

OPTIMIZATION OF MIX DESIGN OF SELF-COMPACTING CONCRETE USING MATLAB

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Abstract

As we know concrete is a complex mixture with varying properties of each ingredient, where in any property of any material can influence the outcome of concrete. Therefore inter-relationship between input variables lead to varying output parameters like fresh and hardened properties. These inter-relationships can be deduced and formulated using previous experimental data. MATLAB helps in formulating the relationships between input variables and output parameters. In the present study input parameters like Volume of Paste, Water Content, Water-cement ratio, Cement Content and Water-Powder content are considered to project output parameters like slump flow, V-funnel, L-box, U-box, J-ring and Compressive strength at 7, 28, 60 and 90 days using experimental results from literature survey. The program thus developed helps us in mix proportioning of input variables for a required set of output parameters. SCC mixes obtained with the help of MATLAB program have been validated by mixing and testing concrete in the laboratory.

Keywords --- Optimization, Mix design, MATLAB, SCC, Design of Experiments

1. INTRODUCTION

Concrete which consolidate under its own weight is called as SCC. Vibration is not required for the compaction of this type of concrete. It is suitable for congested reinforcement and difficult conditions which requires highly fluid concrete. As SCC is different from conventional concrete, most emphasis is given on testing fresh properties. The main assessable properties are ability of filling, ability of passing and resistance for segregation. Specific gravity, volume of paste, dosage of admixtures, cement content and water content are the factors that affect the nature of SCC. Performance of SCC mainly depends on fresh and hardened properties which is also dependent on the above factors. Various factors and its performance can be interrelated using its values.

Under given circumstances, obtaining the best possible results is known as optimization. The main goal of optimization is either to maximize or minimize the desired result or minimize the efforts or both. Optimization can be defined as finding the ultimate condition that gives functional value of either maximum or minimum.

By knowing the input variables, the system performance can be optimized quickly which is known as DOE. It is also known as statistical technique of optimization. It is the best technique which projects maximum information with minimum amount of data. By changing the preconditions of variable called independent or predictor the outcome can be predicted. It is the simplest form of the experiment. Second variable is called as dependent or outcome variable which

changes by changing predictor. Hence there is a need of selecting correct predictors to get desired outcomes.

2. LITERATURE REVIEW

[1]. MIX DESIGN OF SCC: The aim of paper was to develop a new mix design method for self-compacting concrete. Initially the aggregates ratio was determined and the voids of aggregates were then filled with the paste of binders. This mix is tested for self-compacting, flowing ability and other SCC desired properties. The major influencing factors for the properties of SCC are binders, aggregates proportion, mixing water and type as well as proportion of superplasticizer. The proposed method can be used to produce high quality SCC from the results of compressive test, L-box, U-box, V-funnel and slump flow tests. The proposed method is simpler compared to the method suggested by Japanese Ready- Mixed Concrete Association [JRMCA] and also consumes less time and cost saving.

[2]. FRESH PROPERTIES OF SCC: This paper aims at increasing the fresh concrete stability by increasing the fine materials in mix design. The authors resulted with reduced segregation potential of SCC. Coarse and fine aggregates are partially replaced by finer materials which showed low segregation potential in SCC by V-funnel test. The fly ash in SCC develop improved strength after 28-days and also fly ash in SCC produce low segregation potential with high strength concrete. The authors highlighted strength development test and bleeding test.

[3]. OPTIMIZATION OF SCC: Authors aimed in developing a statistical approach to reduce number of trails and provide dependable predictions. D-optimal design and Response surface methodology (RSM) are coupled for various parameters for providing best design of experiment for HSSCC mix proportions. Various factors considered were fly ash (FA) content, water-binder(W/B) ratio, superplasticizer (SP) content, fine aggregate (S/a) percentage and cement content. The optimal design was tested for tests like passing ability, manufacturing cost, compressive strength and segregation.

[4]. OPTIMIZATION OF SCC: The Authors aimed at study of fresh and hardened properties of SCC mix by replacing cement content with different percentages of powder of limestone. The main observation was powder of limestone can be utilized as mineral additive of SCC. With the increase in 20% content of powder of limestone, the 7th day and 28th day compressive strength increases. 28 day strength gives maximum compressive strength at 20% cement content replacing with powder of limestone. But strength reduces as further increase in powder of limestone. Hardened properties as modulus of elasticity, cylinder compressive strength, and flexural strength and split tensile strength increases by adding powder of limestone.

