Evaluating the Effect of Elevated Temparature on Ternary Blended Self Compacting Concrete using Response Surface Methodology

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Abstract - *The present investigation is mainly focused on the evaluation of the effect of elevated temparature on ternary blended self compacting concrete (SCC) using response surface methodology (RSM). In this study, replacement level of silica fume (SF) was kept at 10% for all SCC mixes with varying dosages of fly ash (FA) from 0% to 25% at an increment of 5%. Compressive strength of SCC mixes were determined after 7, 28 and 90 days of curing after exposed to 100 ℃, 200 ℃and 300 ℃ for two hours. Response Surface Methodology (RSM) was performed to obtain the optimum parameters to attain maximum compressive strength. An equation in terms of actual factors has been evolved to make predictions about the response for given levels of each factor.*

Key Words: Self compaction concrete, Response surface methodology, Compressive strength, Elevated temparature

1. INTRODUCTION

The self-compact concrete (SCC) is categorized as an emerging construction material which gets compacted under its self-weight without any vibrators. SCC is very much useful to fill each and every corner of the structural elements. Superplasticizer (SP) can be used in the concrete to get the required workability without any segregation [1]. Ordinary Portland Cement (OPC) is one of the most commonly used construction materials worldwide. The production of OPC releases a huge amount of carbon dioxide (CO_2) into the atmosphere which affects the environment [2]. Many efforts have been put to develop sustainable construction material by partially replacing the cement with the supplementary cementations materials like fly ash, rice husk ash, silica fume, ground granulated blast furnace slag etc [3]. Castillo.C et. al [4] observed a strength loss of 15 to 20% in SCC at an elevated temparature of 100^{o}C to 300^{o}C. Long T.Phan and Nicholas Carino J. [5] noted the losses in relative strength of concrete due to high temperature exposure. The present investigation is mainly focused on the evaluation of the effect of elevated temparature on ternary blended self compacting concrete (SCC) using response surface methodology (RSM).

2. EXPERIMENTAL STUDY

2.1 MATERIALS

In this study Ordinary Portland cement (OPC) 53 grade is used as a binder. Class F (low calcium) fly ash (FA) produced from Rayalaseema Thermal Power Plant (RTPP), Muddanur, A.P and silica fume (SF) collected from Astrra chemicals, chennai were used as supplemtary cementitious materials. Specific gravity of cement, FA and SF was 3.12, 2.12 and 2.2 respectively. Locally available river sand and crushed granite stones of size 12.5 mm were used as fine and coarse aggregate respectively. The bulk specific gravity of the coarse aggregate and fine aggregate were 2.58 and 2.6. Conpast 430 was used as superplasticizer (SP).

2.2 METHODS

Compressive strength of SCC was determined after 7, 28 and 90 days of curing after exposed to 100°C, 200°Cand 300°C for two hours. Design-Expert software was used to perform Response surface methodology (RSM) in order to obtain the optimum parameters to attain maximum compressive strength. RSM is an empirical modeling technique, devoted for evaluation of relations existing between a group of controlled experimental factors and the observed results of one or more selected criteria. A prior knowledge of the studied process is thus necessary to build a realistic model.

2.3 SCC MIX PROPORTIONS

In this study, replacement level of silica fume (SF) was kept at 10% for all SCC mixes with varying dosages of fly ash (FA) from 0% to 25% at an increment of 5% as shown in Table 1. The SCC mix proportions [6] are tabulated in Table 2.

