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A Comparative Study of Effect of Size of Aggregate on Mechanical Properties of Self Compacting Concrete with M55 Grade

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Abstract- Concrete is a versatile widely used construction material. Ever since concrete has been accepted as a material for construction, researchers have been trying to improve its quality and enhance its performance. Recent changes in construction industry demand improved durability of structures. At present there is a large emphasis on performance aspect of concrete. One such thought has lead to the development of Self Compacting Concrete (SCC). It is considered as "the most revolutionary development in concrete construction". SCC is a new kind of High Performance Concrete (HPC) with excellent deformability and segregation resistance. It can flow through and fill the gaps of reinforcement and corners of moulds without any need for vibration and compaction during the placing process. The features of mix proportion of SCC include low water to cementitious material ratio, high volume of powder, high paste to aggregate ratio and less amount of coarse aggregate. One of the popularly employed techniques to produce Self Compacting Concrete is to use fine materials like Fly Ash, GGBFS etc; in concrete, besides cement, the idea being to increase powder content or fines in concrete. The original contribution in the field of SCC is attributed to the pioneering work of Nan Su etal; who have developed a simple mix design methodology for Self-Compacting Concrete. In this method, the amount of aggregate required is determined first, based on Packing Factor (PF). This will ensure that the concrete obtained has good flow ability, self compacting ability and other desired SCC properties. The European Federation of Producers and Applicators of Specialist Products for Structures (EFNARC) [2005] have also laid down certain guidelines for fresh properties of SCC. The present investigation is aimed at developing high strength Self Compacting Concrete of M55 Grade. SCC characteristics such as flow ability, passing ability and segregation resistance have been verified using slump flow, L box and V funnel tests. To study the Physical Properties of the materials used in our work. To study the Mechanical Properties of the obtained SCC & FRSCC.

Keywords: Self-Compacting Concrete, Fly ash, slump flow test, L box test, V funnel test.

I. INTRODUCTION

Concrete is the most widely used construction material today. It is all around us; from offices to schools, roads to railways and dams to homes. It is difficult to point out another material of construction which is as versatile as concrete. It is the material of choice where strength, performance, durability, impermeability, fire resistance and abrasion resistance are required.

The versatility and mould ability of this material, its high compressive strength, and discovery of the reinforcing and pre-stressing techniques which helped to make up for its low tensile strength have contributed largely to its widespread use. It is so closely associated now with every human activity that it touches every human being in his day to day living. We can rightly say that we are in the age of concrete.

- The functional requirements of a fresh SCC are different from those of a vibrated fresh Normal Concrete (NC). Filling of formwork with a liquid suspension requires workability performance like filling ability, passing ability and resistance against segregation.
- Filling ability of concrete is the ability of concrete to flow freely under its own weight, both horizontally and vertically upwards if necessary, and to completely fill the formwork of any dimension and shape without leaving voids.
- Passing ability is the ability of concrete to pass through obstacles such as narrow sections of the form work, closely spaced reinforcement etc. without blocking caused by interlocking of aggregate particles.
- Resistance to segregation is maintaining homogeneity throughout mixing, transportation and casting. The dynamic stability refers to the resistance to segregation during placement. The static stability refers to the resistance to bleeding, segregation and surface settlement after casting.

1. Constituents of Self Compacting Concrete:

- Coarse Aggregate
- Fine Aggregate
- Cement
- Water
- Mineral Admixtures (Fly Ash)
- Chemical Admixtures

2. Mechanical Properties of Self Compacting Concrete:

Fresh SCC mixes must meet three key properties:

- Ability to flow into and completely fill intricate and complex forms under its own weight
- Ability to pass through and bond to congested reinforcement under its own weight.
- High resistance to aggregate segregation.

Due to the high cement, SCC may show more plastic shrinkage or creep than ordinary Concrete mixes. These aspects should therefore be considered during designing and specification of SCC. Current knowledge of these aspects is limited and is an area requiring further research.

The workability of SCC can be characterized by the properties like filling ability, passing ability and segregation resistance.

Tests on fresh concrete are Slump flow & T50 test, V-Funnel test & V-Funnel at T5 minutes, L - Box test, U - Box apparatus test, J-Ring test and Orimet Test.

