



Semi self compacting concrete –an innovative material

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ABSTRACT

Self compacting concrete is a form of concrete that is capable of flowing into the congested interior of formwork, passing through the reinforcement and filling it in a natural manner, consolidating under the action of its own weight without segregation and bleeding. The main disadvantage of self compacting concrete is that it is very difficult to make it without using superplasticizers or viscosity modifying agents. The use of these chemical admixtures makes the production cost of self compacting concrete high. An attempt has been made to develop a new material which will combine the advantages self compacting concrete and the normal compacting concrete. This innovative new material is given the name semi self compacting concrete. Semi self compacting concrete can be made without the use of chemical admixtures at the same time it is capable of flowing easily under the action of minimal external energy without the need for vibration. The procedure for making semi self compacting concrete has been presented. Semi self compacting concrete mixes were cast. Tests on fresh and hardened semi self compacting concrete were conducted. It is found that the semi self compacting mixes developed satisfied the requirements of flowability, passability and segregation resistance. The 56th day strength of the mixes was found to be satisfactory.

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Introduction

Concrete is the conventional form of material used for the construction of buildings, bridges, roads and other structures. Controlling the quality of concrete in the field is an extremely difficult task for the engineers. A certain amount of water is required for lubricating, handling the concrete without segregation, placing it in congested locations without the loss of homogeneity, and for compacting it. But the use of excess water for mixing the concrete and inadequate compaction may result in the reduction of strength and durability of the concrete by the formation of capillary cavities and air voids. The production of concrete that does not require vibration was a challenge for the researchers.

With the introduction of super-plasticizers and viscosity modifying agents, it is now possible to produce concrete with high fluidity, good cohesiveness and does not require external energy for compaction. Self compacting concrete is a form of concrete that is capable of flowing into the congested interior of formwork, passing through the reinforcement and filling it in a natural manner, consolidating under the action of its own weight without segregation and bleeding. Self compacting concrete has many advantages over the conventional concrete. Some of the advantages of self compacting concrete are reduction in manpower, excellent surface finishes, easier placing, free from honey combs, reduced permeability, improved durability, reduction in noise levels, absence of vibration and ensured compaction. The major disadvantage of self compacting concrete is that it cannot be made without using super plasticizers or viscosity modifying agents. Use of these chemical admixtures will increase the production cost of self compacting concrete. Self compacting concrete is yet to become a popular

construction material as the production cost of self compacting concrete is higher than that of normal compacting concrete due to the use of chemical admixtures. Hence an attempt has been made to introduce a new material which will combine the advantages of both self compacting concrete and normal compacting concrete. This innovative new material is called Semi self compacting concrete.

Semi Self Compacting Concrete

Semi self compacting concrete is a form of concrete that is capable of flowing into the congested interior of formwork, passing through the reinforcement and filling it in a natural manner and consolidating under the action of minimum external energy, without the use of chemical admixtures. In developing semi self compacting concrete, partial replacement of aggregates with industrial byproducts such as flyash is done to economize its use. It does not require vibration.

Semi self compacting concrete has a high rate of flow ability, at the same time the cost will be comparable with that of normal compacting concrete. Semi self compacting concrete has an edge over normal compacting concrete due to its better performances like better surface finishes, easier placing, elimination of honey comp cavities, reduced permeability, improved quality, durability etc. Also it is economical compared to self compacting concrete due to reduced cost of construction as chemical admixtures are not used in designing the mixes. Hence it combines the advantages of both normal compacting concrete and self compacting concrete and has a high potential to become a promising material in the construction industry.

Literature Review

Self compacting concrete, a new kind of high performance concrete was first developed in Japan in the year 1988.

Okamura¹ proposed a mix design method for self compacting concrete. The main idea proposed was to conduct first test on paste in order to examine the properties and compatibility of the super plasticizer, cement, fine aggregate and pozzolanic materials, which was then followed by the trial mix of self compacting concrete. The standard mix design method of self compacting concrete proposed by Japanese Ready-Mixed Concrete Association is a simplified version of Okamura's method².

