MIX DESIGN OF SELF COMPACTING CONCRETE USING LIME

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ABSTRACT. In this paper**,** Investigation for establishing a rational mix-design method with self-compatibility been carried out from the viewpoint of making self-compacting concrete. The design has been achieved using polycarboxylate ether as super plasticiser and Lime as an agent to reduce the bleeding and segregation. First, the optimum amount of superplasticizer is found using marsh cone test. The amount of paste (cement and water) is fixed as per the mix design requirement of the Indian Standard. The size amount of aggregate (coarse as well as fine) required is determined, and the content lime is then evaluated by trails to ensure that the concrete thus obtained has flowability, self-compacting ability and other desired SCC properties. Slump flow, J-Ring, V-funnel, L-flow, U-box and compressive strength tests were carried out to examine the performance of SCC, and the results indicate that the proposed method could produce successfully SCC of high quality. This method is simpler, easier for implementation and less time-consuming.

Keywords: Segregation, Bleeding, Self-Compacting, Flowability, Mix Design

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INTRODUCTION

SCC is the new kind of self-compactable concrete with excellent deformability and segregation resistance. It can fill the mould and heavily reinforced section without need of any vibration and compaction. This is increasingly used where horizontal element (floor) and vertical elements (walls) are constructed using concrete only. Self-compacting concrete have high fluidity, good segregation resistance and good compatibility as compared to ordinary concrete. Several authors have proposed different design methodology in order to obtain self compacting concrete.

Okamura and ozawa [1] proposed an empirical approach in which firstly coarse aggregates and fine aggregates are fixed and then self-compactibility is achieved by adjusting water to cement ratio and dose of super plasticizer. Peterson and Bilberg [2] proposed a design procedure based on close packing aggregate method, void content and blocking criteria. Sedran and De Larrard [3] proposed design procedure software is used which is based on compressive packing model. Khayat et al [4] proposed a design procedure uses statistical relation obtained between different mixture parameters and properties of concrete. Su et al [5] proposed a design procedure the content of fine and coarse aggregates is controlled by using the packing factor. Saak Jennings and Shah [6] proposed a procedure is based on rheology of paste model in which new segregation-controlled design methodology is introduced for SCC. Edamasta et al [7] proposed a procedure empirical relation between fine aggregate volume, volumetric water to powder ratio and super plasticizer ration is fixed by conducting mortar V-funnel testing and by using mortar flow.

Shi and Yang [8] proposed design procedure combination of paste theory and ACI guidelines are used to design self-consolidating light weight concrete. Hwang and Tsai [9] proposed a procedure maximum density theory and plastic theory is used to derive the densified mixture design algorithm Ferrara Park and Shah [10] proposed a design procedure steel fibre reinforced self-compacting concrete is based on paste rheology model. Ozbay et al [11] proposed the design procedure is based on L18 orthogonal array with six factors namely w/c ratio, fine aggregate to total aggregate, percentage fly ash content, air entraining agents' content and superplasticizer content. Ghazi and Al-jadiri [12] proposed the design procedure is based on ACI 211.1 method of proportioning conventional concrete and EFNARC method for proportioning SCC. Bouziane [13] proposed a design procedure is more useful in evaluating the effect of three types of sand proportion river sand, crushed sand and dunes sand) on fresh and hardened properties of SCC. Sebaibi and Benzerzour [14] proposed the design procedure is based on FNEN 206-1 standard and compressive packing model Khaleel and Razack [15] proposed the procedure is based on three phase system i.e. paste, mortar and concrete.

In this paper, a mix proportioning method modifying the design mix design methodology based on Indian standard guidelines is proposed. Poly carboxylic ether has been used as high-water reducing agent to enable the concrete its self-compacting properties. Lime is used as cement replacement. The results show that the design method can be used for mix proportioning of the self-compacting concrete.

TEST METHODS OF SCC

L-Flow Test: L-test used to measure the flowability and passing ability of the concrete. Firstly, the flowability is measured by pouring the concrete in L-Test apparatus with no reinforcement and then the flowability is measured using reinforcement. Then the height is compared in both the cases.

