Characterization of Self-compacting Concrete using Viscosity Modifying Admixtures

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Abstract - *Viscosity-modifying admixtures change SCC cohesion without changing fluidity (VMA). These admixtures are added to the SCC to make it less sensitive to tiny variations in quantities and circumstances. This is done by decreasing fluctuations in sand moisture, particles, and grain size distribution. They shouldn't be used to avoid a solid mix design and careful selection of other SCC ingredients. Both prerequisites aren't met.*

Key Words: Viscosity Modifying Admixture, Rheology, V-funnel, L-box

1. Introduction

As megastructures are built across the world, self-compacting concrete (SCC) is becoming more popular. It's one of the latest high-performance concrete innovations in our industry. Reinforcement congestion affects many places. Cyclonic storms and massive pillar capacity additions. SCC is the sole alternative for tough site settings. The genuine quality of the concrete in the final building and its longevity should be enhanced by developing a concrete mix that minimises the impact of site-specific craftsmanship on putting and compaction. This drove SCC's growth.

SCC is an innovation in concrete technology because to its improved performance and more pleasant working environment. It's employed for thin components and big, robust constructions. SCC is considered the most major technological innovation in concrete technology in recent history. SCC will likely replace ordinary concrete due of its many features. SCC, sometimes called Rheodynamic concrete, does not require vibration for placement and compaction. Even with crowded reinforcement, it may flow under its own weight, filling formwork and compacting fully. The hardened concrete is thick, uniform, and as durable as typical vibrated concrete. SCC's theory is that aggregate settlement is proportional to new concrete viscosity.

SCC may be made with typical concrete ingredients. Tighter tolerances are needed to regulate workability. SCC is proportioned more scientifically than ordinary concrete mixes. SCC mix must have a high powder content, but less coarse aggregate, high-range superplasticizer, and VMA. SCC is workable by balancing fluidity, deformability, filling ability, and segregation resistance. Okamura in Japan developed it, and it's shown to be inexpensive and durable. It's a type of concrete that doesn't require vibration or compaction during placement since it can flow through reinforcing and formwork corners. SCC is fluid, resists segregation, and self-compacts without vibration during placement.

1.1 Viscosity modifying admixtures

Viscosity-modifying admixtures change SCC cohesion without changing fluidity (VMA). These admixtures are added to the SCC to make it less sensitive to tiny variations in quantities and circumstances. This is done by decreasing fluctuations in sand moisture, particles, and grain size distribution. They shouldn't be used to avoid a solid mix design and careful selection of other SCC ingredients. Both prerequisites aren't met.

1.2 Functions of VMA

A VMA modifies cement paste rheology. Yield point is the force required to move concrete. The slump test can be used to determine the yield point of concrete. Plastic viscosity defines a concrete's reluctance to flow. Friction causes viscosity. Plastic viscosity affects concrete's flow rate.

Getting the right concrete rheology requires balancing the yield point and plastic viscosity. VMAs modify the rheological characteristics of concrete by raising the plastic viscosity and yield point. Plasticizers are used with a VMA to reduce the yield point.

So, VMAs are admixtures for specialised uses. They reduce segregation in highly flowable concrete, washout in underwater concrete, friction and pressure in pumped concrete, compensate for poor aggregate grading, notably a lack of particles in the sand, reduce concrete bleeding, and improve semi-dry concrete green strength.

2. METHODOLOGY

This chapter describes the process in depth. As the effort involves improving the qualities of concrete, several trials have been conducted. The work performed in relation to a flowchart that was created expressly for this project. They are discussed in further detail.

