Specific Method of Computerized Grading Kurve- A MATLAB based GUI for Concrete Mix Design

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Abstract— The conventional and computerized methods for designing concrete mix are presented in this work. In the case of the traditional system, inattention to the aggregate's passing percentage and grading is noted. The calculation begins using the usual method based on the desired slump and necessary water content. The fine aggregate and coarse aggregate content, which is calculated regardless of aggregate grading, is a crucial factor in mix proportioning. As a contemporary technique, the "Specific Method of Computerized Grading Kurve", a system based on aggregate grading, has been devised. Through the use of a Graphical User Interface built on MATLAB, the "SMCGK" technique has been automated. For various grades of concrete, the mix proportions were determined using both the conventional approach and the SMCGK technique.

Keywords— Concrete Mix Design, MATLAB, GUI, Standard Grading Curve, SMCGK technique

I. INTRODUCTION

There is conventional method of concrete mix design with guidelines of Indian Standard Method in which grading of fine and coarse aggregates is not focused. Grading of aggregates affects the parameters like workability, required water content, cement content and proportion of fine and coarse aggregate content. The calculation and determination of these parameters is concrete mix proportioning. Percentage passing of aggregates and their combinations is governed by grading curves. The method presented in this research paper is combining the guidelines of IS 10262:2019, particle size distribution of aggregates and grading curves of 20mm MSA. A computerized technique has been developed which is tilted as 'Specific Method of Computerized Grading Kurve'. The method is associated with calculations, use of grading curve graphs, correlation with actual sieve analysis. Determination of fine and coarse aggregate content based on grading curve, requires lot of calculation, graphical/analytical method and experience based interpretation. For ease in application of this method for technocrats, computerized automation is needed. Moreover, Graphical User Interface based on MATLAB is used for automation of technique.

II. METHOD OF PROPORTIONING FOR CONCRETE MIX DESIGN

A. *Convectional Method*

The guidelines given in IS 10262: 2019 for concrete mix design are followed.

B. *SMCGK Technique*

Specific Method of Computerized Grading Kurve is a technique developed based on gradation of aggregate. The ideal reference for gradation of aggregate are standard grading curves. There are four grading curves for 20mm nominal size of aggregate. The grading curves suggests percentage passing of aggregates for every aperture size, which gives minimum voids in the concrete. The fraction of different sizes of coarse aggregate and fine aggregate shall be combined to achieve one of the curve from standard grading curves. Based on the type of work and placing condition the curve can be selected. Curve 1 leads to coarser aggregates and becoming finer towards curve 2, 3 & 4. The actual percentage passing of fine aggregate and coarse aggregate are considered for combinations to achieve one of the curve. The analytical method is incorporated to decide the fine aggregate to coarse aggregate ratio. The procedure is more calculative and with lot of interpretation of data. The automation of this method facilitates determination of fine aggregate to coarse aggregate proportion. Four different proportions of fine aggregate content to coarse aggregate based on grading curves are obtained as alternatives. Fig. 1 shows the grading curves for 20mm aggregates.

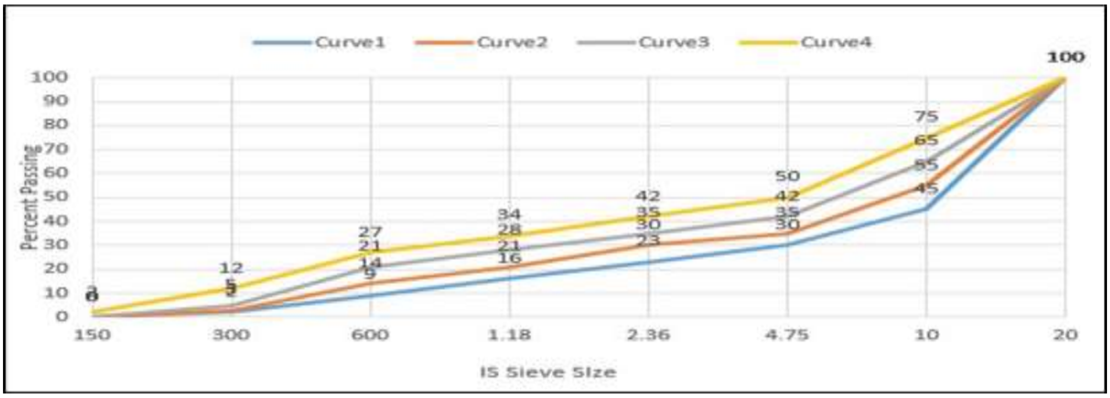

Fig. 1. The grading curves for 20mm aggregate

III. COMPUTERIZATION OF SMCGK TECHNIQUE USING MATLAB

Step 1: Grade of concrete and cement given as input. This step calculates target strength

Step 2: Selection of water content

a) Water/cement ratio given as input and it calculates water content based on slump required.

