Mix Proportion Evaluation of SCC Using Taguchi Method

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Abstract- *Self-compacting concrete (SCC) was developed in order to get rid of space problem due to highly congested reinforcement of structural elements. This study has been done to optimize testing procedure by means of design of experiments (DoE). Taguchi methods was used for standard L (3) orthogonal array (OA) of four factors with three material parameters levels to make a total of 9 number of trail mixes. The parameters taken in this study are water powder ratio, cementitious material quantity, super-plasticizer and steel fibre amount. The responses of material factors are scrutinized for maximizing the compressive and tensile strength of self compacting concrete. The results show that the definite percentages of the diverse constituent material assisted to give better compressive strength and split tensile strength. The steel fibres and fly ash measure played an imperative character to raise the compressive and split tensile strength. The role of super plasticizer dose is noted to be comparatively high spotted on the fresh concrete featuress of SCC.*

Keywords- Self compacting concrete, Fiber, Super-plasticizers, Admixture, Design of experiments (DoE), Taguchi method.

I. INTRODUCTION

In Japan and Europe, Self-compacting concrete was initially developed. It is a type of concrete that is capable to flow and fill every division of the corner of the formwork (In shuttering), even when the dense reinforcement is present, purely by means of its own weight and exclusive of any vibration or other type of voids removal process.

In 1986 the development of SCC has made a major impact on the construction industry by prevail over some of the difficulties associated to freshly readied concrete. Several difficulties has been reported when it is in fresh form like skill of workers, type and configuration of a structural section, density of reinforcement, ability to pump, resistance to segregate and mostly compaction. Self compacting concrete is rich in fines content and found to be more lasting. Numerous researches have been listed on the global growth of SCC and its micro-social system and strength aspects. Instead of various researches and construction systems conducted widespread, the Bureau of Indian Standards (BIS) has not fixed out a standard mix method to get proper mix design trials and self-compact capacity testing methods. The behavior of Self Compacting Concrete is same as that of conventional concrete comprises of binder, fine aggregate, coarse aggregates, water, fines and admixtures. In order to get the rheological properties of SCC. SCC should have more fines content, super plasticizers with viscosity modifying agents (VMA) to some extent.

Objectives of Present Study

Following are the objectives of this research

To develop a systematic methodology for determining the optimum proportions of different parameters which gives high flow ability, passing ability and highest value of compressive strength and tensile strength.

To analyze the influence of different factors at different levels by using Taguchi method (DoE).

II. LITERATURE REVIEW

The relevant literature pertaining to the present research carried out in India and abroad has been reviewed and presented as under:-

Aliha et. al. (2022) proposed an analytical approach L32 Taguchi design to determine the optimum configuration of epoxy base PC mixture prepared from four different ingredients, they are epoxy resin, fine silica aggregate, coarse silica aggregate and E-glass fiber. In order to get the best results some fracture toughness tests under mode I were done on symmetric semi-circular bend specimen as per the design of experiment proposed by Taguchi's method. All the four ingredients were mixed in different i.e. fiber (0–2%), fine aggregate (20–35%), epoxy resin (13–28%) and coarse aggregate (41–56%). It has been concluded that mixture including minimum percentages of fiber and coarse aggregate, resin (25–28%) and moderate fine filler (28–31%), offers the best fracture energy and values of toughness.

For getting the best option of solution for activator, **Bayat and Eslami (2022)** suggested the Taguchi based-IMCDM method in which experimental results of non-orthogonal arrays were forecasted. A case study was done to get the best possible mixture of sodium silicate activators on the basis of ASTM C150. Three factors together with the weight percentage of sodium oxide (Na_2O) in slag, silicate modulus (SiO_2/Na_2O) and water to slag (W/S) ratio were examined by assessing the drying shrinkage of the mortar, setting time, mini-slump cone tests and compressive strength. The best activator found was $Na_2O = 6\%$, $SiO_2/Na_2O = 0.8$ and W/S = 0.42

According to Sharifi et. al. (2020), several factors affects the design mix of concrete. In this study, A model has been presented using Taguchi optimization method to get the most appropriate mix design of the high strength self-consolidating concrete (HSSCC). It was observed that the suggested method was effectual in attaining the most appropriate mix design. The investigational outcomes specified a notable enhancement in the overall quality of concrete differentiated to the decision maker's assessed mixture design. Parameters like amount of cement, w/c ratio and mixing timings are the most remarkable factors influencing the mix design of concrete.