Table 1. Fabrication of SCC mixes

Mixes	Cement	Silica fume	Fly ash
C90SF10FA0	90%	10%	0%
C85SF10FA5	85%	10%	5%
C80SF10FA10	80%	10%	10%
C75SF10FA15	75%	10%	15%

C70SF10FA20	70%	10%	20%
C65SF10FA25	65%	10%	25%

Table 2. SCC mix Proportions of Constituent Materials

Mix Type	Binder kg/m³	Cement Kg/m³	SF Kg/m³	AF Kg/m³	Water l/m³	12.5mm kg/m³	Sand kg/m³	SP l/m³
C90SF10FA0	520	468	52	0	187	721.60	863.36	6.24
C85SF10FA5	515	438	52	25	185	721.60	863.36	6.24
C80SF10FA10	510	408	51	50	184	721.60	863.36	6.24
C75SF10FA15	505	379	51	75	182	721.60	863.36	6.24
C70SF10FA20	500	350	50	100	180	721.60	863.36	6.24
C65SF10FA25	495	322	50	125	178	721.60	863.36	6.24

3. RESULTS AND DISCUSSION

3.1. COMPRESSIVE STRENGTH

This section describes the compressive strength properties of SCC at elevated temparature at different curing periods. These values were then compared those of water cured concrete mixes. The compressive strength values of concrete mixes are tabulated in Table 3.

Table 3. Compressive strength of concrete mixes

Mechanical property	Age (days)	Temperature (^{0}C)	Fly ash replacement levels					
			0	5	10	15	20	25
Compressive Strength, *f'ck* (MPa)	7	Ambient	26.48	27.11	27.80	27.99	27.07	26.91
		100	25.46	26.09	26.78	26.97	26.05	25.89
		200	24.32	25.37	25.67	25.92	24.94	24.75
		300	23.43	24.19	25.37	25.40	24.21	23.83
	28	Ambient	45.38	46.03	47.07	47.74	47.10	46.21
		100	44.99	45.64	46.67	47.35	46.70	45.82
		200	44.17	44.68	45.18	46.19	46.03	45.35
		300	43.44	43.59	44.65	45.53	45.41	44.38
	90	Ambient	48.16	48.56	49.63	50.33	49.34	48.93
		100	47.26	47.66	48.99	49.69	48.89	48.82
		200	45.69	46.85	47.56	48.04	47.80	47.51
		300	45.18	45.57	46.02	46.88	46.25	45.99

It is observed that the mix C75SF10FA15 has got higher compressive strength values at all ages at various temparature. It is due to the pozzolanic action of fly ash and reaction of silica fume with cement in the mix. It is also observed that the increase of temparature from 100^{0}C to 300^{0}C decreased the compressive strength of SCC at all ages. It is mainly due to the water loss due to high temparature which leads to increase the voids in the concrete.

3.2. RESPONSE SURFACE METHODOLOGY

This section describes the Response Surface Methodology (RSM) to obtain optimum parameters to attain maximum compressive strength of SCC mixes. Design-Expert Software is used to perform RSM. The Model F-value of 5499.94 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise. P-values less than 0.0500 indicate model terms are significant. In this case A, B, C, AB, AC, A^2, C^2 are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model From the model analysis, the Model BC was observed as insignificant and hence, the BC model have not been considered during the development of final equation. The ANOVA results [7] of compressive strength of SCC were tabulated in Table 4.

Table 4. ANOVA for compressive strength

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	7150.23	9	794.47	5499.94	< 0.0001	significant
A-cd	5788.00	1	5788.00	40069.00	< 0.0001	
B-T	76.95	1	76.95	532.67	< 0.0001	
C-F%	9.58	1	9.58	66.35	< 0.0001	
AB	0.7242	1	0.7242	5.01	0.0287	
AC	0.5819	1	0.5819	4.03	0.0491	
BC	**0.0139**	**1**	**0.0139**	**0.0960**	**0.7578**	**Not significant**
A^2	3021.33	1	3021.33	20915.96	< 0.0001	
B^2	0.4309	1	0.4309	2.98	0.0891	
C^2	17.06	1	17.06	118.11	< 0.0001	
Residual	8.96	62	0.1445			
Cor Total	7159.19	71				

Final equation which has been evolved is shown below.

$$\mathbf{CS = +17.18546+1.32927cd - 0.006045T + 0.222001F\% - 0.00002cd * T + 0.000299cd * F\% + 0.000015T * F\% - 0.010975cd^2 - 7.73611E\text{-}06T^2 - 0.007806F\%^2}$$

The equation in terms of actual factors can be used to make predictions about the response for given levels of each factor. Here, the levels should be specified in the original units for each factor. This equation should not be used to determine the relative impact of each factor because the coefficients are scaled to accommodate the units of each factor and the intercept is not at the center of the design space. Optimum values for compressive strength of SCC mixes are represented in Table 5.