Or

b) Directly water content based on trials or experience can be given as input.

c) Dosage of admixture and percentage of water reduction due to admixture also given as input. It will calculate corrected water content.

Step 3: Calculation of cement content

From step 2 water/ cement ratio and corrected water content is used to calculate cement content using formula, Cement content = $\frac{water\ content}{w/c}$

Step 4: Grading of Aggregate

a) The sieve analysis of fine and coarse aggregate is substituted as input from sieve analysis of coarse aggregate; the program automatically selects percentage passing of 4.75 mm sieve size as β.

b) α is the percentage passing value of 4.75 mm sieve for four curves, the program automatically selects value of α based on curve selected.

c) The proportion of fine and coarse aggregate is designated as 1:k Where k is volume of coarse aggregate with respect to fine aggregate.

Step 5: Calculate $k = (100 - \alpha) / (\alpha - \beta)$

Step 6: Mix Calculation

a) Specific gravity of cement, fine aggregate, coarse aggregate and admixture is required as input.

b) water absorption of fine and coarse aggregate (if any) is also available as input.

Step 7: Output will be cement content, corrected water content, fine aggregate and coarse aggregate content, admixture dosage for per m^3 of concrete and their proportions.

A. DEVELOPMENT OF GRAPHICAL USER INTERFACE

In MATLAB guide function, a graphical user interface is created for ease of use. Fig. 2 shows a flowchart to design GUI for concrete mix design. The GUI front-end panel design for both the methods, which are used to calculate the concrete mix proportion. Fig. 3 and Fig. 4 shows the GUI front-end panel design. The 'Calculate' is a push button retrieves all of the inputs and computes the desired outputs using the algorithm described. The output section shows cement content, SCM content, water content, admixture, fine & coarse aggregate content in kg/m^3. Finally, it gives proportion of Cement, Fine Aggregate, Coarse Aggregate with water-cement ratio. The solved examples of MATLAB GUI based concrete mix proportioning for M25 grade of concrete are shown in fig. 5 and 6.

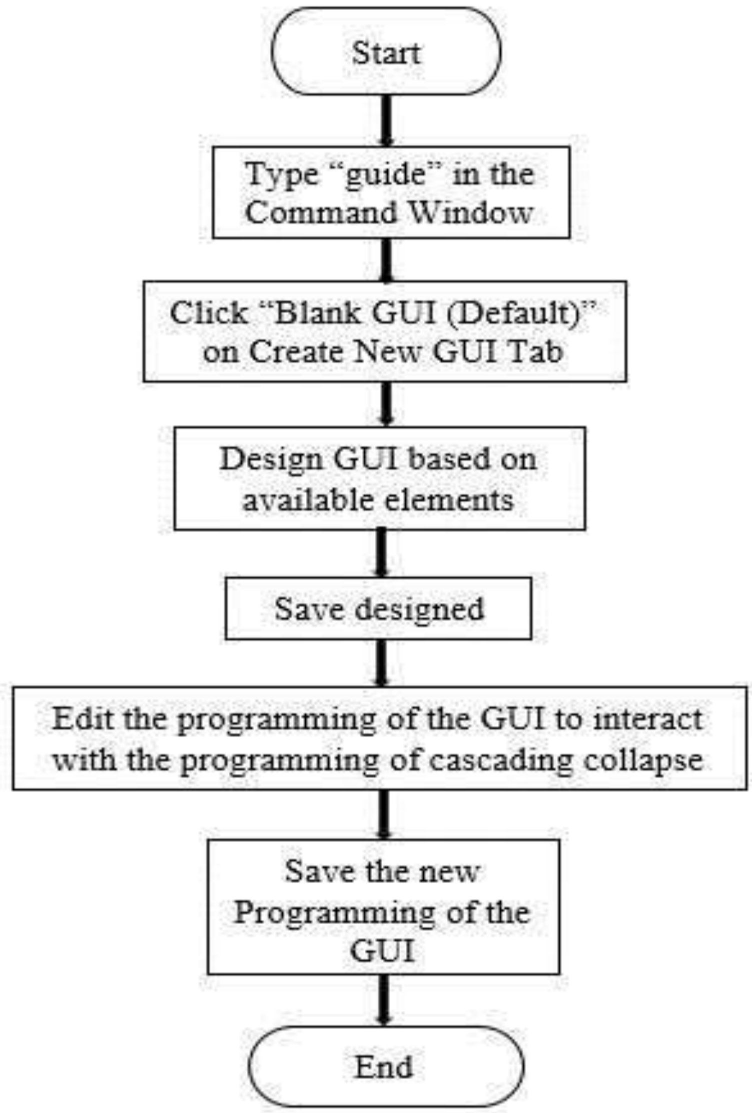

Fig. 2. Flowchart to design a GUI [13]

