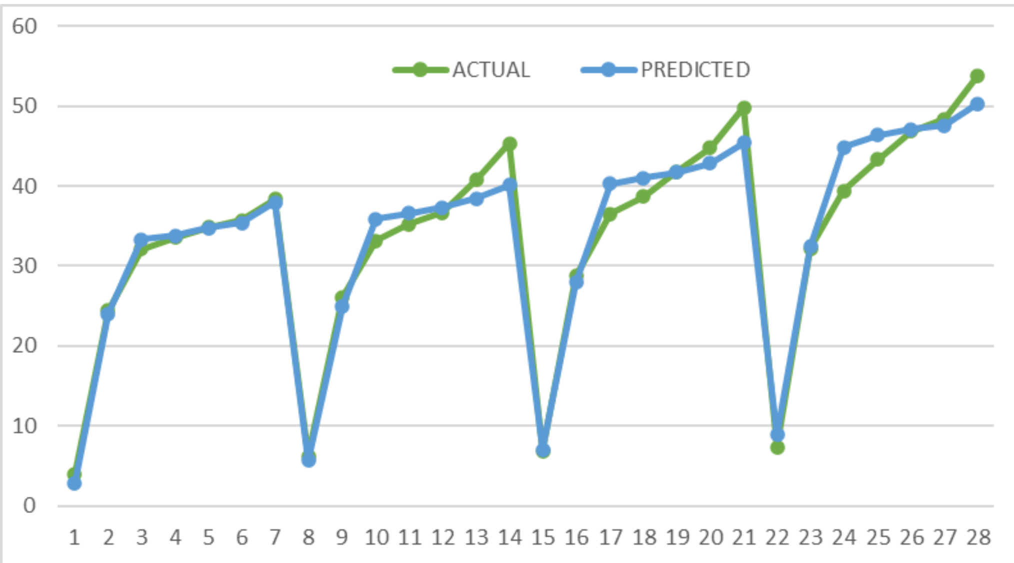

Chart 10: Actual vs Predicted Compressive Strengths using Flexural Strengths

7.2 Regression Analysis Using MATLAB

7.2.1 Compressive Strength from Split Tensile Strength

The regression equation to predict the Compressive Strength from Split Tensile Strength is:

Compressive strength = -11.10 + 26.51 (Split Tensile Strength)

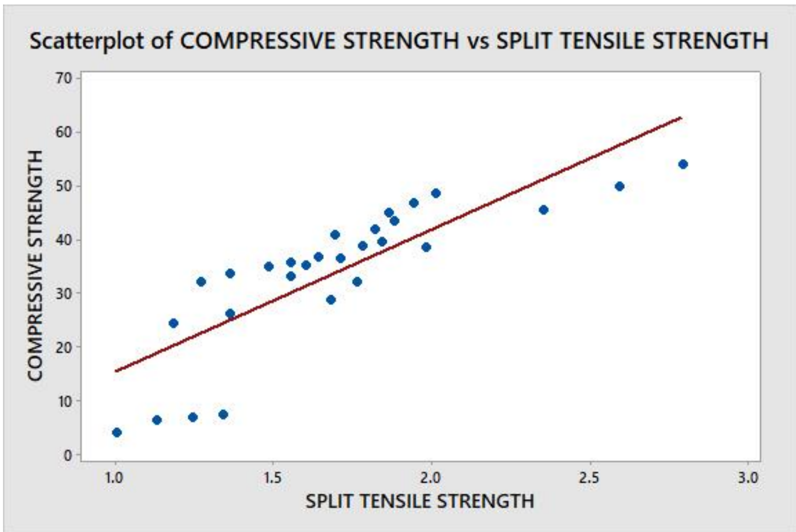

Chart 11: Split Tensile Strength vs Compressive Strength

7.2.2 Compressive Strength from Flexural Strength:

The regression equation to predict the Compressive Strength from Flexural Strength is:

Compressive strength = -16.04 + 11.647 (Flexural Strength)