Table 5. Optimum values for compressive strength of SCC

cd	T	F%	CS
68.605	47.008	17.460	58.207

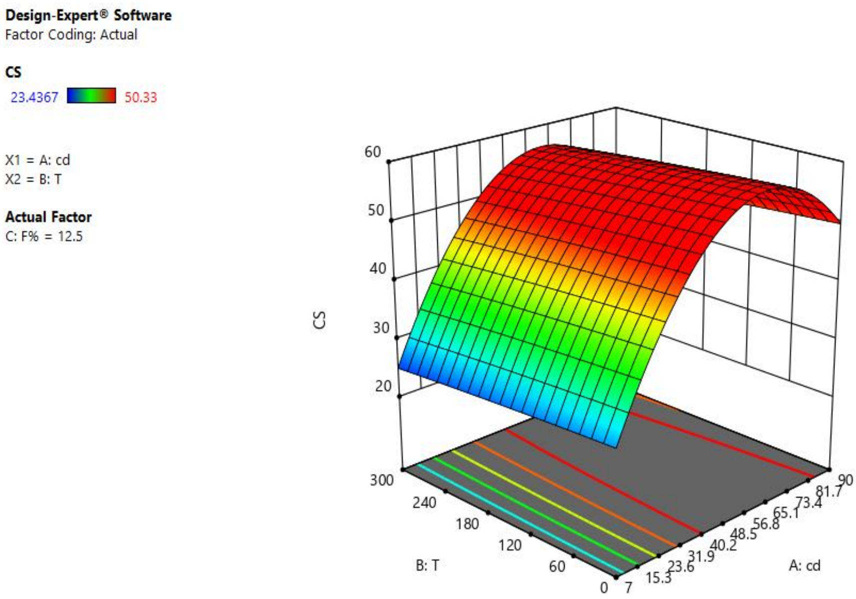


Fig.1. Curing Days Vs Temparature Vs Compressive strength pattern (RSM)