Nan Su et al³ developed a simple mix design method for self-compacting concrete. However this method depends on the selection of a parameter called packing factor for which no scientific guidelines are available.

Persson⁴ compared the mechanical properties of self compacting concrete and the corresponding properties of normal concrete. It was found that creep, shrinkage and elastic modulus of Self compacting concrete coincided well with the corresponding properties of normal concrete when the strength was held constant.

Malathy⁵ evaluated the optimum dosage of super-plasticizer for each mineral admixture at different replacement levels to develop the high strength self-compacting concrete and to check the self-compatibility as per the Japanese Standard for Civil Engineering Specifications.

Malathy and Govindasamy⁶ made an attempt to develop the mix design for Self compacting concrete of different grades varying from M₂₀ to M₆₀ and tests are conducted for the fresh and hardened properties of self compacting concrete. A mix design chart has been developed to obtain the quantity of cement, fly ash, sand and coarse aggregate required for different grades of self compacting concrete.

Vengala, Sudharsan and Ranganath⁷ made an experimental study to obtain self-compactable concrete. Fifteen mixes were investigated. The water-cement ratio was maintained constant for all excepting for the initial mixes. Super-plasticizer was employed to increase the workability of normal slump concrete. The super-plasticizer dosage was also kept constant. To obtain the required flow in Self compacting concrete, fly ash replacement of 5,10,15,20 and 25 percent, respectively, of coarse aggregate was adopted. Viscosity Modifying Agent (VMA) was tried in different dosages to stabilize the mix further. Slump flow test and L box tests as recommended in literature were carried out to obtain the properties of flow ability and workability of fresh concrete. The mechanical properties of hardened concrete were also investigated in terms of compressive strength.

Riaz, Vishnuram and George⁸ made an experimental study on medium strength self-compacting concrete using fly ash. An attempt was made to arrive at mix proportions for medium strength M₂₀ and M₂₅ grade of Controlled Concrete (CC) self compacting concrete using locally available materials. Fly ash was used as a replacement for cement in self compacting concrete. The aim is to arrive at different mix proportions of concrete from different percentages of fly ash with required quantity of super-plasticizers and viscosity modifying agents in order to satisfy the workability requirements and to determine the different physical and mechanical properties of concrete. Experimental works also included studying properties of fresh and hardened state of normal compacting concrete and self compacting concrete.

Based on the literature review, it is found that self compacting concrete cannot be made without using super

plasticizers or viscosity modifying agents. Use of these chemical admixtures will increase the production cost of self compacting concrete. Hence an attempt has been made to produce a concrete that has the ability to get consolidated, under minimum external energy without using vibrators. This concrete is designated as semi self compacting concrete.

Methodology

With the availability of 43 and 53 grade cements in Indian market, it is easy to meet the strength requirements of concrete mixes. However, it is very difficult to meet the requirements of workability and durability. Poor workability will lead to difficulties in placing concrete which will lead to honey combs.

In the field, those who are making concrete will try to add more water than required to improve the workability which is not a good practice. Workability has to be improved wither by adding chemical admixtures or mineral admixtures. The cost of chemical admixtures is high and hence addition of chemical admixtures to improve the workability is not common for making concretes having normal strength.

The introduction of semi self compacting concrete will enable the engineers to design mixes with a very high workability without any need to add the costly chemical admixtures. In developing semi self compacting concrete, partial replacement of aggregates with industrial byproducts such as flyash is done. The steps involved in the design of semi self compacting concrete mixes are given in Fig.1.

From the flowchart, it can be seen that the coarse aggregate is replaced with the required amount of flyash if its content is more than that of the fine aggregate otherwise the fine aggregate is replaced with flyash until the mix satisfies the requirements of semi self compacting concrete. Thus the general principle that the quantity of coarse aggregate must be slightly less than that of the fine aggregate followed in designing self compacting concrete mixes is followed while designing semi self compacting concrete mixes.