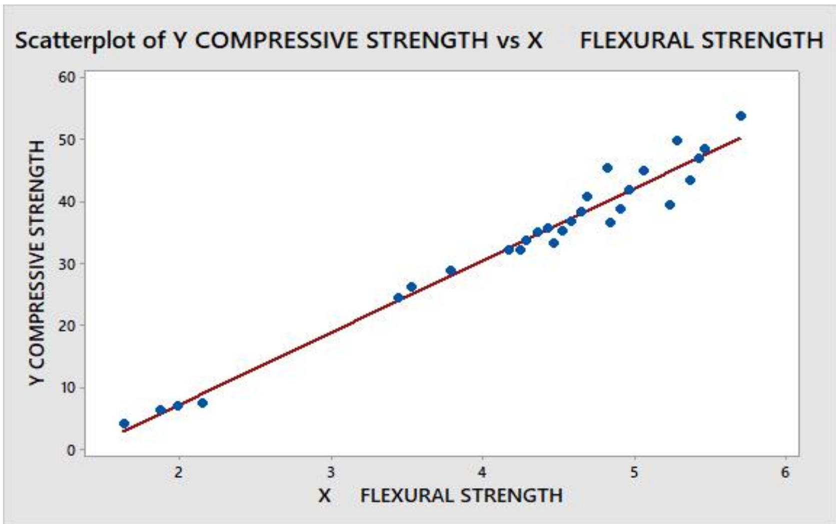

Chart 12: Flexural Strength vs Compressive Strength

7.3 Regression Analysis Using PYTHON:

7.3.1 Compressive Strength from Split Tensile Strength

Table 6: Actual and Predicted Compressive Strengths from Split Tensile Strengths

ACTUAL COMPRESSIVE STRENGTH IN MPa	PREDICTED COMPRESSIVE STRENGTH IN MPa
4.00	15.40
24.38	20.17
32.14	22.56
33.56	24.94
34.86	28.13
35.70	29.98
38.37	41.38
6.22	18.85
26.12	24.95
33.18	29.98
35.22	31.31
36.68	32.37
40.74	33.69
45.33	51.19
6.84	21.76
28.76	33.43
36.49	34.22
38.67	36.08
41.84	37.14
44.81	38.20
49.86	57.55

7.38	24.42
32.16	35.55
39.40	37.67
43.32	38.73
46.84	40.32
48.39	42.17
53.84	62.85