The hardened properties of SCC like compressive strength, split tensile strength and flexural strength are determined after proper curing of concrete specimens.

3. Advantages of Self Compacting Concrete:

- Improved quality of concrete and reduction of onsite repairs.
- Faster construction times.
- Lower overall costs.
- Facilitation of introduction of automation into concrete construction.
- Improvement of health and safety is also achieved through elimination of handling of vibrators.
- Possibilities for utilization of "dusts", which are currently waste products and which are costly to dispose of.
- Better surface finishes.
- Easier placing.
- Thinner concrete sections.
- Greater Freedom in Design.
- Improved durability, and reliability of concrete structures.

4. Disadvantages of Self Compacting Concrete:

- Material selection is stricter.
- Construction costs increase, compared with regular concrete.
- Many trial batches and laboratory tests are required to use a designed mixture.
- Higher precision is required when measuring and monitoring.
- There is no internationally accepted test standard for self-compacting concrete mix.

5. Applications of Self Compacting Concrete:

- Construction of raft and pile foundations.

- Retrofitting and repairing constructions.
- Structures with complex reinforcement distributions.
- Construction of earth retaining systems.
- Drilled shafts.
- Columns.

II. RESEARCH METHODOLOGY

1. Flowchart of Work:

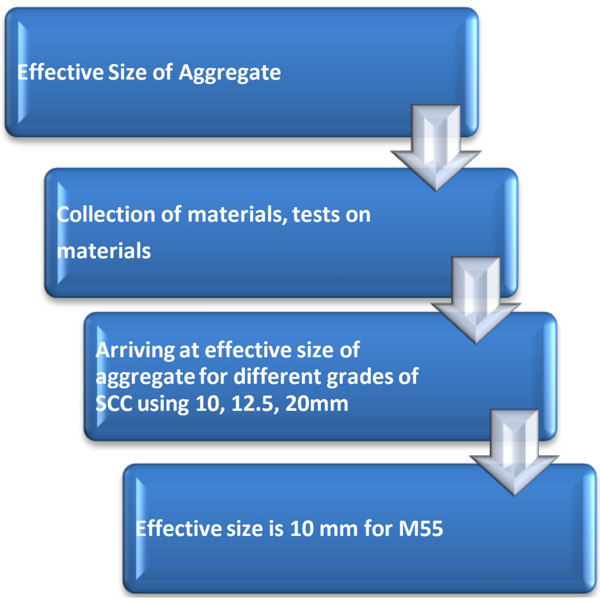

Fig 1. Flow Chart.

2. Experimental Program:

Wide spread applications of SCC have been restricted due to lack of standard mix design procedure and testing methods. It is pertinent to mention that only features of SCC have been included in Indian Standard Code of practice for plain and reinforced concrete (fourth revision), [2000].

Slump flow test, L-box test, V-funnel test, U-box test, Orimet test & GTM Screen test are recommended by EFNARC [European Federation of Producers and Applicators of Specialist Products for Structures, May 2005] for determining the properties of SCC in fresh state.

The experimental program consisted of casting and testing specimens for arriving at the maximum size of aggregate. M55 grade of concrete is considered in this study. In the first stage the effective maximum size of aggregate for M55 grade of concrete was arrived. Nan Su method of mix design [2001] was adopted to arrive at the suitable mix proportions. The mix proportion for M55 grade was arrived, taking the different sizes of aggregate into consideration. The effective size of aggregate was arrived for M55 grade of concrete, based on the mechanical properties and fresh properties of SCC.

A total of 27 cubes of standard size 150 mm x 150 mm x 150 mm, 27 prisms of standard size 100 mm x 100 mm x 500 mm and 27 cylinders of 150 mm diameter and 300 mm height were cast for determining the compressive strength, flexural strength and split tensile strength respectively.

The parameters of the study thus included size of aggregate and age of curing for satisfying the fresh properties of SCC as per EFNARC specifications [2005] based on a number of trials.

The present investigation is mainly directed towards developing a mix with good SCC, with different sizes of coarse aggregate and for M55 grade of concrete. The details of fresh properties and hardened properties of SCC with different sizes of coarse aggregate are discussed.

3. Batching and Mixing of Self Compacting Concrete:

The proportioning of the quantity of cement, cementitious material like Fly ash, fine aggregate and coarse aggregate has been done by weight as per the mix design. Water, super plasticizer and VMA were measured by volume. All the measuring equipments are maintained in a clean serviceable condition with their accuracy periodically checked.