Taguchi method **has been used Emara et al. (2018)** to get the effect and optimization of self-compacting rubberized concrete. Design of experiment was done by orthogonal array to accommodate four parameters with four levels. These factors are the coarse rubber percentage, fine rubber percentage, viscocrete and fly ash percentage in the concrete mix. To investigate the influencing parameters of self-compacting rubberized concrete, the S to N ratio and the analysis of variance are used. The result denotes that there is a fall in the strength with rising rubber content but apparently raise in impact resistance has been monitored.

The mechanical properties and workability of Self compacting rubberized concrete were estimated by **Khalil et. al. (2015)** in order to diminish the negative effect of rubber aggregate on the characteristics.

The effects on the mechanical properties of FRC are analyzed through the volume fraction and length of basalt fiber has been noticed by **Jiang et al (2014).** The upshot specifies that adding basalt fiber appreciably enhances the flexural strength, tensile strength and toughness index. Whereas, there is no any major change in compressive strength observed. Besides this, the length of basalt fiber presents the effects on the mechanical properties.

An experimental study has been performed by **Bhalchandra et.al. (2012)** to notice the change in compressive strength and flexural strength over normal SCC by using steel fibre content and found the 25.75% and 19.47% increment in compressive strength and flexural strength respectively over normal SCC.

Abdulhadi et al. (2012) used polypropylene fiber in M30 grade concrete. Compressive, split tensile strength and a relation between them has been obtained. The range of polypropylene fiber is kept between 0% to 1.2% volume fractions by weight of cement.

III. DESIGN OF EXPERIMENT

Design of Experiment (DoE) is a organized approach to get better the quality of given material parameters. This investigational work was performed to examine the effect of steel fibres at diverse dosage of cementing material and superplasticizer. The design of experiments (DoE) was employed by Taguchi to optimize experimentation process and these simultaneously improved techniques are called "Taguchi method" which decreases the number of experiments. By using the typical proportion materials shown in Table 1, 9 mixes of self-compacting concrete (SCC) are evaluated and detailed in Table 3.

Variable	**Water Cement Ratio**		**Fly Ash**		**Steel Fibres**		**Superplasticizer**	
	Code	**Absolute**	**Code**	**Absolute**	**Code**	**Absolute**	**Code**	**Absolute**
1	P1	0.4	Q1	0	R1	50	S1	0.8
2	P2	0.38	Q2	20	R2	30	S2	1.2
3	P3	0.36	Q3	40	R3	15	S3	1.6

Table 1- Mix parameters and their levels

In this study, a standard L_9 (3^4) orthogonal array (OA) of four parameters with three material factors levels to vary a total of 9 trail mixes. L_9 orthogonal array are used Table 2.

Table 2- Design matrix of L_9 (3^4) orthogonal array with parameters and their coding

Variable	Variable 1		Variable 2		Variable 3		Variable 4	
	Water Cement Ratio (%)		Fly Ash (%)		Steel Fibres (mm)		Superplasticizer (%)	
	Code	Absolute	Code	Absolute	Code	Absolute	Code	Absolute
1	P1	0.4	Q1	0	R1	50	S1	0.8
2	P1	0.4	Q2	20	R2	30	S2	1.2
3	P1	0.4	Q3	40	R3	15	S3	1.6
4	P2	0.38	Q1	0	R2	30	S3	1.6
5	P2	0.38	Q2	20	R3	15	S1	0.8
6	P2	0.38	Q3	40	R1	50	S2	1.2
7	P3	0.36	Q1	0	R3	15	S2	1.2
8	P3	0.36	Q2	20	R1	50	S3	1.6
9	P3	0.36	Q3	40	R2	30	S1	0.8

By using the typical proportion materials shown in Table 1, 9 mixes of self-compacting concrete (SCC) are evaluated and detailed in Table 3.