2.1 Rheology of concrete

The science of the deformation and flow of matter, rheology is concerned with the interactions between stress, strain, strain rate, and time. Rheology is the study of materials whose flow characteristics are more complex than those of ideal liquids, which are governed by Newton's rule of viscous flow, namely. Liquids whose shear stress is proportional to the rate of shear strain are referred to as Newtonian. The flow characteristics of new concrete do not comply. For concrete, the ratio of shear stress to shear rate is not constant. The fact that concrete can stand in a pile (as in a slump test) indicates that a certain minimum tension is required for flow to take place.. The minimum stress is called as yield stress and designated by symbol τ_0. Thus for fresh concrete the flow equation is expressed by Bingham equation which can be written as

$$\tau = \tau_0 + \mu \gamma'$$

Where τ = yield value indicating cohesion of material.

μ = Plastic viscosity

γ' = Rate of shear.

Thus, Bingham's equation describes the connection between shear stress and material cohesion, plastic viscosity, and shear load application rate.

2.2 Mix Design Results

Table -1: Mix Design Summary

Material required as per mix design (In Kg)	**For M 35 Grade**	**For M 25 Grade**
Cement	390	360
Course Aggregare	1083	978
Fine Aggregate	580	562
Water	148	145
Plasticizer	3.9	3.7
V.M.A.	2.75	2.75

3. EXPERIMENTAL INVESTIGATION

The investigation of properties of self-compacting concrete has been divided into two main parts based on its physical forms.

Investigation of properties in hardened state which includes three properties

Compressive Strength

Tensile Strength

Flexural Strength

Investigation of properties in fresh state (Rheological). This investigation includes following tests:

Slump Flow Test

V- funnel Test

L- Box Test

J- Ring Test

Slump Flow Test

The slump flow is used to assess the horizontal free flow of SCC in the absence of obstructions. It was first developed in Japan for use in assessment of underwater concrete. The test method is based on the test method for determining the slump. The diameter of the concrete circle is a measure for the filling ability of the concrete.

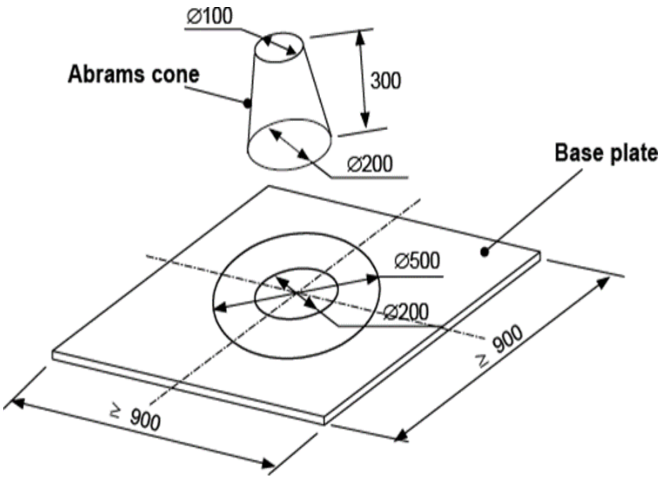

Fig.-1 Slump Flow Test

Assessment of test

This is a simple, speedy test process; however, two individuals are required to measure the T500 or T500mm time. It may be utilised on site, however the size of the base plate makes it fairly cumbersome and flat ground is required. It is the most popular test and provides an accurate evaluation of filling ability. It does not indicate the concrete's capacity to move through reinforcement without obstruction, but it may indicate resistance to segregation. It might be claimed that the entirely free flow, unrestricted by boundaries, is not reflective of concrete building in actuality, but the test can be used advantageously to evaluate the consistency of delivery of ready-mixed concrete to a site from load to load..

Equipments

The apparatus is shown in figure.

Mould in the shape of a truncated cone with the internal dimensions 200 mm diameter at the base,100 mm diameter at the top and a height of 300 mm.