The mixing process is carried out in electrically operated concrete mixer. The materials are laid in uniform layers, one on the other in the order - coarse aggregate, fine aggregate and cementitious material. Dry mixing is done to obtain a uniform color.

The fly ash is thoroughly blended with cement before mixing. Self Compacting characteristics of fresh concrete are carried out immediately after mixing of concrete using EFNARC specifications [2005].The workability properties of Normal Concrete (NC) Viz., slump was maintained in the range of 75 – 100 mm and compaction factor was 0.9. In higher strength concretes, these are maintained by adjusting the mineral and chemical admixtures.

4. Testing Methods Introduction:

4.1 Slump Flow Test and T50 cm 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 diameter of the concrete circle is a measure of the filling ability of concrete.

Slump Flow is definitely one of the most commonly used SCC tests at present. This test involves the use of slump cone with conventional concretes as described in ASTM C 143 [Standard Test Method for Slump of Hydraulic-Cement Concrete]. The main difference between Slump Flow Test and ASTM C 143 [Standard Test Method for

Slump of Hydraulic-Cement Concrete] is that the Slump Flow Test measures the spread or flow of concrete sample, once the cone is lifted rather than the traditional slump (drop in height) of the concrete sample. The T50 test is also determined during the Slump Flow Test. It is simply the amount of time that the concrete takes to flow to a diameter of 50 centimeters.

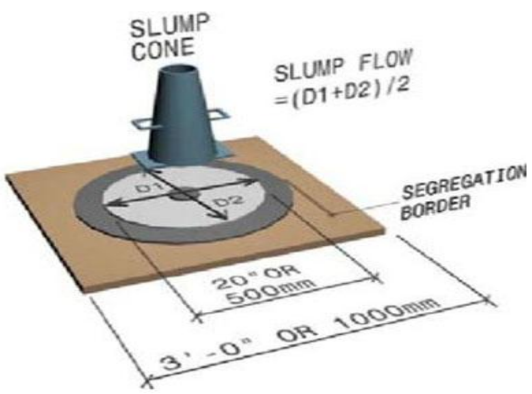

Fig 2. Slum Flow Test.

4.2 L – Box Test: This test, based on a Japanese design for underwater concrete, has been described by Peterson, 1999. This test assesses the flow of concrete, and also the extent to which it is subjected to blocking by reinforcement.

The apparatus consists of a rectangular-section box in the shape of an 'L', with a vertical and horizontal section, separated by a moveable gate, in front of which, vertical lengths of reinforcement bars are fitted. The vertical section is filled with concrete, and then the gate is lifted to let the concrete flow into the horizontal section. When the flow has stopped, the height of the concrete at the end of the horizontal section is expressed as a proportion of that remaining in the vertical section called as H2/H1 ratio or blocking ratio. It indicates the slope of the concrete when the concrete is at rest. This is an indication of passing ability, or the degree to which the passage of concrete through the bars is restricted.

The horizontal section of the box can be marked at 200mm and 400mm from the gate and the time taken to reach these points measured. These are known as the T20 and T40 times and are indicators of the filling ability.

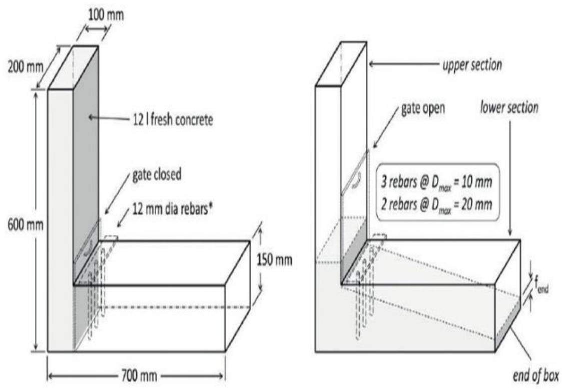

Fig 3. L-Box Test.

4.3 J-Ring Test:

The J – Ring test has been developed at the University of Paisley. The test is used to determine the passing ability of the concrete. The equipment consists of a rectangular section (30mm x 25mm) open steel ring, drilled vertically with holes to accept threaded sections of reinforcement bar. These sections of bar can be of different diameters and spaced at different intervals in accordance with normal reinforcement considerations. The diameter of the ring of vertical bars is 300mm, and the height 100 mm.