3. MATERIALS AND METHODOLOGY

3.1 Materials Used

MATLAB is the fourth generation programming language which is developed as programming language by Math works. It is used for processing matrices, data and allows functional plotting, algorithms, Implementation, user interface creation and program interface of other languages.

3.1.1 Cement

The cement of 53 Grade used for the current project. Various tests are conducted on cement to meet the requirement of IS 12269-1987 provisions.

3.1.2 Fine Aggregates

Fine aggregate used in this project is passing through IS Sieve of 4.75mm sieve size with water absorption of 1.0%. The sieve analysis conducted and it confirms to Zone III as per the specifications of IS: 383-1970.

3.1.3 Coarse Aggregates

The coarse aggregates are taken 10 mm down size. Water absorption is taken as 0.5% and it confirms to as per the specifications of IS: 383-1970 for graded aggregates.

3.1.4 Fly Ash

The Class C fly ash used in the current project which is brought from Raichur power plant with the specific gravity as 1.47.

3.1.5 Water

The portable water was used during the mix design. For better results the pH value of the water should be 6 to 8.

3.1.6 Super Plasticizer

The 1.5% of Super Plasticizer used here is polycarboxylic ether manufactured by BASF Company by the weight of powder content (cement + fly ash) is used as a chemical admixture.

Methodology

- Various experimental results are collected from literature survey with varying input values such as Volume of Paste, cement-content, water-cement ratio and water content.
- Mix proportioning is carried out to obtain desired output properties of concrete and to regulate the use of raw materials. Mix proportion helps in reducing trail mixes and obtaining good quality concrete. There are many methods used to design SCC mixes.
- SCC differs from Normal concrete or conventional concrete in the way it is mixed. In SCC paste is first formed and then aggregates are added to the paste inducing flow properties that defines SCC. Volume of paste [Mixture of cement, filler and water] governs the flow properties and quantities of cement, water and aggregates individually.
- Mix proportions of SCC are done by empirical methods. The relationship between input and output parameters are established using previous experimental results.
- From the obtained relationship it is possible to predict input parameters required for desired output values, the results thus obtained can be validated by mixing concrete using the input values predicted.

4. EXPERIMENTAL PROGRAM

From the data collected, values have been averaged to obtain inter relationship in the MATLAB software. Input values and output parameters are taken in to consideration to formulate inter-relationship between input values and output parameters. The input values considered are Volume of paste, cement content, water-powder ratio, volume of powder and Water Content and output parameters considered are fresh properties of SCC.

```

function [Vmin,Vmax,Ubox,Lbox,Slumpflow,T50,jring,CS7,CS28,CS60,CS90]=opt (VP,WC,WP,VPOW, CC)
Vmin=VP/0.0685;
Vmax=VP/0.065;
Ubox=VP/0.045;
Lbox=VP/0.05;
Slumpflow=(VP)*10000/5.28;
jring=VP/0.06;
T50=VP/0.15;
CS7=VP/0.012;
CS28=(VP)/0.009;
CS60=VP/0.0068;
CS90=VP/0.0042;
WVmin=WC/28
WVmax=WC/22
WSlumpflow=WC/0.26
PVmin=WP/0.058;
PVmax=WP/0.047;
PSlumpflow=WP/0.000475;
PT50=WP/0.122;
Pjring=WP/0.050;
VSlumpflow=(VPOW)*10000/2.95;
VT50=VPOW/0.13;
VVmin=VPOW/0.033;
VVmax=VPOW/0.025;
Vjring=VPOW/0.028;
CSlumpflow=CC/0.62;
CT50=CC/140;
CVmin=CC/47.84;
CVmax=CC/36.89;
Cjring=CC/50;
disp(sprintf('Vmin= +%5.2f seconds',Vmin))

```

Fig 4.1: Developed Formulae in MATLAB

The above figure 4.1 represents the development of formulae in MATLAB. The window shows the pictorial representation of the inter-relationship between the considered inputs and outputs.