Base plate of a stiff non absorbing material, at least 900mm square, marked with a circle marking the central location for the slump cone, and a further concentric circle of 500mm diameter

Trowel
Scoop
Ruler
Stopwatch (optional)

Procedure

The test requires approximately 6 litres of concrete, sampled routinely. Wet the base plate and the interior of the slump cone, Place the base plate on sturdy, level ground and the droop cone in the centre of the base plate, pressing down hard. Use the scoop to fill the cone. Do not tamp the concrete; instead, use the trowel to level it with the top of the cone. Remove any excess concrete from around the cone's base. Raise the cone vertically and permit the concrete to freely flow out. Start the stopwatch simultaneously and record the time required for the concrete to reach the 500mm (50cm) spread circle. (This is the time for the T500) Determine the concrete's ultimate diameter in two perpendicular directions. Determine the mean of the two diameter measurements. This is the slump flow in millimetres. Note any mortar or cement paste without coarse aggregate at the edge of the concrete pool.

Explanation of outcome

The bigger the slump flow (SF) value, the greater the capacity of the material to fill a formwork under its own weight. A minimum value of 650mm is necessary for SCC. There is no widely acknowledged guidance for acceptable tolerances around a particular value, however 50mm, as with the associated flow table test, may be acceptable.

The T500 time is a supplementary flow indicator. The lesser the time, the higher the flowability. According to the research conducted by Brite Eu Ram, a time range of 3-7 seconds is appropriate for civil engineering applications, whereas 2-5 seconds is good for housing applications.

In the event of extreme segregation, the majority of coarse aggregate will remain in the centre of the concrete pool, while mortar and cement paste will remain on the concrete's perimeter. In the event of mild segregation, a border of mortar devoid of coarse aggregate may form around the perimeter of the concrete pool. There is no promise that segregation will not occur if none of these occurrences occur, as this is a time-dependent factor that can arise after a longer duration.

V-Funnel Test

The test was created in Japan, and Ozawa et al. utilised it. As seen in Figure 8, the equipment comprises of a V-shaped funnel. In Japan, the O funnel, a variant of the V-funnel with a circular part, is also utilised. The stated V-funnel test is used to measure the filling ability (flowability) of 20mm aggregate concrete. The time it takes for around 12 litres of concrete to flow through the equipment is measured once the funnel is filled with concrete. The funnel may then be refilled with concrete and given five minutes to settle. If the concrete exhibits segregation, the flow time will be greatly increased.

Evaluation of test

Although the test is intended to determine flowability, the outcome is impacted by other concrete qualities. The inverted cone form will reflect any tendency of the concrete to set if, for instance, there is an excessive amount of coarse aggregate. High flow time is also related with limited deformability as a result of a significant paste viscosity and high inter-particle friction.

Although the equipment is straightforward, the influence of the funnel's angle and the wall effect on the flow of concrete is unclear.

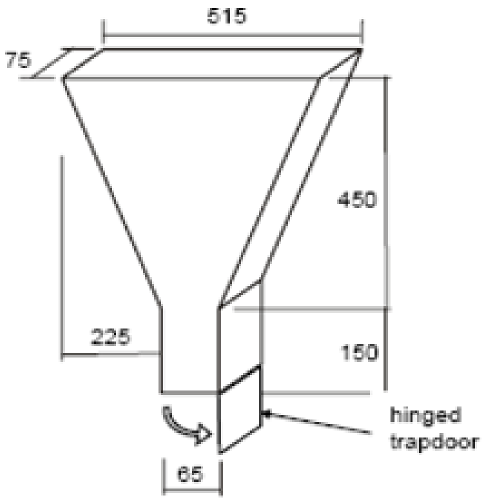

Fig.-2 V-funnel Test

Equipments

V-funnel
bucket (±12 liter)
trowel
scoop
stopwatch

Procedure flow time

Approximately 12 litres of concrete are required for the test, sampled routinely. Place the V-funnel on stable ground. Moisten the funnel's inside surfaces. Maintain the trap door open so any excess water may drain. Close the pit's entrance and position a bucket beneath. Fill the device to the brim with concrete without compacting or tamping it; just level the concrete with the trowel. After filling the trap door, open it within 10 seconds and allow the concrete to flow out under gravity. When the trap door is opened, start the timer and record the duration of the discharge (the flow time). This is assumed to be the case when light can be seen entering the funnel from above. The entire examination must be completed within 5 minutes.