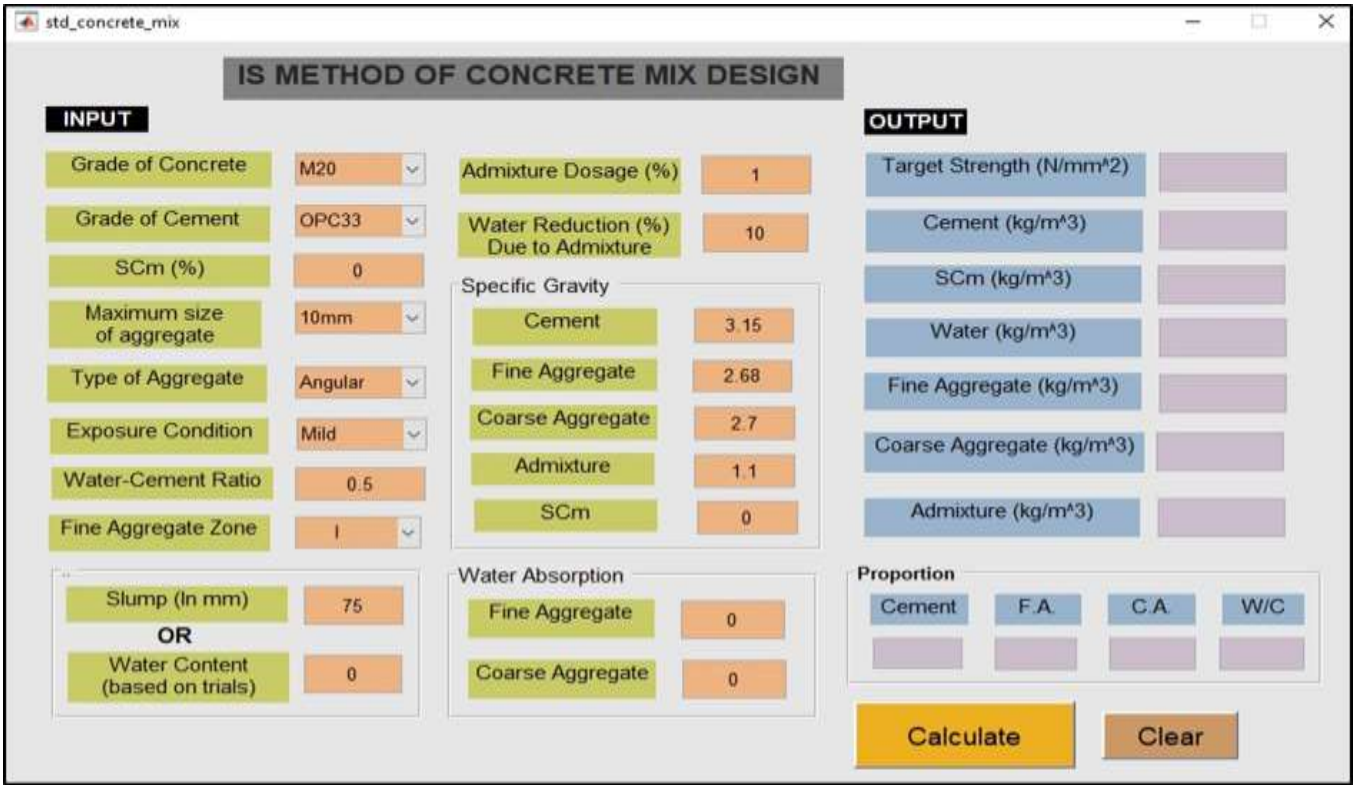

Fig. 3: GUI for Conventional Method of Concrete Mix Design

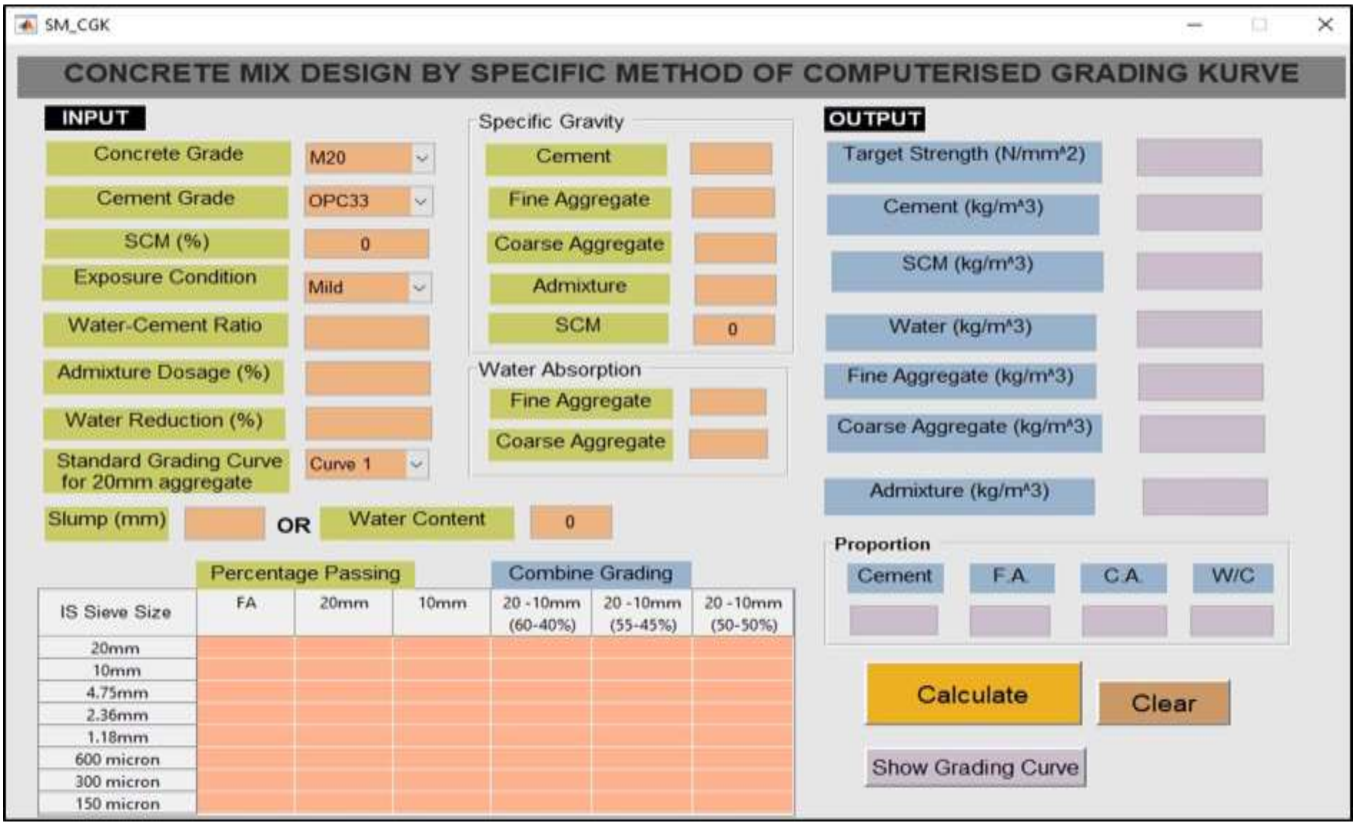

Fig. 4: GUI for SMCGK Technique of Concrete Mix Design

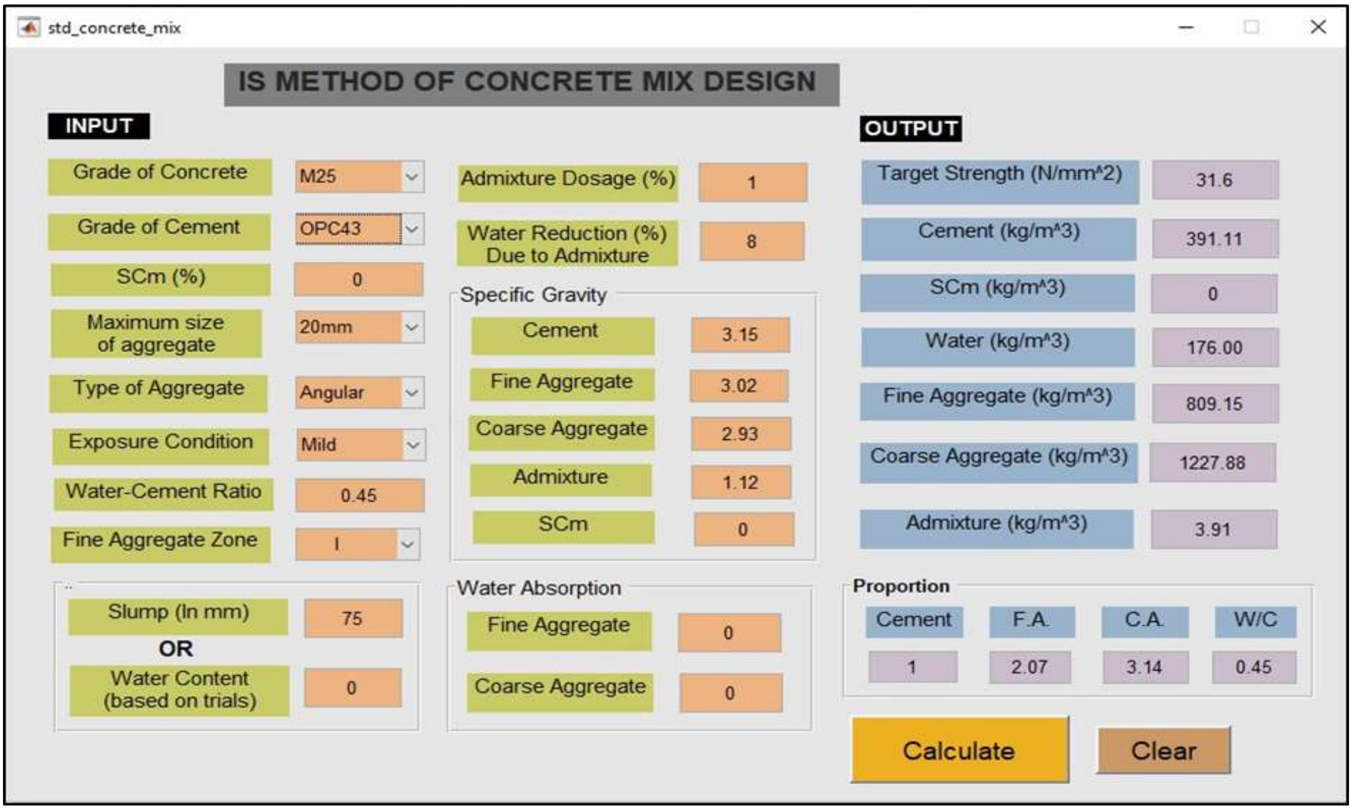