U-Flow Test: In U-Flow test flowability is measured by pouring the concrete in the left limb of the U –Test apparatus then the concrete is opened and concrete is rise in right limb therefore rise in the limb is noted which represent self compactibility of concrete.

Flow Table Test: Flow Table Test is used to determine the consistency of concrete. The concrete is filled in slump cone which is placed on the centre of the flow table the cone is then lifted and. the flow table is then lifted up and dropped that allow the concrete to flow. The diameter of the spread concrete is measured.

V-funnel: V-funnel measures a viscosity property of concrete and also detect the arching effect of aggregate. The flow time through the V funnel is measured. Large quantity of coarse aggregate will increase funnel flow time significantly.

J-Ring: This test measures the passing ability of concrete under its own weight to completely fill the space between the foam work. The slump cone filled with concrete is placed in between the J Ring apparatus. The cone is lifted and height of spread concrete after passing J Ring apparatus is noted with respect to the height of concrete in between the J Ring apparatus.

Compressive Strength Test: Compressive strength is the most common and useful property of concrete. In this test concrete cubes were tested once enough strength had been gained, normally after 28day, and placed in the curing tank until the age of testing. The cube of edge length of 150mm is used.

METHODOLOGY

With the help of superplasticizer, the viscosity of cement paste has been reduced to its minimum value. Then the amount and the grading of aggregate is decided in such a way that the obtained concrete is highly consistent and workable. To avoid internal segregation in the mix it is important to decide the maximum nominal size of coarse aggregate (C.A) as well as right proportion of coarse aggregate (C.A)/fine aggregate (F.A) needed to be chosen.

Mix design procedure of the proposed design

The mix design is based on the basic definition of concrete. To make the concrete, highly workable the amount of superplasticizer is kept to its maximum optimum content. Cement paste is chosen the dispersing medium and it consists of 40% of the total volume of total concrete. The rest 60% volume is occupied by the aggregate. To make concrete a homogeneous fluid, i.e. segregation resistant proper gradation of aggregate is also required. Since the obtained concrete was highly workable, it bleeds rapidly. To avoid bleeding, lime is used as an anti-bleeding agent.

Step 1: Optimization of superplasticizer content

Superplasticizer de-flocculate the cement particles which makes the cement paste more workable. It also reduces the viscosity of the paste thus results in more fluid. Hence, in super workable concrete it is essential to use a high range water reducer or superplasticizer. The optimum amount of superplasticizer is decided by using Marsh Cone Test. The test is based on the time taken by the paste to flow through marsh cone in less time. Paste is formed by mixing the consistent water and superplasticizer to the cement. As the content of superplasticizer is kept on increasing in consecutive samples the corresponding time to empty the marsh cone decreases. While adding different quantities of superplasticizer in the paste of consecutives sample, a quantity of superplasticizer is achieved after which either the time increases or remains roughly constant. That amount is considered as optimum superplasticizer content.

Step 2: Fixing the cement paste content

SCC contains higher amount of cement paste as compared to normal concrete. Therefore, in SCC the aggregates can easily adjust their position in the fresh state that would result in self-compaction. Cement paste acts as a lubricating agent for aggregates in fresh state, so its quantity needs to be fixed. If the quantity of cement paste is more than the required value there would be a chance of bleeding and internal segregation. As the quantity of superplasticizer used is high therefore, the amount of cement paste is fixed upto40% of the total concrete volume.

Step 3: Fixing the w/c ratio.

The quantity of water depends upon the desired workability and strength. To make SCC more workable it is important to decide the water content. As the quantity of water increases it would result in high workability but at the same time compressive strength and segregation resistance would decrease. The amount of water in SCC generally depends upon the consistency of cement. The water content in SCC is fixed at 8-10% more than the consistent water. So, w/c ratio for SCC mixture is generally kept between0.38 to 0.43.

Step 4: Proportioning of fine and coarse aggregate content

Fine and coarse aggregates should be proportioned in such a way that resulting concrete should provide desired workability and satisfactory strength. Fine aggregate increases the viscosity of paste and decreases the workability. So, the proportioning of fine aggregate should be done in such a way that the mixture provides enough viscosity due to which the internal segregation is avoided and finally, the obtained concrete is homogenous. Total aggregate content is taken as 60% of total volume of concrete and additional 5% stone dust (passing from 4.75mm and retained on 2.36mm) of total aggregate volume is also added. Equal volumetric proportion of coarse and fine aggregate of total volume of aggregate is taken.