L-Box Test

Petersson has detailed this test based on a Japanese design for underwater concrete. The test evaluates the flow of the concrete as well as its resistance to blockage by reinforcing. The device is depicted in the picture. The equipment consists of an L-shaped rectangular box with a vertical and horizontal part, divided by a movable gate, in front of which reinforcing bars are mounted vertically. After filling the vertical part with concrete, the gate is raised to let the concrete to flow into the horizontal area. When the flow has ceased, the height of the concrete at the end of the horizontal section is indicated as a percentage of the remaining height in the vertical section (H2/H1 in the diagram). It represents the resting slope of the concrete. This is an indication of passing capacity, or the degree to which concrete cannot pass through the bars. The horizontal portion of the box can be marked 200mm and 400mm from the gate, and the timings required to reach these places can be measured. These are known as the T20 and T40 timings, and they indicate the capacity for filling. The bar sections may have varying diameters and be placed at varying intervals; in accordance with standard reinforcing considerations, three times the maximum aggregate size may be suitable. The bars can be put at essentially any distance apart to apply a greater or less rigorous test of the concrete's ability to pass.

Assessment of test

This is a commonly utilised laboratory and maybe field test. It evaluates the capacity of SCC to fill and pass, and a severe lack of stability (segregation) can be observed visually. Additionally, segregation can be found by later cutting and analysing horizontal concrete portions. Unfortunately, there is no consensus on materials, size, or placement of reinforcing bars, making it challenging to compare test findings. There is no information about the impact of the apparatus' wall and the resulting "wall effect" on the concrete flow, although this setup replicates, to some extent, what occurs on-site when concrete is contained within formwork.

When measuring times, two operators are necessary, and operator error is unavoidable.

Equipments

L box of a stiff non absorbing material see figure .
trowel
scoop
stopwatch

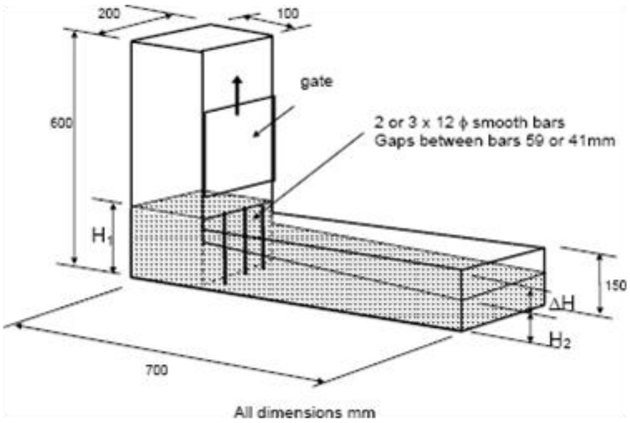

Fig.-3 L-Box Test

Procedure

Approximately 14 litres of concrete are required for the test, when sampled properly. Adjust the apparatus to a level position on solid ground, ensuring the sliding gate can open easily, and then close the gate. Moisten the inside surfaces of the device and remove excess water. Fill the device' vertical portion with the concrete sample. Allow it to rest for 1 minute. Raise the slidable gate and let the concrete pour into the horizontal part. Start the timer and note the time it takes for the concrete to reach the 200 mm and 400 mm markings simultaneously. After the concrete stops flowing, "H1" and "H2" lengths are measured. Calculate the blocking ratio, H2/H1. The entire examination must be completed within 5 minutes.

Interpretation of result

If the concrete is as fluid as water, it will be horizontal at rest, hence H2/H1 = 1. The closer this test score, the "blocking ratio," is to one, the greater the concrete's flow. The EU study team proposed an acceptable minimum value of 0.8. T20 and T40 periods can provide some insight into the ease of flow, although no commonly accepted numbers exist. Visual inspection reveals the obvious blockage of coarse aggregate beneath the reinforcing bars.