Fig. 5: Concrete Mix Design of M25 Grade using Conventional Method

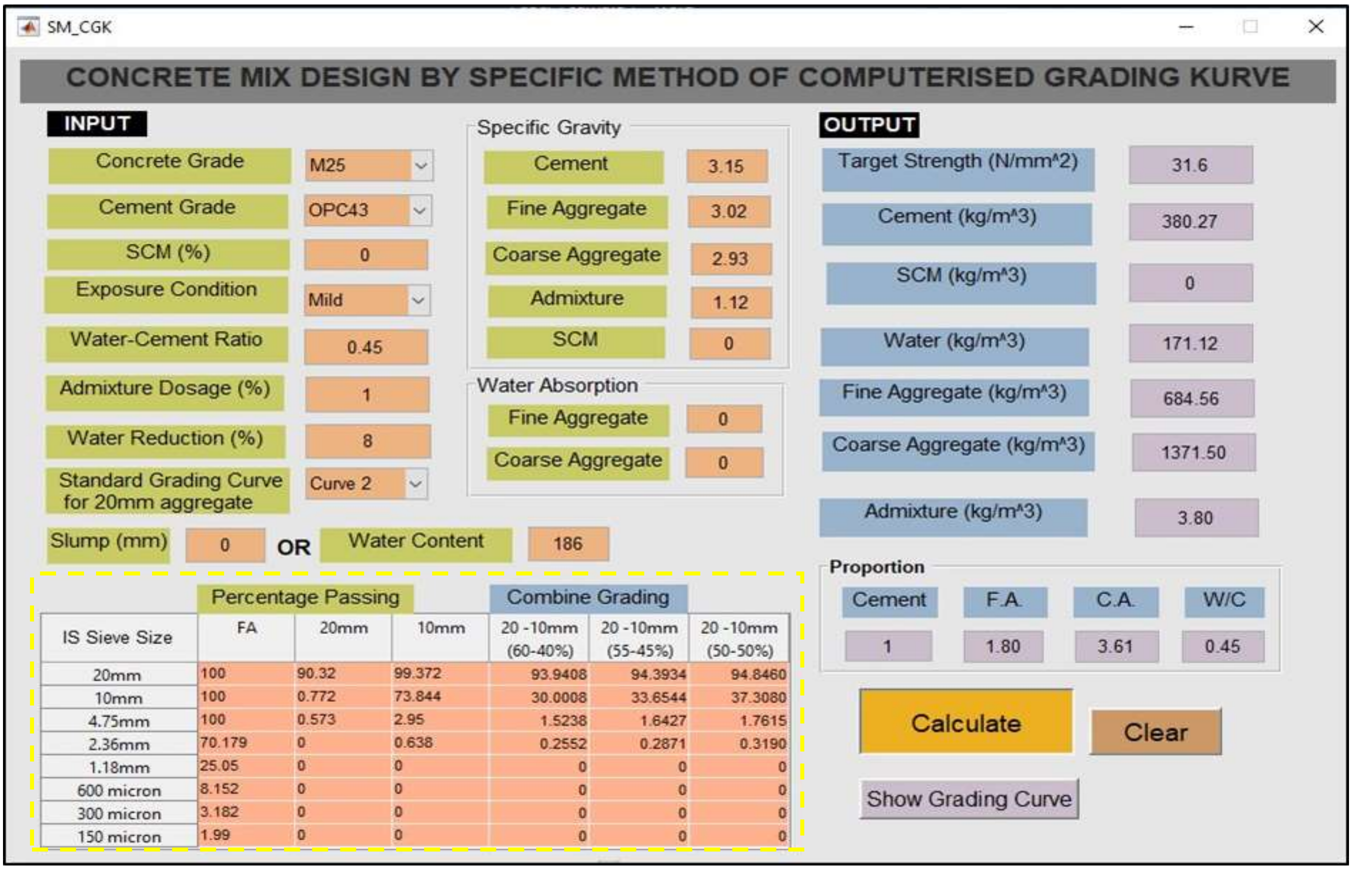

Fig. 6: Concrete Mix Design of M25 Grade using SMCGK Technique

The yellow marked box portion is an additional feature of this GUI. This feature is accepting the percentage passing of Fine & Coarse aggregate, which required as input for selection of grading curve. The Fine & Coarse aggregate are also combined. Additionally, it suggests different combinations of coarse aggregate fractions 20mm and 10mm (if supplied) as shown in Fig. 7