Table 3- Details of Mix Proportion

Experiment No.	Water (kg/m3)	Cement (kg/m3)	Fly ash (kg/m3)	F.A (kg/m3)	C.A (kg/m3)	HRWR (kg/m3)	Steel fibres (kg/m3)
1	215	510	0	1008	781	4.08	4.4
2	215	408	102	1008	781	6.12	4.4
3	215	306	204	1008	781	8.16	4.4
4	194	510	0	1008	781	8.16	4.4
5	194	408	102	1008	781	4.08	4.4
6	194	306	204	1008	781	6.12	4.4
7	174	510	0	1008	781	6.12	4.4
8	174	408	102	1008	781	8.16	4.4
9	174	306	204	1008	781	4.08	4.4

The reason is to pick the best mixture of control parameters so that the product or process is most robust. The obtained results are given in table below:

Table 4- Experimental Results

Experiment No.	Fresh concrete test		Hardened concrete test			
	Slump flow(mm)	L-box (h2/h1)	Compressive strength (MPa)		Split tensile strength (MPa)	
			7th day	28th day	7th day	28th day
Mix no.1	692	0.89	28	38	2.05	2.57
Mix no.2	710	0.94	26	42	2.02	2.92
Mix no.3	730	0.96	25	40	2	2.85
Mix no.4	700	0.94	34	46	2.22	2.88
Mix no.5	692	0.89	28	44	2.16	3.02
Mix no.6	690	0.86	23	39	1.96	2.48
Mix no.7	668	0.84	32	42	2.32	2.98
Mix no.8	685	0.86	26	40	2.14	2.8
Mix no.9	680	0.86	26	39	2.12	2.82