4. RESULTS AND DISCUSSIONS

Following the proportioning of the concrete to obtain the necessary qualities of self-compacting concrete, the following tests were conducted to assess whether or not the concrete satisfied these criteria.

4.1 Results of tests done hardened concrete

During this stage of the testing, we will be utilising M35 and M25 concrete, both of which are different grades.

In order to evaluate the material's ability to withstand compression, we made a set of 12 cubes out of it after it had been cured for 7, 14, and 28 days, respectively.

Before casting 12 cylinders, we cured the material for seven days, fourteen days, and twenty-eight days respectively in order to get an accurate reading of the tensile strength of the materia During this round of the testing, we will use M35 and M25 concrete, which are of distinct grades.

To examine the material's capacity to endure compression, we created a set of 12 cubes from it after 7, 14, and 28 days of curing, respectively.

Before casting 12 cylinders, the material was cured for seven days, fourteen days, and twenty-eight days in order to obtain an accurate assessment of the material's tensile strength.

After the material had been cured for 7, 14, and 28 days, a total of 12 beams were cast to assess its flexural strength at each of these intervals.

In order to complete the process of acquiring the appropriate rheological qualities, several types of testing are also conducted..

After the material was cured for 7, 14, and 28 days, we cast a total of 12 beams so that we could evaluate its flexural strength at each of those time intervals.

In addition, different kinds of tests are carried out in order to complete the process of achieving the desired rheological properties.

Table -2: Test Result Summary of hardened concrete

Grade Of Concrete	**Type Of Concrete**	**Compressive Strength**	**Splitting Tensile Strength**	**Flexural Strength**
M 35	Normal	36.60	3.84	3.95
	Scc	33.31	3.87	4.05
M 25	Normal	27.60	3.51	3.32
	Scc	27.05	3.47	3.36

Above results are summary of tests done after 28 days of curing. These results are mean of 12 cubes each.

4.2 Results of tests done fresh concrete

Table -3: Test Result Summary of fresh concrete

Grade Of Concrete	**Slump Flow**	**V funnel time**	**L- box ratio**	**J- Ring**
M 35	620	7.0	0.91	7.5
	625	7.5	0.89	7.0
	615	8.0	0.85	6.8
M 25	675	8.0	0.85	6.8
	680	10.0	0.95	7.4
	695	9.5	0.82	7.8

4.2 Mathematical Modelling

From above results following mathematical modelling has been established for compressive strength, tensile strength and flexural strength.

Mathematical modelling for compressive strength

σ cus = 0.028(0.04E - 0.5x4 - 0.0036x3 + 0.0924x2 - 0.444x + 36.089)

Where σ cus = Compressive strength of self-compacting concrete

Mathematical modelling for tensile strength

σ ts = 0.23(0.002E-1.95x4 – 4.01x3 + 0.995x2 - 0.4x + 5.289)

Where σ ts = Tensile strength of self-compacting concrete

Mathematical modelling for flexure strength

σ ts = 0.23(0.00195E-1.95x4 – 4.01x3 + 0.995x2 - 0.4x + 5.289)

Where σ fs = Flexural strength of self-compacting concrete

In above equations, x is variable and is defined as the ratio of slump value in m by weight of VMA/cum.

And E is the modulus of elasticity of self-compacting concrete

5. CONCLUSION

All of the samples, when they were fresh, exhibited self-compacting properties that were satisfactory. Following are some observations that were made based on the findings of the hardened state concrete:

- The compressive strength of Self compacting concrete is found to be 33.31 Mpa on average, whereas the compressive strength of normal cement concrete is found to be 36.6 Mpa.

- The flexural and tensile strengths did not experience major changes.
- Adding VMA to SCC was found to be an effective solution for preventing the segregation by making the concrete more cohesive.
- SCC with VMA is very effective in increasing pump-ability of concrete.

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