The J – Ring can be used in conjunction with the Slump flow test. These combinations judge the flowing ability and the passing ability of the concrete.

The slump flow spread was measured to assess flow characteristics. The J – Ring bars can be set at any spacing to impose a more or less severe test of the passing ability of the concrete. After the test, the difference in height between the concrete inside and that just outside the J – Ring is measured. This is an indication of passing ability, or the degree to which the passage of concrete through the bars is restricted.

III. EXPERIMENATL STUDY

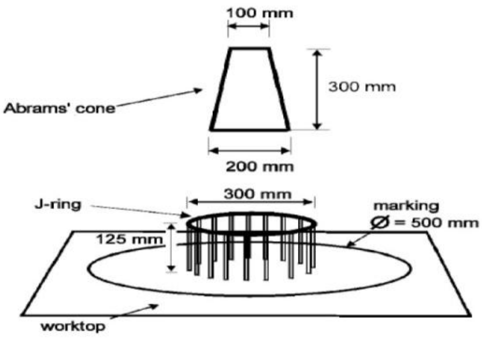

Fig 4. The mix proportion of M55 grade of concrete designed.

1. Mix Proportion of Self Compacting Concrete:
The mix proportion of M55 grade of concrete designed on the basis of Nan Su method for different maximum sizes of aggregates 10, 12.5 and 20 mm.

For the mix proportions obtained, highlights the details of various parameters including total aggregate – cement ratio (A/C), water – cement ratio (w/c), coarse aggregate- fine aggregate ratio (CA/FA) and fine aggregate – total aggregate ratio (S/a) for various aggregate sizes.

Table 1. Parameters of M55 grade self-Compacting Concrete Mix Proportions.

Size of aggregate (mm)	A/C	w/c	w/p	CA/FA	S/a
10	2.42	0.38	0.269	0.935	0.520
12.5	2.43	0.366	0.257	0.914	0.514
20	2.45	0.365	0.236	0.820	0.550

2. Compressive strength:
The results of the mechanical properties obtained based on the specimens tested as per Indian standard test procedures (as per IS: 516) are discussed. M 55 grade of concrete, three maximum sizes of aggregate and three different ages of curing are the variables of investigation.

Table 2. Compressive strength of M55 grade Self Compacting Concrete.

Size of Aggregate	3 Days	7 Days	28 Days
20 mm	31.80	46.30	74.00
12.5 mm	36.20	49.00	77.10
10 mm	38.33	49.66	79.30

3. Split Tensile Strength:
The details of the split tensile strength of M 55 grade of concrete for different sizes of aggregate. A similar trend as that of compressive strength was noted with regard to the size of aggregate. This was true at all the three different ages of curing.

Table 3. Split Tensile Strength of M55 grade Self Compacting Concrete.

Size of Aggregate	3 Days	7 Days	28 Days
20 mm	2.40	6.04	9.15
12.5 mm	2.80	5.90	9.62
10 mm	2.85	6.36	9.95

4. Flexural Strength:
The details of the flexural strength of the different sizes of aggregate and three grades of concrete are. At 3, 7 and 28 days the effective size of aggregate was 10 mm for M 55 grade. When the tensile stress applied to SCC beams less than its tensile strengths, then the beam is capable of resisting flexural moment. Further increase in loads causes vertical cracks.

Normally, flexural cracks initiated the cracking in SCC beams. These cracking appeared out of the flexural zone. Further increase in load causes shear cracks which appeared at the diagonal areas of beam.

Table 4. Flexural Strength of M55 grade Self Compacting Concrete

Size of Aggregate	3 Days	7 Days	28 Days
20 mm	4.03	6.75	8.50
12.5 mm	4.60	7.47	9.13

10 mm	5.35	7.65	9.35

IV. CONCLUSION

As described earlier, Nan Su method of mix design [2001] was adopted to design the SCC mix for M55 grade of concrete. As understood, Nan Su method is based on the basic principle that the paste of binders are filled in the voids of aggregates ensuring that the concrete obtained has flow ability, self-compacting ability and other desired SCC properties.