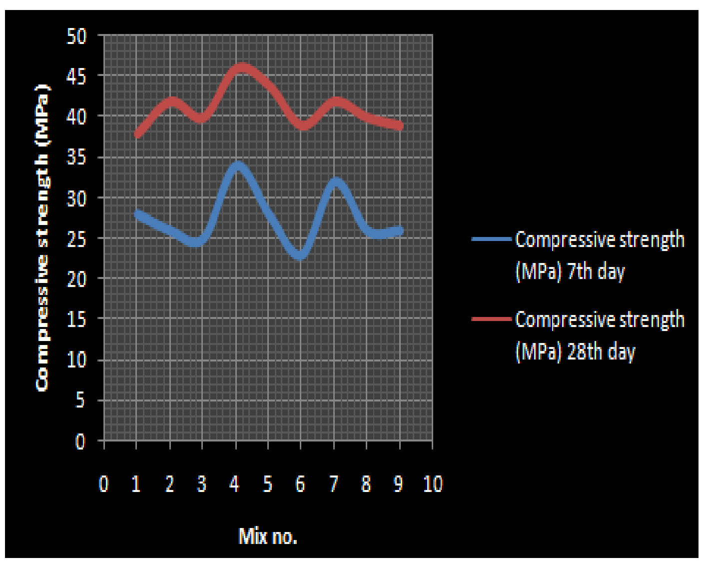

Figure 1- 7 days and 28 days Compressive Strength

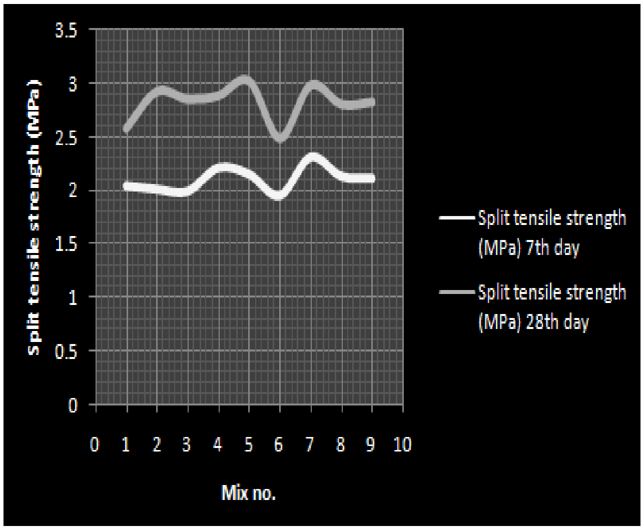

Figure 2 - 7 days and 28 days Split Tensile Strength

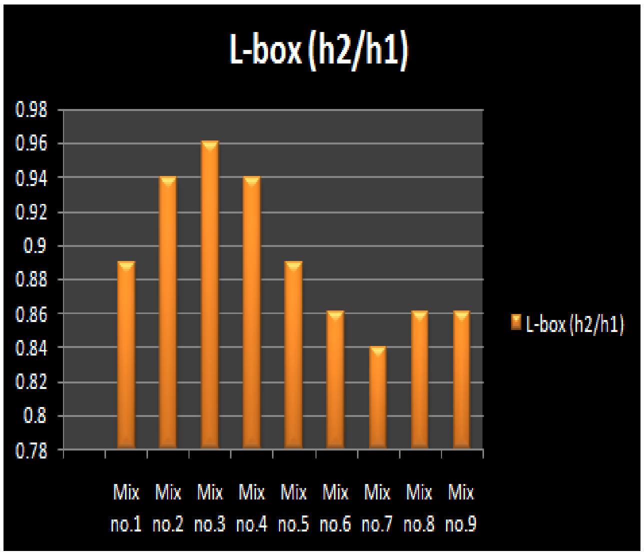

Figure 3 - L-box Test

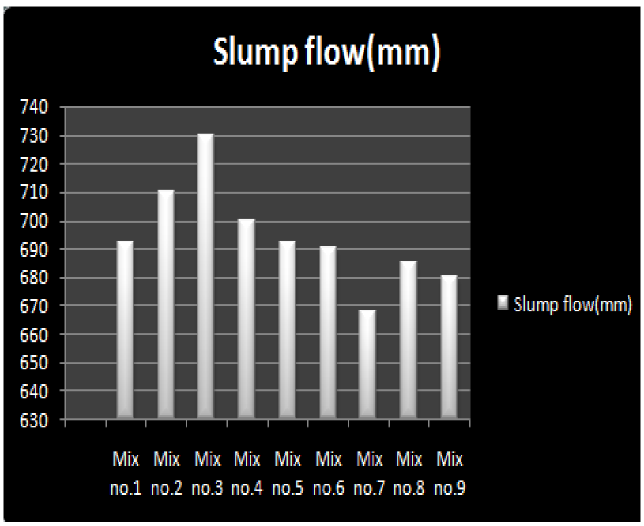

Figure 4 - Slump Flow

IV. DISCUSSIONS AND CONCLUSIONS

From the results of present research following conclusions were drawn-

1. The optimum ratio for 7th day compressive strength are obtained at water powder ratio at P2 (0.38%), fly ash % at Q1 (0%), steel fibre type at R2 (30mm) and super plasticizer content at S3 (1.6%). Whereas best results for 28th days compressive strength are noted at water powder ratio at P2 (0.38%), fly ash % at Q1 (0%), steel fibre type at R2 (30mm) and super plasticizer content at S3 (1.6%).
2. In case of 7th Days split tensile strength, the optimum proportion is obtained at water powder ratio at P3 (0.34%), fly ash % at Q1 (0%), steel fibre type at R3 (15mm) and super plasticizer content at S2(1.2%). Though, The most favourable proportion for 28th day split tensile strength are found at water powder ratio at P2 (0.38%), fly ash % at Q2 (20%), steel fibre type at R3 (15mm) and super plasticizer content at S1 (0.8%).
3. The best proportion for slump flow and L-box result are found for water powder ratio at P1 (0.42%), fly ash % at Q3 (40%), steel fibre type at R3 (15mm) and super plasticizer content at S3 (1.6%). In addition to this, the slump flow value of 9 trial mixes found in the range of 550mm to 800mm. From L-Box test, satisfactory results have been shown for passing ability ratio in all trials.
4. It has been observed that when there is enhancement in fly ash % of the mix, the flow ability and passing ability increases. However, the best possible dosage of fly ash from the fresh test result is found at 40% replacement of cement material and best hardened properties of concrete are found at 20% fly ash substitution from cement.
5. It has also been noted that super plasticizer doesn't take much role in a strengthening of concrete but it executes critical role in a fresh behavior of SCC. The optimum dosage of super plasticizer observed from the results is 1.6% by weight of cement which gives enhanced self-compacting features to the concrete.
6. According to these experimental results, all the 9 mixes are able to establish a higher strength concrete exclusive of vibration, with fulfills all the workability necessities of SCC as per EFNARC.
7. A linear decrement of workability characteristics (passing ability, filling ability and segregation resistance) of the SCC mixes has been observed with reducing water-cement ratio.

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