	Percentage Passing			Combine Grading		
IS Sieve Size	FA	20mm	10mm	20 -10mm (60-40%)	20 -10mm (55-45%)	20 -10mm (50-50%)
20mm	100	90.32	99.372	93.9408	94.3934	94.8460
10mm	100	0.772	73.844	30.0008	33.6544	37.3080
4.75mm	100	0.573	2.95	1.5238	1.6427	1.7615
2.36mm	70.179	0	0.638	0.2552	0.2871	0.3190
1.18mm	25.05	0	0	0	0	0
600 micron	8.152	0	0	0	0	0
300 micron	3.182	0	0	0	0	0
150 micron	1.99	0	0	0	0	0

Fig. 7. Percentage passing of aggregate as input and obtained combined grading of aggregate as output

IV. VERIFICATION OF SPECIFIC METHOD OF COMPUTERIZED GRADING CURVE

Concrete mix design is prepared for different properties by conventional method and SMCGK Technique for M20, M25 and M30 grade of concrete. The casting of concrete has been done to get the fresh as well as hardened properties, which are tabulated below.

Table 1: Comparison of Properties of Concrete by Conventional and SMCGK Technique

Grade of Concrete	Concrete Mix Design Methods	Proportions (C:FA:CA)	Slump (mm)	Compaction Factor	Compressive Strength (N/mm^2)	
					7 days	28 days
M30	Conventional	1 : 1.832 : 3.04	135	0.84	21.89	33.25
	SMCGK	1 : 1.97 : 2.81	105	0.92	25.32	35.98
M25	Conventional	1 : 2.08 : 3.22	115	0.90	23.29	30.49
	SMCGK	1 : 2.18 : 3.11	105	0.86	21.62	31.86
M30	Conventional	1 : 2.02 : 3.19	70	0.80	22.79	31.15
	SMCGK	1 : 2.04 : 3.27	75	0.872	22.57	31.21
M20	Conventional	1 : 2.37 : 3.53	125	0.83	12.51	23.40
	SMCGK	1 : 2.48 : 3.42	130	0.85	12.52	26.78

The fresh and hardened properties of conventional and SMCGK are compared. The strength of concrete by SMCGK Technique has been increased in the range of 5% to 13%.

V. IMPLEMENTATION OF SMCGK TECHNIQUE FOR DATASET OF CONCRETE MIX PROPORTIONS

The SMCGK Technique has been implemented to design 50 concrete mix proportions with different ingredient properties. The grades considered for mix are M20, M25, M30, M35 and M40. The input values are incorporated in SMCGK GUI, which calculates water, cement, fine aggregate, coarse aggregate content with their proportions as output. The proportions for four different grading curves have been calculated and data set of 50 mix designs varying with respect to four standard grading curves constituting 200 mix proportions has been prepared and tabulated below.

Table 2: Concrete Mix Proportions by Specific Method of Computerized Grading Curve