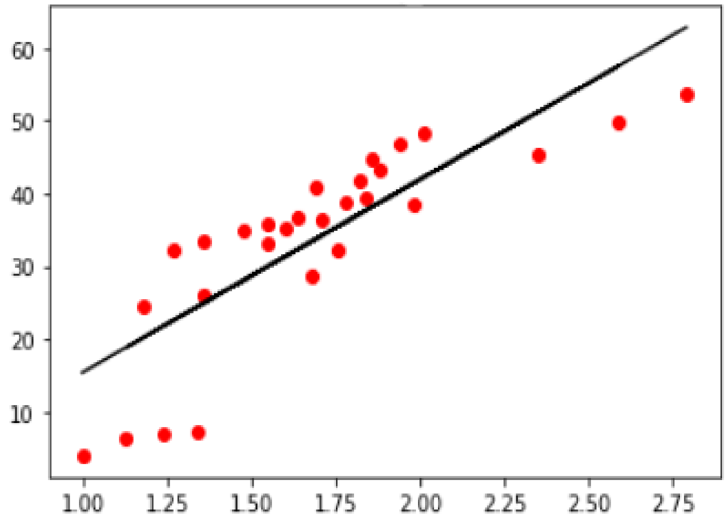

Chart 13: Split Tensile Strength vs Compressive Strength

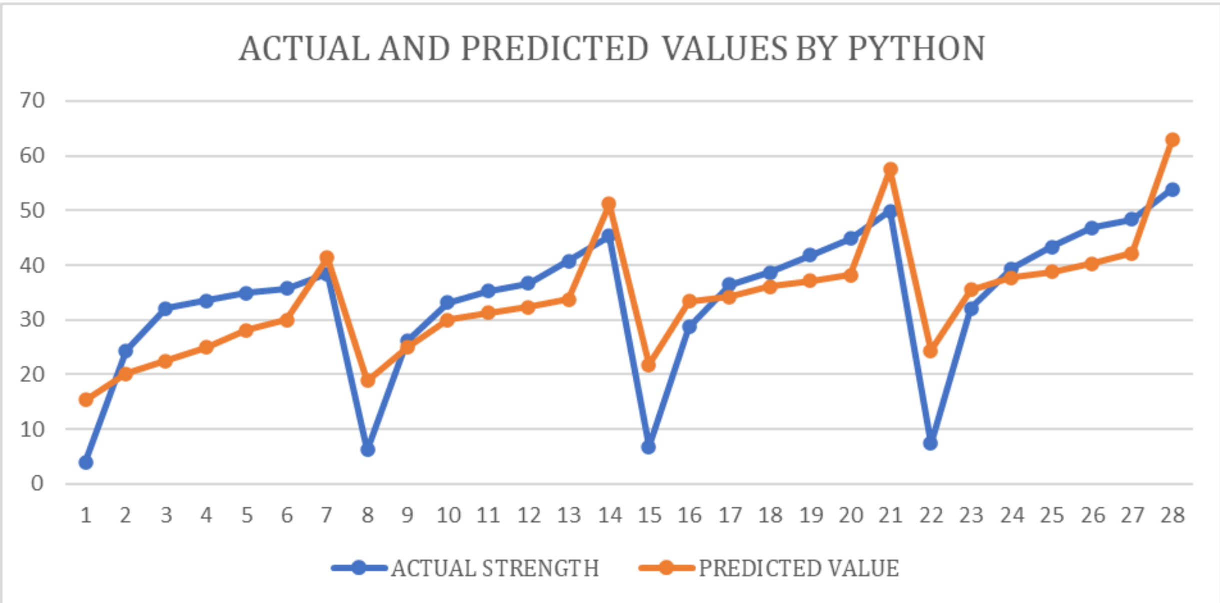

Chart 14: Actual vs Predicted Compressive Strengths using Split Tensile Strengths

7.3.2 Compressive Strength from Flexural Strength

Table 7: Actual and Predicted Compressive Strengths from Flexural Strengths

ACTUAL COMPRESSIVE STRENGTH IN MPa	PREDICTED COMPRESSIVE STRENGTH IN MPa
4.00	2.82
24.38	24.02
32.14	33.34
33.56	33.80
34.86	34.74
35.70	35.43
38.37	38.00
6.22	5.62
26.12	24.95
33.18	35.90
35.22	36.60
36.68	37.30
40.74	38.46
45.33	40.09
6.84	7.02
28.76	27.98
36.49	40.33
38.67	41.03
41.84	41.72
44.81	42.89
49.86	45.45
7.38	8.88