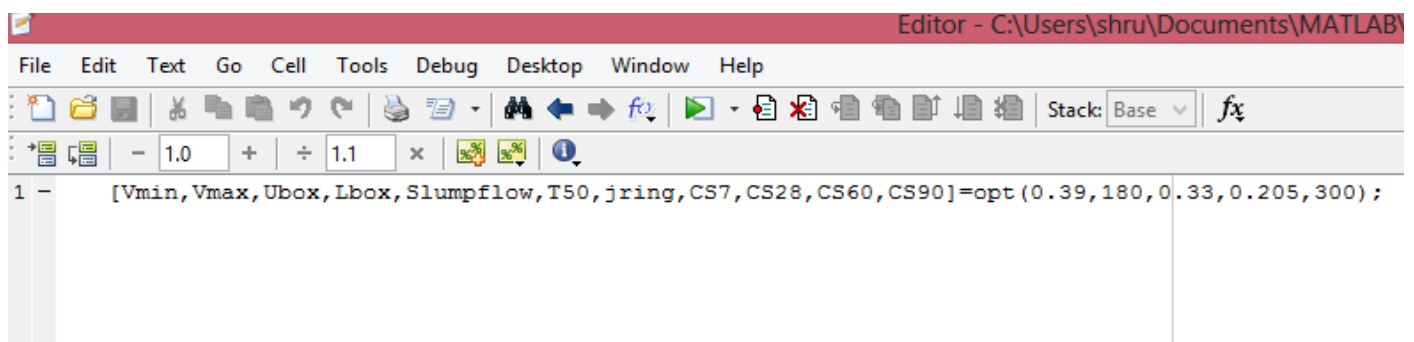


Fig 4.2: Main window of Inter-relationship in MATLAB

Figure 4.2 represents the main window of inter-relationship formulae in MATLAB. The main window shows the pictorial representation of the inter-relationship between the

considered inputs values and outputs parameters. The output results changes with the change of input values in this main window.

The results obtained from the MATLAB are verified by manual testing of fresh properties of SCC. The inputs considered in lab testing are volume of paste and cement content and the outputs considered are slump flow, T50, j-ring test, L-box test, U-box test and V-funnel test. Various mix values are considered for testing to obtain different results.

5. RESULT AND DISCUSSION

Varied inputs and outputs considered are calculated using inter-relationship formulae developed in the MATLAB. The output values obtained for varying input values are tabulated using the formulae. Various results are considered by varying various input values as shown in the Figure 5.1.

Sl No	VP	WC	W/P	VPOW	CC	Slump flow	T50	Vmin	Vmax	J-ring
1	0.39	180	0.33	0.205	300	739	2.6	5.69	6	6.5
2	0.41	180	0.33	0.205	300	776	2.7	5.99	6.31	6.8
3	0.38	185	0.33	0.205	300	711		6.61	8.41	
4	0.38	190	0.33	0.205	300	731		6.79	8.6	
5	0.38	180	0.35	0.205	300	737	2.87	6.03	7.45	7
6	0.38	180	0.36	0.205	300	758	2.95	6.21	7.6	7.2
7	0.38	180	0.33	0.245	300	830	1.88	7.42	9.8	8.8
8	0.38	180	0.33	0.22	300	746	1.69	6.67	8.8	7.8
9	0.38	180	0.33	0.205	390	629	2.79	8.15	10.75	7.8
10	0.38	180	0.33	0.205	450	726	3.2	9.4	12.2	9