Sr. No	Grade of Concrete	Water-cement ratio	Cement Content (kg/m^3)	Specific Method of Computerized Grading Curve			
				Proportion Curve 1	Proportion Curve 2	Proportion Curve 3	Proportion Curve 4
1	M20	0.50	344.84	1 : 1.67 : 4.31	1 : 1.99 : 4.00	1 : 2.43 : 3.57	1 : 2.94 : 3.08
2	M25	0.48	359.21	1 : 1.59 : 4.11	1 : 1.90 : 3.81	1 : 2.32 : 3.40	1 : 2.80 : 2.93
3	M30	0.44	391.87	1 : 1.44 : 3.71	1 : 1.71 : 3.44	1 : 2.09 : 3.07	1 : 2.53 : 2.65
4	M35	0.42	410.53	1 : 1.36 : 3.51	1: 1.62 : 3.26	1 : 1.99 : 2.91	1 : 2.39 : 2.51
5	M40	0.36	420.41	1 : 1.36 : 3.51	1 : 1.62 : 3.26	1 : 1.98 : 2.90	1 : 2.39 : 2.50
6	M20	0.50	344.84	1 : 1.74 : 4.09	1 : 2.03 : 3.79	1 : 2.44 : 3.39	1 : 2.90 : 2.92
7	M25	0.48	367.2	1 : 1.61 : 3.78	1 : 1.88 : 3.51	1 : 2.25 : 3.13	1 : 2.68 : 2.70
8	M30	0.44	391.87	1 : 1.50 : 3.52	1 :1.75 : 3.27	1 : 2.10 : 2.91	1 : 2.50 : 2.51
9	M35	0.42	410..53	1 : 1.42 : 3.33	1 : 1.65 : 3.09	1 : 1.98 : 2.76	1 : 2.36 : 2.38
10	M40	0.38	428.53	1 : 1.36 : 3.20	1 : 1.59 : 2.97	1 : 1.91 : 2.65	1 : 2.27 : 2.29
11	M20	0.50	344.84	1 : 1.78 : 4.28	1 : 2.08 : 3.97	1 : 2.50 : 3.55	1 : 2.98 : 3.06
12	M25	0.48	359.21	1 : 1.70 : 4.08	1 : 1.98 : 3.79	1 : 2.39 : 3.38	1 : 2.84 : 2.91
13	M30	0.43	400.98	1 : 1.49 : 3.59	1 : 1.74 : 3.33	1 : 2.10 : 2.97	1 : 2.49 : 2.56
14	M35	0.41	420.54	1 : 1.41 : 3.39	1 : 1.65 : 3.15	1 : 1.98 : 2.81	1 : 2.36 : 2.42
15	M40	0.38	428.53	1 : 1.40 : 3.36	1 : 1.63 : 3.11	1 : 1.96 : 2.78	1 : 2.34 : 2.39

16	M20	0.50	344.84	1 : 1.66 : 4.16	1 : 1.94 : 3.86	1 : 2.34 : 3.45	1 : 2.80 : 2.97
17	M25	0.48	359.21	1 : 1.58 : 3.97	1 : 1.85 : 3.68	1 : 2.23 : 3.29	1 : 2.67 : 2.83
18	M30	0.43	400.98	1 : 1.39 : 3.49	1 : 1.63 : 3.24	1 : 1.96 : 2.89	1 : 2.34 : 2.49
19	M35	0.41	420.54	1 : 1.31 : 3.29	1 : 1.54 : 3.06	1 : 1.85 : 2.73	1 : 2.21 : 2.35
20	M40	0.36	436.38	1 : 1.28 : 3.21	1 : 1.50 : 2.98	1 : 1.81 : 2.66	1 : 2.16 : 2.30
21	M20	0.50	352.51	1 : 1.75 : 4.11	1 : 2.04 : 3.82	1 : 2.45 : 3.41	1 : 2.92 : 2.94
22	M25	0.48	367.20	1 : 1.67 : 3.92	1 : 1.95 : 3.64	1 : 2.34 : 3.25	1 : 2.78 : 2.80
23	M30	0.44	400.58	1 : 1.50 : 3.54	1 : 1.76 : 3.28	1 : 2.11 : 2.93	1 : 2.51 : 2.53
24	M35	0.42	419.65	1 : 1.42 : 3.35	1 : 1.66 : 3.11	1 : 1.99 : 2.77	1 : 2.37 : 2.39
25	M40	0.375	439.36	1 : 1.37 : 3.22	1 : 1.60 : 2.99	1 : 1.92 : 2.66	1 : 2.28 : 2.30
26	M20	0.50	344.84	1 : 1.69 : 4.22	1 : 1.98 : 3.92	1 : 2.40 : 3.50	1 : 2.87 : 3.01
27	M25	0.48	359.21	1 : 1.61 : 4.02	1 : 1.89 : 3.74	1 : 2.28 : 3.33	1 : 2.74 : 2.87
28	M30	0.43	400.98	1 : 1.41 : 3.54	1 : 1.66 : 3.28	1 : 2.01 : 2.93	1 : 2.40 : 2.53
29	M35	0.41	420.54	1 : 1.33 : 3.34	1 : 1.57 : 3.10	1 : 1.90 : 2.77	1 : 2.27 : 2.39
30	M40	0.36	447.02	1 : 1.26 : 3.15	1 : 1.48 : 2.92	1 : 1.79 : 2.61	1 : 2.14 : 2.25
31	M20	0.50	344.84	1 : 1.80 : 4.23	1 : 2.10 : 3.93	1 : 2.52 : 3.50	1 : 3.00 : 3.02
32	M25	0.48	359.21	1 : 1.72 : 4.03	1 : 2.00 : 3.74	1 : 2.41 : 3.34	1 : 2.86 : 2.87
33	M30	0.44	391.87	1 : 1.55 : 3.64	1 : 1.81 : 3.38	1 : 2.17 : 3.02	1 : 2.59 : 2.60
34	M35	0.42	410.53	1 : 1.47 : 3.44	1 : 1.71 : 3.20	1 : 2.05 : 2.85	1 : 2.45 : 2.46
35	M40	0.36	436.38	1 : 1.39 : 3.27	1 : 1.62 : 3.04	1 : 1.95 : 2.71	1 : 2.32 : 2.33
36	M20	0.50	344.84	1 : 1.71 : 4.16	1 : 2.01 : 3.86	1 : 2.42 : 3.45	1 : 2.89 : 2.97
37	M25	0.48	359.21	1 : 1.63 : 3.97	1 : 1.92 : 3.69	1 : 2.31 : 3.29	1 : 2.76 : 2.83
38	M30	0.44	391.87	1 : 1.47 : 3.58	1 : 1.73 : 3.33	1 : 2.08 : 2.97	1 : 2.49 : 2.56
39	M35	0.42	410.53	1 : 1.40 : 3.39	1 : 1.64 : 3.15	1 : 1.97 : 2.81	1 : 2.36 : 2.42
40	M40	0.36	425.73	1 : 1.37 : 3.34	1 : 1.61 : 3.10	1 : 1.94 : 2.76	1 : 2.32 : 2.38
41	M20	0.50	344.84	1 : 1.76 : 4.13	1 : 2.05 : 3.83	1 : 2.46 : 3.42	1 : 2.93 : 2.95
42	M25	0.48	359.21	1 : 1.67 : 3.94	1 : 1.95 : 3.65	1 : 2.35 : 3.26	1 : 2.79 : 2.81
43	M30	0.44	391.87	1 : 1.51 : 3.55	1 : 1.76 : 3.30	1 : 2.12 : 2.94	1 : 2.52 : 2.54
44	M35	0.42	409.52	1 : 1.43 : 3.36	1 : 1.67 : 3.12	1 : 2.00 : 2.79	1 : 2.39 : 2.40
45	M40	0.39	442.11	1 : 1.31 : 3.07	1 : 1.53 : 2.85	1 : 1.83 : 2.55	1 : 2.18 : 2.20