Requirements of semi self compacting concrete

Concrete is classified as self compacting, if it satisfies the requirements of filling ability, passing ability and resistance to segregation. Many tests are available in the literature to check the filling ability, passing ability and segregation resistance. The commonly adopted tests for self compacting concrete are shown in Table 1.

For the present study, slump flow test, J-Ring test and V-funnel test have been identified to test the filling, passing and segregation resistance. The acceptance criteria for semi self compacting concrete has been assumed to have a value which is approximately midway between the values of self compacting concrete and normal compacting concrete. The concrete mixes developed using the semi self compacting concrete mix design procedure will be classified as semi self compacting mixes, if the requirements given in Table 2. are satisfied.

Mix ratios and Material Contents for Normal Concrete

The normal compacting concrete mixes for M20, M25, M30, M35, M40 and M45 were designed using the excel spread sheet developed for British Standard (BS) method. The design details are shown in Table 3.

Developing semi self compacting concrete from normal compacting concrete

The mix proportions designed for normal concrete were modified to obtain semi self compacting mixes using the procedure given in Fig.1. Initially 10% of the coarse aggregate is replaced with flyash and the amount of water required for semi

self compacting concrete mix is determined from the water powder ratio. Powder content is taken as weight of cement and flyash. If the obtained proportion of concrete mix satisfies the acceptance criteria of semi self compacting concrete, it is considered to be semi self compacting; otherwise higher percentage of coarse aggregate is replaced by flyash to obtain semi self compacting concrete mix proportion.

Mix Ratios and Material Contents for semi self compacting concrete

The semi self compacting concrete mixes were designed for M20, M25, M30, M35 and M40 concrete without using any chemical admixtures. M45 mix could not be developed without using chemical admixtures as it did not satisfy the requirements of semi self compacting concrete without admixtures. The details of the mixes designed are shown in Table 4.

Tests on semi self compacting concrete

Tests were conducted on fresh and hardened semi self compacting concrete specimens. The filling ability, passing ability and resistance to segregation were found from the Slump Flow Test, J-Ring Test and V-funnel Test respectively. Compressive strengths of semi self compacting concrete mixes were found after 7,14, 28, 35 and 56 days of curing.

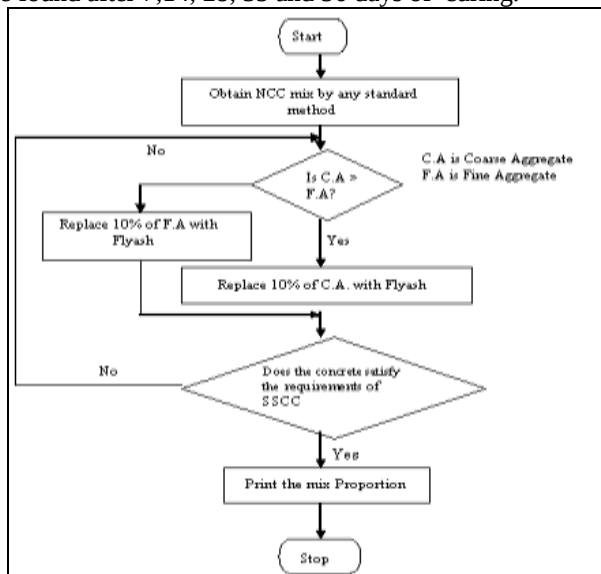


Fig.1. Flowchart for the Design of Semi Self Compacting Concrete Mixes

Results of the Tests on Fresh semi self compacting concrete

The mixes were developed using British Standard Method and the designed mixes were made semi self compacting by replacing coarse aggregate content with flyash by trial and error method. Five mixes were designed and the fresh concrete mixes were subjected to following three tests.