Fig 5.1: Varied input and output values from MATLAB

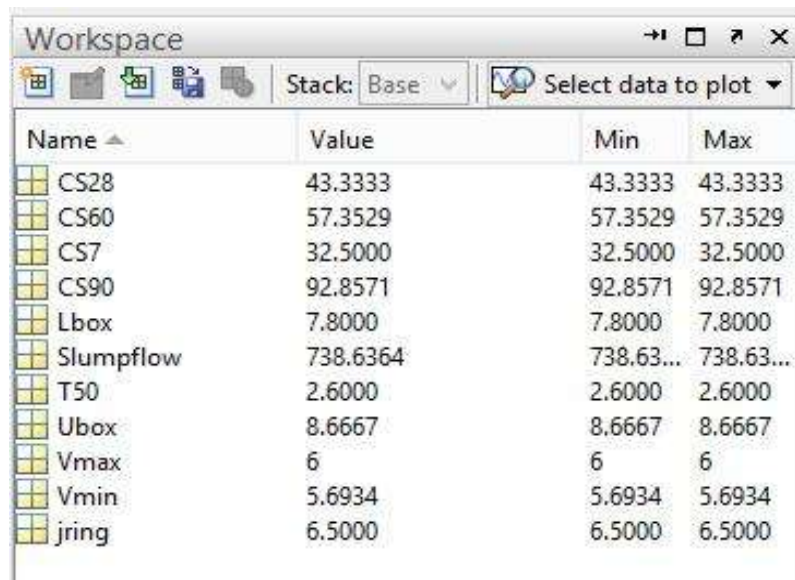
The output results depend on different parameters. The inter-relationship formulae between individual relationships are not sufficient to get desired output value hence there is need of different inter-relationship linked with various input values. For example in the Figure 5.1, with respect to slump flow there is decrease in sl no 2 to sl no 3 as volume of paste is taken as 0.38 and water content as 185litres. So it shows that slump flow increase as volume of paste decrease but by increasing water content.

```
Vmin= + 5.69 seconds
Vmax= + 6.00 seconds
Ubox= + 8.67 seconds
Lbox= + 7.80 seconds
Slumpcone= +738.64 millimeter
jring= + 6.50 ratio
CS7= +32.50 Newton/square millimeter
CS28= +43.33 Newton/square millimeter
CS60= +57.35 Newton/square millimeter
CS90= +92.86 Newton/square millimeter
WVmin= + 6.43 seconds
WVmax= + 8.18 seconds
WSlumpcone= +692.31 millimeter
PVmin= + 5.69 seconds
PVmax= + 7.02 seconds
PSlumpcone= +694.74 millimeter
Pjring= + 6.60 ratio
PT50= + 2.70 centimeter
VVmin= + 6.21 seconds
VVmax= + 8.20 seconds
VSlumpcone= +694.92 millimeter
Vjring= + 7.32 ratio
VT50= + 1.58 centimeter
CVmin= + 6.27 seconds
CVmax= + 8.13 seconds
CSlumpcone= +483.87 millimeter
Cjring= + 6.00 ratio
CT50= + 2.14 centimeter
^^
```

Fig 5-2: Command window

Figure 5.2 represents the command window obtained by the MATLAB results. It consists of inter-relationship formulae between input values and output parameters and the units

for the results. It is an experimental value obtained from considering volume of paste as 0.39 ratio and water-cement ratio of 180 liters as input values.



Name	Value	Min	Max
CS28	43.3333	43.3333	43.3333
CS60	57.3529	57.3529	57.3529
CS7	32.5000	32.5000	32.5000
CS90	92.8571	92.8571	92.8571
Lbox	7.8000	7.8000	7.8000
Slumpflow	738.6364	738.63...	738.63...
T50	2.6000	2.6000	2.6000
Ubox	8.6667	8.6667	8.6667
Vmax	6	6	6
Vmin	5.6934	5.6934	5.6934
jring	6.5000	6.5000	6.5000

Fig 5.3: Workspace

Figure 5.3 represents the workspace result obtained from the MATLAB. The values obtained should be rounded off considering their decimal values. These are results obtained from the input values; it varies according to variation of input values. The results obtained are shown in command window and workspace in the result sheet.

The results obtained from the MATLAB which is obtained from the formulae developed from the inter-relationship of input values and output parameters. As shown in the table the value of volume of paste and water-cement ratio is varied accordingly to test the fresh properties of SCC.

The results obtained from the experiments with the variation of volume of paste and water-cement ratio. SCC is tested for fresh properties with various input values. The volume of paste is taken as 0.39, 0.41 and 0.43 by keeping constant water content as 185 liter. Then water content is varied as 190 liter and 195 liter by keeping volume of paste 0.38 constant.

The above results are compared for the results of fresh properties of SCC obtained from MATLAB and experimental results respectively. The values obtained from the formulae of the MATLAB are giving similar results to the results obtained from the tests conducted for the fresh properties of SCC.

6. CONCLUSION

From the above results and the project can be concluded as follows:

- The main aim of the project is to optimize the SCC mix proportion using MATLAB

- The formulae are developed in the MATLAB using the various results obtained from literature survey validated by experiments
- The different input parameters considered are volume of paste and water-cement ratio and fresh properties and compressive strength as output parameters.
- The experiment results are similar to that of projected MATLAB results. The comparisons of results are tabulated.

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