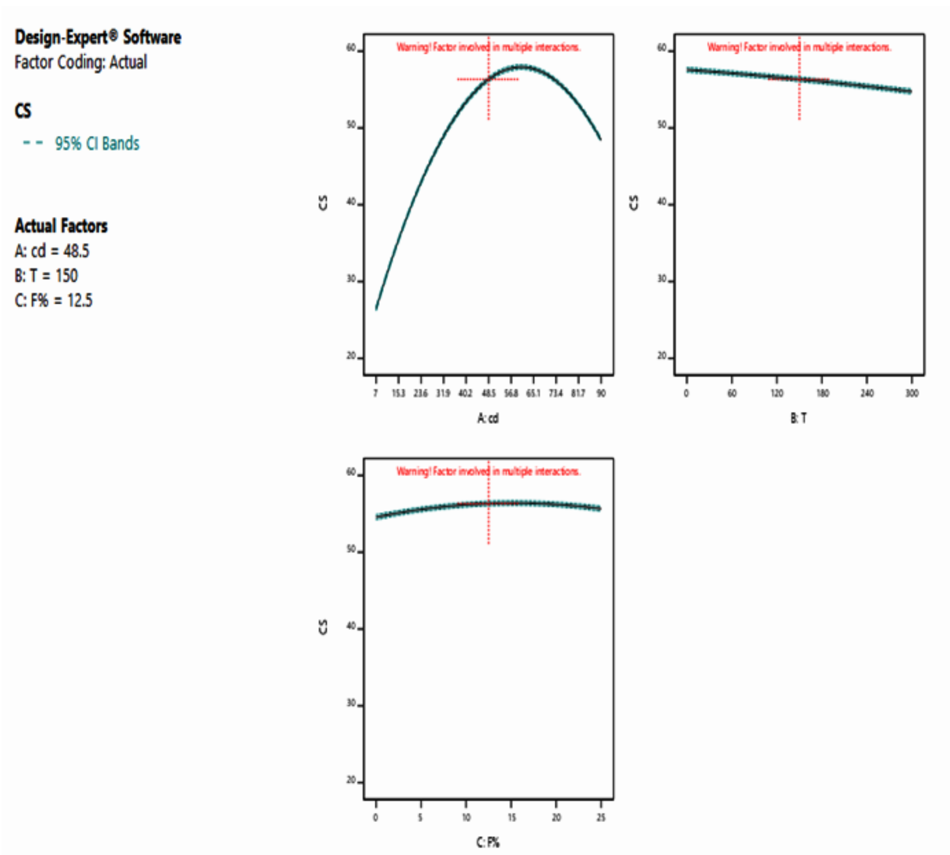


Fig. 2. Factorial graphs

It is observed that Actual factors noted as 48.5 from the graph Curing Days Vs Compressive strength, 150 from the graph Temparature Vs Compressive strength and 12.5 from the graph fly ash percentage Vs Compressive strength. From the Figure 3, it is clearly seen that the optimum value of curing period is 68.6051, optimum value of temparature is 47.0076 and optimum value of fly ash percentage is 17.46. That is, at 68.60 curing period, at an elevated temparature of 47.01^{0}C and at 17.46% of fly ash replacement, a maximum compressive strength of 58.2072 MPa was attained.

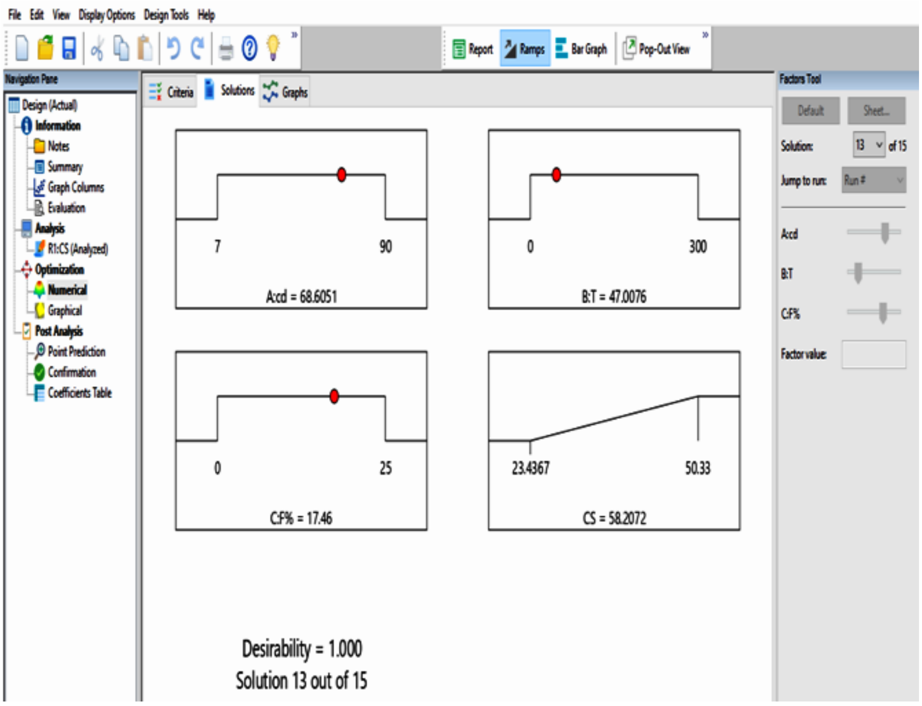
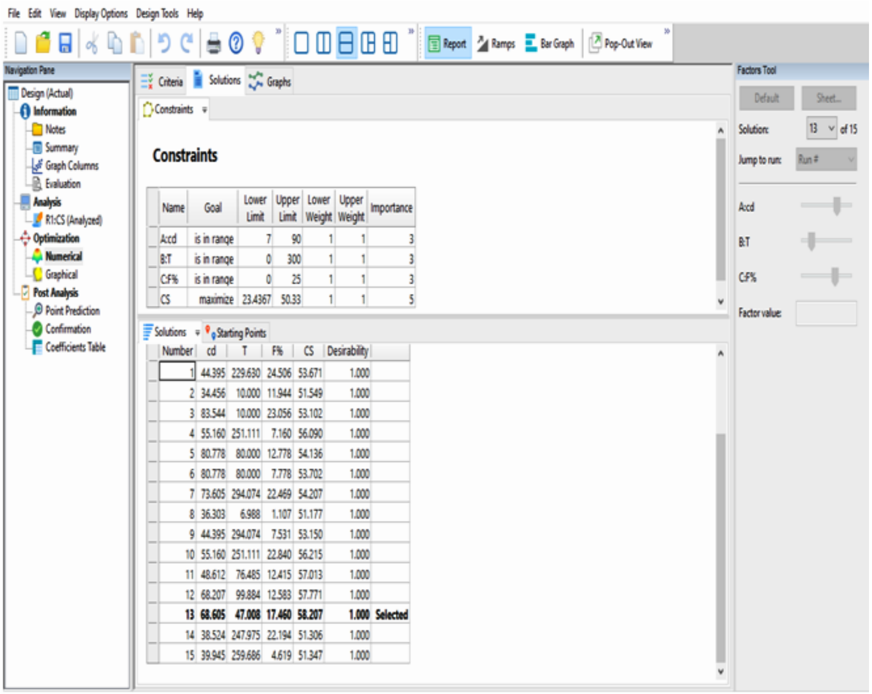