- 1) Slump Flow Test
- 2) J-Ring Test
- 3) V-Funnel Test

The results of the tests on fresh semi self compacting concrete are given in Table 5. It is seen from the table that all the semi self compacting concrete mixes satisfy the criteria and hence deemed to have the semi self compacting ability.

Results of the Tests on Hardened semi self compacting concrete

The specimens used were standard cubes of size $150 \times 150 \times 150$ mm. Tests were conducted using compression testing machine of capacity 2000kN. The tests were carried at a uniform rate of $14\text{N/mm}^2/\text{minute}$ after the specimen had been centered in the testing machine. The compressive strengths of semi self

compacting concrete mixes after 7days, 28days, 35days and 56 days of curing were found. For normal compacting concrete, compressive strengths were found after 28days of curing. For the different grades of concrete, graphs are plotted between the compressive strengths and number of days and the graphs are shown in Fig2.

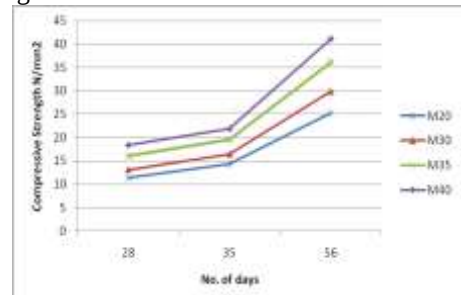


Fig 2. Compressive strength of Semi Self Compacting Concrete without using Super Plasticizer

The comparison of compressive strength for normal compacting concrete and semi self compacting concrete without using super-plasticizer is shown in Table 6.

Inference

It is found that 28th day compressive strengths of semi self compacting concrete are lower than that of the required characteristic strength. This is mainly due to the presence of flyash. However the 56th day strengths of semi self compacting concrete without super plasticizers are meeting the requirements.

Cost of Concrete Mixes

The different grades of concrete such as M20, M25, M30, M35 and M40 mixes of normal compacting concrete were designed, following the guidelines given in SP:23.

For all the above grades of concrete, semi self compacting concrete mixes were designed using the mix design procedure developed for semi self compacting concrete.

Adopting the rates prevailing at the place of investigation, the cost/m³ of normal compacting concrete and semi self compacting concrete were arrived and the details are shown in Table 7.

It can be seen from Table.7 that the cost of semi self compacting concrete are only marginally higher that that of normal compacting concrete.

Conclusions

A new innovative concrete namely semi self compacting concrete has been developed, which is superior to normal compacting concrete. The workability of semi self compacting concrete is very high compared to normal compacting concrete. Hence it can be easily placed in places of heavy reinforcements. The requirements of semi self compacting concrete have been recommended.

The flow properties of semi self compacting concrete mixes developed for various grades satisfy the recommended values. It has been found that the cost of semi self compacting concrete is only marginally higher than that of normal compacting concrete. The cost of semi self compacting concrete is 5% more, for M20, M25 and M30 mixes, and 10% more, for M35 and M40 mixes when compared to normal compacting concrete.

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Table 1. List of Methods Available for tests on Fresh Self compacting concrete

Sl. No	Method	Property
1	Slump-flow	Filling ability
2	T ₂₀ slump flow	Filling ability
3	J-Ring	Passing ability
4	V-funnel	Filling ability
5	V-funnel	Segregation Resistance
6	L-Box	Passing ability
7	U-Box	Passing ability
8	Fill-Box	Passing ability
9	GTM Screen test	Segregation Resistance
10	Orimet	Filling ability

Table 2. Requirements for Self compacting concrete and Semi self compacting concrete

Sl. No.	Test	Property	Acceptance Criteria for self compacting concrete	Acceptance Criteria for semi self compacting concrete
1.	Slump flow	Filling ability	Minimum diameter 650 mm	Minimum diameter 300 mm
2.	J-Ring	Passing ability	Maximum level difference 10 mm	Maximum level difference 25 mm
3.	V-funnel	Filling ability	Maximum time 12 seconds	Maximum time 25 seconds
4.	V-funnel	Segregation resistance	T5 time should not exceed V-funnel time by 3 seconds	T5 time should not exceed V-funnel time by 15 seconds