Step 5: Gradation of coarse aggregate and fine aggregate

The maximum nominal size of coarse aggregate is taken as 10-12.5 mm. Aggregates whose size is greater than 10-12.5 mm are less segregation resistant, thus they settled down in the mix. Also, with increase in size of aggregate the consistency of concrete also reduces because more viscous mortar is required to avoid internal segregation. The fine aggregate used in mix is of Zone-III as per IS 383**.**

Step 6: Optimization of lime content to avoid bleeding

Lime has been added in the mix to avoid bleeding as well as to fill the gap in the grading of fine aggregates. Since lime reacts with water to form calcium hydroxide ($Ca\ (OH)_2$) which is also the by-products of cement, therefore it is important to use lime content as low as possible. However, with the increase in lime content the consistency of mix increases and the mix becomes more segregation resistant. In this study, 10% of cement is replaced by 15.15%, 21.21%, and 27.27% lime.

RESULTS AND DISCUSSION

The above proposed mix design is based on trial method. For the optimization of superplasticizer content Marsh Cone Test is used and for concrete performance flow table and j ring test is taken as reference test. Different properties considered during the experiments are (i) Flowability (ii) Segregation resistance (iii) Bleeding (iv) Diameter of spread and (v) J-ring height. (i) Flowability (ii) Segregation resistance and (iii) Bleeding are measured relative to the other sample. More the number of (+)ve signs higher is the value. More number of (-)ve sign, lower is the value. These values are based on visual inspection during the J-ring and flow table test. Higher the value of flowability and segregation resistance, better is the design. Lower the value of bleeding better is the design. The procedure of obtaining the above-mentioned mix is as follows.

Optimizing superplasticizer content

The test is followed as per ASTM C939. The content of superplasticizer was changed and the corresponding time taken by the cement paste to empty the funnel was noted and the test was performed on the consistent w/c ratio which was 0.32(by mass). Polycarboxylic ether was used as superplasticizer which was 50% diluted having a specific gravity of 1.04. The amount of cement used in experiment was 3.6 kg.

Table. 1 time required for the V-Funnel test.

Sp (ml)	90	120	160	200	240
Time (sec)	240	230	200	196	190

From the table 1, 160ml superplasticizer was the optimum content which is 4.61% of cement by mass.

Fixing fine and coarse aggregate content

Flow table and J ring test were performed for fixing the content of fine and coarse aggregate. In the flow table test, average diameter of poured concrete on flow table was measured. It has been observed that when concrete is poured on flow table and if there is a formation of heap of aggregate at the centre of table, it means that the concrete tends to segregate. After 2 min if there would be a boundary of bled cement on the periphery of concrete on the table, it means that the concrete has bled. Based upon the above observations the mix has been decided. Since, the heap of aggregate was not formed on the table while testing, a different mix containing same proportion was tested on J ring test. Viscosity modifying agent was also used to modify the viscosity of the concrete. Generally, it is kept as 1-2% of cement by mass. The following trials have been done to figure out the appropriate design.

Trial -I: The amount of cement paste is fixed at 40% of the total volume of concrete and the rest 60 % volume is occupied by the aggregates. The w/c ratio is fixed at 40% (by mass). The amount of super plasticizer is taken up to its optimum content. 4.61% superplasticizer and 2 % viscosity modifying agent of the mass of cement is also added. The flow table test has been conducted on the different quantities of fine and coarse aggregate (20mm nominal size). Fine aggregate of Zone III was selected for the mixture.

Table. 2 proportioning of fine and coarse aggregate.

	C.A/F.A (BY VOLUME)	FLOWABILITY	SEGREGATION RESISTANT	BLEEDING	AVERAGE DIAMETER (MM)	J-RING HEIGHT (MM)
Trial-A	7:3	-	-	+++	>800	>10
Trial-B	1:1	-	+	+++	>800	>10
Trial-C	10:11	++	++	++	780	>10

In all the above 3 trials, from table 2, it is evident that trial C is the best because it has more flowability as a homogenous mixture as compared to other trials but the quantity of coarse aggregate at the centre is more as compared to the periphery which means that the chance of settlement of coarse aggregates in the bulk concrete is more. So, to improve homogeneity there was a need to decrease the nominal size of coarse aggregate.