Figure 3. Optimum Parameters



Constraints

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
Accd	is in range	7	90	1	1	3
B:T	is in range	0	300	1	1	3
C:F%	is in range	0	25	1	1	3
CS	maximize	23.4367	50.33	1	1	5

Number	cd	T	F%	CS	Desirability	
1	44.395	229.630	24.506	53.671	1.000	
2	34.456	10.000	11.944	51.549	1.000	
3	83.544	10.000	23.056	53.102	1.000	
4	55.160	251.111	7.160	56.090	1.000	
5	80.778	80.000	12.778	54.136	1.000	
6	80.778	80.000	7.778	53.702	1.000	
7	73.605	294.074	22.469	54.207	1.000	
8	36.303	6.988	1.107	51.177	1.000	
9	44.395	294.074	7.531	53.150	1.000	
10	55.160	251.111	22.840	56.215	1.000	
11	48.612	76.485	12.415	57.013	1.000	
12	68.207	99.884	12.583	57.771	1.000	
13	**68.605**	**47.008**	**17.460**	**58.207**	**1.000**	**Selected**
14	38.524	247.975	22.194	51.306	1.000	
15	39.945	259.686	4.619	51.347	1.000	

Figure 4. Constraints and Optimum Parameters

4. CONCLUSIONS

Based on the experimental study, the following conclusions have been drawn.

- The mix C75SF10FA15 has got higher compressive strength values at all ages at various temparature.
- The increase of temparature from 100^0C to 300^0C decreased the compressive strength of SCC at all ages. It is mainly due to the water loss due to high temparature which leads to increase the voids in the concrete.
- It is observed that Actual factors noted as 48.5 from the graph Curing Days Vs Compressive strength, 150 from the graph Temparature Vs Compressive strength and 12.5 from the graph fly ash percentage Vs Compressive strength.
- It is clearly seen that the optimum value of curing period is 68.6051, optimum value of temparature is 47.0076 and optimum value of fly ash percentage is 17.46. That is, at 68.60 curing period, at an elevated temparature of 47.01^0C and at 17.46% of fly ash replacement, a maximum compressive strength of 58.2072 MPa was attained.

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