46	M20	0.50	344.84	1 : 1.74 : 4.24	1 : 2.03 : 3.93	1 : 2.44 : 3.51	1 : 2.91 : 3.03
47	M25	0.48	359.21	1 : 1.66 : 4.04	1 : 1.94 : 3.75	1 : 2.33 : 3.35	1 : 2.77 : 2.89
48	M30	0.44	391.87	1 : 1.50 : 3.65	1 : 1.75 : 3.39	1 : 2.10 : 3.02	1 : 2.50 : 2.60
49	M35	0.42	410.53	1 : 1.42 : 3.45	1 : 1.65 : 3.20	1 : 1.99 : 2.86	1 : 2.37 : 2.46
50	M40	0.39	442.11	1 : 1.29 : 3.16	1 : 1.51 : 2.93	1 : 1.82 : 2.61	1 : 2.17 : 2.25

VI. DISCUSSION

1. Water/cement ratio, cement content and proportions are varying with respect to grade of concrete. However fine aggregate to coarse aggregate proportion is remaining same irrespective of grade of concrete. The ratio of fine to coarse aggregate is changing as per standard grading curves.
2. As per Table 5 of IS method, the value of volume of coarse aggregate per unit volume of total aggregate can be obtained, but zone of fine aggregate and water/cement ratio are needed for correction volume of coarse aggregate per unit volume of total aggregate. The grading of total aggregate is ignored in present conventional method.
3. SMCGK Technique is inclusive of grading of total aggregate will be suggesting volume of coarse aggregate per unit volume of total aggregate irrespective of other parameters.
4. All the proportions presented above have been studied for inter relation of fine to coarse aggregate and volume of coarse aggregate per unit volume of total aggregate. The finding of the study has been presented in the following Table 3.

Table 3: Volume of Coarse Aggregate per Unit Volume of Total Aggregate for Different Grading Curves

Nominal Maximum Size of Aggregate	Volume of Coarse Aggregate per Unit Volume of Total Aggregate for Different Grading Curves			
	Curve 1	Curve 2	Curve 3	Curve 4
20 mm	0.70 – 0.72	0.65 – 0.67	0.58 – 0.60	0.50 – 0.52

VII. CONCLUSIONS

All the mix proportions by conventional method and SMCGK technique have been studied and compared. Following are the conclusions of present research:

1. As per SMCGK Technique, volume of coarse aggregate per unit volume of total aggregates depends only on grading curves irrespective of any other parameter. Refer Table 3 for volume of coarse aggregate to volume of total aggregates.
2. The proportion of coarse aggregate has increased and proportion of fine aggregate has decreased by SMCGK technique as compared to the conventional method. This trend of reduction in fine aggregate and increment of coarse aggregate content has been observed for all mixes.
3. In the present era, scarcity of natural sand has made artificial aggregate (fine aggregate) equivalent to cement from cost point of view. SMCGK technique has lowered fine aggregate content by 10% leading to reduce the cost of concrete. SMCGK Technique helps to reduce depletion of natural resource-sand.
4. SMCGK Technique based on grading of aggregate governs minimum voids in the concrete which leads improved durability of concrete and structure.

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