32.16	32.41
39.40	44.87
43.32	46.38
46.84	47.08
48.39	47.55
53.84	50.34

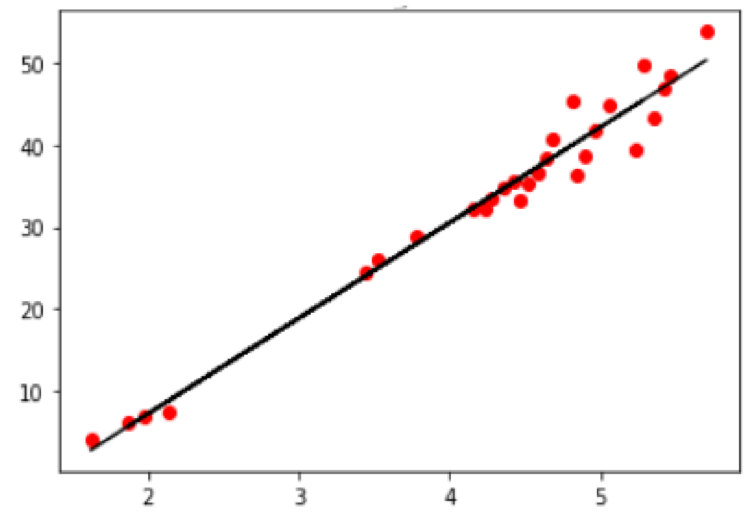

Chart 15: Flexure Strength vs Compressive Strength

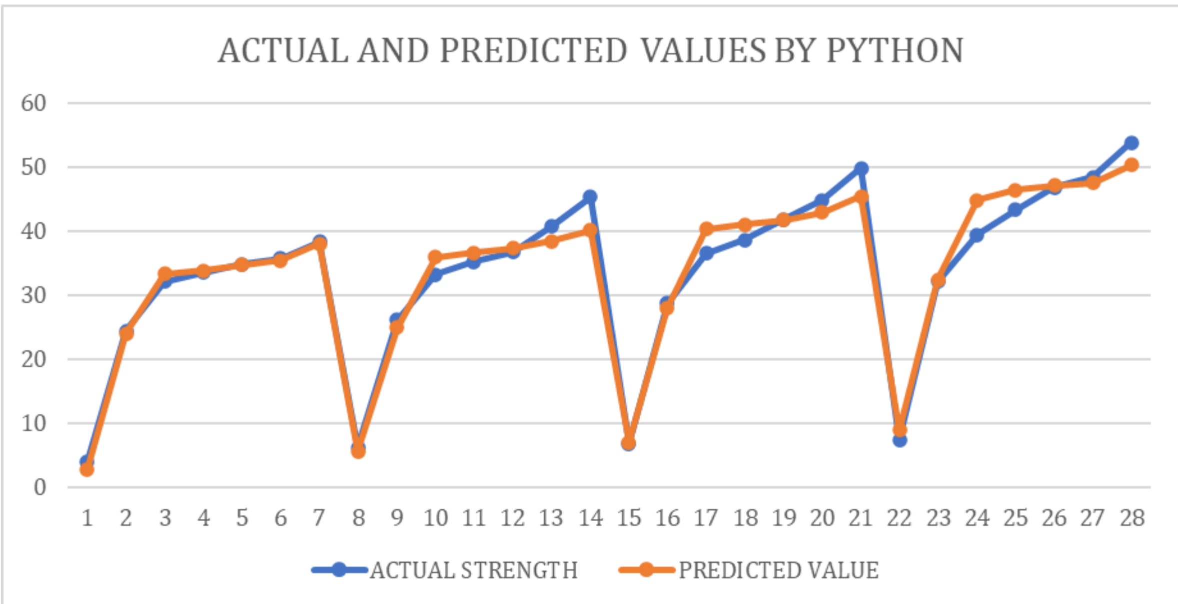

Chart 16: Actual vs Predicted Compressive Strengths using Flexural Strength

8. CONCLUSIONS:

Based on the above study, the following observations are made regarding the strength properties of ternary blended Self compacting Geo-polymer concrete.

- The strength properties of Self compacting Geo-polymer concrete mixes containing different combinations were observed increasing for increasing of different Quartz powder percentages.
- Amongst all the mixes, the mix with 20% Quartz powder content has obtained highest strength properties compared to other combinations.
- There was only slight difference in compressive strengths between 20%, 30%, 40% and 50% replacement.
- A negligible strength can be observed for nominal mix with 0% Quartz powder content.
- The presence of silica in both fly ash and Quartz powder is responsible for imparting strength in Self compacting Geo-polymer concrete.
- Based on experimental results, it is observed that there is a significant improvement in the strength properties of Self compacting Geo-polymer concrete with Quartz powder replacement when compared to complete fly ash based Self compacting Geo-polymer concrete.
- As percentage replacement of Quartz powder increases in Self compacting Geo-polymer concrete, its hardened properties increased but its workability decreased.
- Efflorescence was observed at nominal mix, which is not preferable and increase in Quartz powder replacement is appreciable incorporating in Self compacting Geo-polymer concrete.
- Replacement of fly-ash with Quartz powder has enhanced the overall performance in Fresh & Mechanical characteristics of Self compacting Geo-polymer concrete.
- After performing Regression analysis in three different tools. The positive Linearity among variables depends on actual R^2 and adjusted R^2 but for obtained data set they are found to be almost similar, but the standard error was varied. As the least count error was obtained by Mini tab it can be suggested as best tool for proposed data.
- The obtained R^2 value in mini tab is 0.678 & 0.969 for split tensile and flexure which can conclude as good for chosen data set.

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