The packing factors assumed on the basis of better compatibility and strength, from a number of trials is 1.12 for M55 grade of concrete. From Nan Su method of mix design for SCC, the density, compatibility and strength are dependent on how effectively the aggregates are packed. Hence, the size of aggregate, shape and texture of aggregate also plays a deciding factor in the values of fresh and hardened properties.

The mix proportion of M55 grade of concrete designed on the basis of Nan Su method is given in the Table -1 for different maximum sizes of aggregate Viz. 10, 12.5 and 20mm. For the mix proportions obtained, shows the details of various parameters including total Aggregate – Cement ratio (A/C), water – cement ratio (w/c), Coarse Aggregate - Fine Aggregate ratio (CA/FA) and fine aggregate – total aggregate (S/a) for various aggregate sizes.

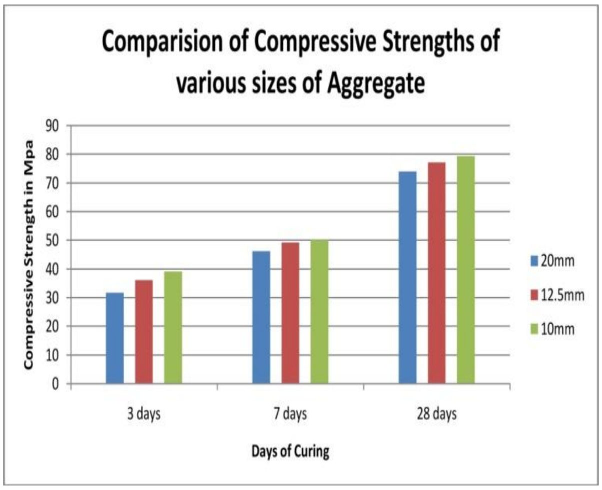

Fig 5. Graph: Comparison of Compressive Strength of Various Sizes of Aggregate with Self Compacting Concrete.

Based on the systematic and detailed experimental study conducted on SCC mixes with an aim to develop performance mixes, the following are the conclusions arrived. The mixes designed using the lower size of aggregate yielded better fresh properties than higher size of aggregates. As the strength of concrete increases, the effective size of aggregate has decreased.

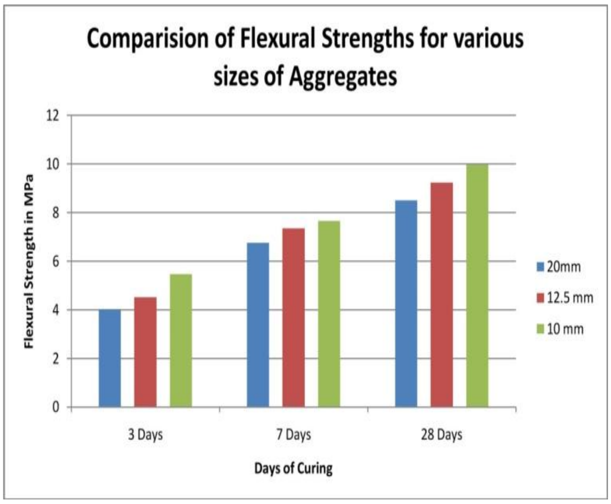

Fig 6. Graph: Comparison of Flexural Strength of Various Sizes of Aggregate with Self Compacting Concrete.

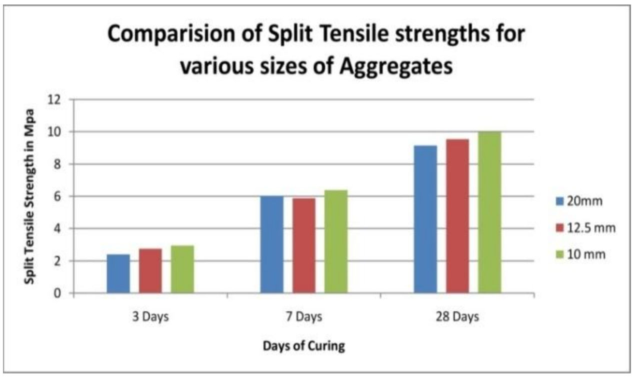

Fig 7. Graph: Comparison of Split Tensile Strength of Various Sizes of Aggregate with Self Compacting Concrete.

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