Trial II In this trial the proportions of mix are kept same as in trial I(C). Only the nominal size of coarse aggregate was graded.

Table 3 Grading of coarse aggregate.

	C.A/F.A (BY VOLUME)	%OF 20MM COARSE AGGREG-ATE	%OF 12.5MM COARSE AGGREG-ATE	FLOWABILITY	SEGREGATION RESISTA-NT	AVERAGE DIAMET-ER (MM)	J RING HEIGHT (MM)
Trial –A	10:11	100	0	+	-	780	>10
Trial –B	10:11	70	30	+	+	765	>10
Trial –C	10:11	30	70	++	++	730	>10
Trial –D	10:11	0	100	+++	+++	700	>10

In above all trials, from table 3, it is evident that trial –D was the best, as it has better segregation resistance and flowability of the homogenous mixture has also improved. Instantly after pouring the concrete on flow table the diameter was recorded. After few minutes bleeding occurs and the diameter increases. Therefore, to avoid bleeding and internal segregation it is important to fill the gap in the grading and hence stone dust was used to make mix more segregation resistant.

Trial III The stone dust that passed through 4.75mm and retained on 2.36mm was used and the quantity of stone dust was fixed at 5% of the total aggregate volume.

Table 4 Proportioning of coarse and fine aggregate

	C.A/F.A (BY VOLUME)	FLOWABILITY	SEGREGATION RESISTAN-CE	BLEEDING	AVERAGE DIAMETER (MM)	J RING HEIGHT (MM)
Trail –A	1:1	+	+	+++	740	>10
Trail –B	10:11	++	++	++	720	10

It can be seen from the table 4, Trial-III (B) has passed the J ring test and the obtained concrete has good flowability and segregation resistance. But after few minutes cement started bleeding. To avoid bleeding in the mix, powdered lime has been added. Since the lime reacts with water therefore extra water get consumed by lime, thus lime acts as an anti-bleeding agent. Cement was replaced with different percentage of lime and observations were made accordingly.

Trial IV Cement was replaced with different percentage of lime (by mass) and observations were made accordingly.

Table 5 addition of lime at different percentages

S.NO	CEMENT REPLACED	LIME ADDED	AVERAGE DIAMETER(MM)	J RING HEIGHT(MM)	BLEEDING
Trial –A	10%	15.15%	720	8	++
Trial –B	10%	21.21%	735	8	+
Trial –C	10%	27.27%	740	6	-

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Table 5 shows that the bleeding in Trial –C was less in comparison to the other trials and each of them has passed the J-ring and flow table test. V-funnel, L-box, U-box and Compression test has also been carried out on these samples to take care of flowability, filing ability, passing ability and strength. All these tests were performed on trial –A, as it contains minimum lime content and also bleeding was less in comparison to trial-I and trial-II. The following result has been obtained on performing these tests. Different physical properties of the final design of fresh and hardened concrete is shown in table 6. It can be seen that the properties are acceptable for self-compacting concrete.

Table. 6 Observations obtained after performing different test.

S.NO	TYPES OF TESTS	DESCRIPTION OF RESULTS	OBSERVED RESULTS
1	V funnel	Time taken (T)	10 sec
2	L Box	H_2/H_1	0.96
3	U Box	X_1-X_2	10 mm
4	Compression Testing	Compressive strength at 28 days (MPa)	30 Mpa

H_2= Height of concrete at the end of L Box.

H_1= Height of concrete at the rebar of L Box.

X_1= Height of concrete in the limb where concrete is poured first.

X_2= Height of concrete in the second limb after opening the middle gate.

CONCLUDING REMARKS

From the above data it has been concluded that the obtained concrete was SCC. Obtained concrete has satisfactory flowability, filing ability, passing ability and consistency. It has been concluded that the obtained mix has achieved the strength of 30 MPa. Lime was used as an anti-bleeding agent for the mix. If the bleeding is more than the content of lime can also be increased or 0.2-0.3% of superplasticizer can be reduced from its optimum content.

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