Table 3. Mix Ratios and Material Contents for Normal Compacting Concrete

Sl. No.	Grade	Mix Proportion C:FA:CA	Water/ Cement ratio	Cement content kg/m ³	Sand Content kg/m ³	Coarse aggregate content kg/m ³	Water content l/m ³
1	M20	1: 2.1: 4.06	0.55	327.27	686.62	1331.68	180
2	M25	1: 2.1: 4.06	0.55	327.27	686.62	1331.68	180
3	M30	1: 1.91: 3.87	0.52	346.15	659.60	1338.88	180
4	M35	1: 1.68: 3.57	0.48	375.00	630.40	1339.60	180
5	M40	1: 1.51: 3.22	0.44	409.09	619.49	1316.42	180
6	M45	1: 1.31: 2.90	0.40	450.00	587.45	1305.55	180

C- Cement

FA – Fine aggregate

CA – Coarse aggregate

Table 4. Mix Proportions for Semi self compacting concrete

Sl. No.	Grade	C: FA:CA: Flyash	w/c ratio	Water/ powder ratio	Cement content kg/m ³	FA content kg/m ³	CA content kg/m ³	Flyash content kg/m ³	Water content l/m ³
1	M20	1:2.1:2.98:0.99	1.10	0.55	327.27	686.62	975.10	325.03	358.96
2	M25	1:2.1:2.98:0.99	1.10	0.55	327.27	686.62	975.10	325.03	358.96
3	M30	1:1.91:2.52:1.35	1.22	0.52	346.15	659.50	870.78	468.64	423.70
4	M35	1:1.68:2.33:1.25	1.08	0.48	375.00	630.40	870.78	468.31	405.60
5	M40	1:1.51:1.91:1.28	1.01	0.44	409.09	619.49	781.10	526.42	411.83

Table 5. Results of the Tests on Fresh Semi self compacting concrete

Sl. No.	Grade	Cement: FA:CA: Flyash	Slump Flow Diameter (mm)	J-Ring Height Difference (mm)	V-Funnel Flow Time (Sec)
1	M20	1:2.1:2.98:0.99	390	23	25
2	M25	1:2.1:2.98:0.99	390	23	25
3	M30	1:1.91:2.52:1.35	480	24	14
4	M35	1:1.68:2.33:1.25	460	25	16
5	M40	1:1.51:1.91:1.28	480	24	18

Table 6. Comparison of Compressive Strength for Normal Compacting Concrete and Semi Self Compacting Concrete

Grade	Compressive Strength of normal compacting concrete at 28days (N/mm ²)	Compressive Strength of semi self compacting concrete at 28days (N/mm ²)	Compressive Strength of semi self compacting concrete at 35days (N/mm ²)	Compressive Strength of semi self compacting concrete at 56days (N/mm ²)	% Reduction in the Compressive Strength of 56 th day strength of semi self compacting concrete w.r.t 28 day normal compacting concrete strength
M20	25.30	11.36	14.3	25.23	0.07
M25	25.30	11.36	14.3	25.23	0.07
M30	31.75	13.13	16.45	29.91	2.49
M35	35.67	16.10	19.65	36.21	2.84
M40	42.72	18.40	21.86	41.15	3.05

Table 7. Comparison of Cost of Normal Compacting Concrete and Semi Self Compacting Concrete

Sl. No.	Grade of Concrete	Cost of Concrete in Rs./m ³	
		Normal Compacting Concrete	Semi self compacting concrete
1.	M20	2600	2750
2.	M25	2600	2750
3.	M30	2700	2900
4.	M35	2800	3100
5.	M40	3000	3300