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AN EFFECT OF SIZE OF AGGREGATE ON SELF COMPACTING CONCRETE OF M70 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. There is a methodological shift in the concrete design from a strength based concept to a performance based design. 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 guiding principle behind self-compaction is that “the sedimentation velocity of a particle is inversely proportional to the viscosity of the floating medium in which the particle exists”. The other 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 present investigation is aimed at developing high strength Self Compacting Concrete of M70 Grade. The parameters of study include grade of concrete and effect of size of aggregate. The existing Nan Su [2001] method of mix design was based on packing factor for a particular grade of concrete, obtained on the basis of experimental investigation. SCC characteristics such as flowability, passing ability and segregation resistance have been verified using slump flow, L box and V funnel tests.

Keywords— High Performance Concrete , deformability **,** Self Compacting Concrete, segregation resistance, flowability, passing ability, Fly Ash,

I. INTRODUCTION

Self-compacting concrete (SCC) is a concrete, which flows and compacts only under gravity. It fills the mould completely without any defects. Usually self-compacting concretes have compressive strengths in the range of 60-100 N/mm^2. However, lower grades can also be obtained and used depending on the requirement. SCC was originally developed at the University of Tokyo in Japan with the help of leading concrete contractors during 1980’s to be mainly used for highly congested reinforced structures in seismic regions. As durability of concrete structures was an important issue in Japan, an adequate compaction by skilled labors was required to obtain durable concrete structures. This requirement led to the development of SCC. The development of SCC was first reported in 1989.

High strength concrete can be produced with normal concrete. But these concretes cannot flow freely by themselves, to pack every corner of moulds and all gaps of reinforcement. High strength concrete based elements require thorough compaction and vibration in the construction process. SCC has more favorable characteristics such as high fluidity, good segregation resistance and distinctive self-compacting ability without any need for external or internal vibration during the placing process. It can be compacted into every corner of formwork purely by means of its own weight without any segregation. Hence, it reduces the risk of honey combing of concrete.

The versatility and the application of concrete in the construction Industry need not be emphasized. Research on normal and high strength concrete has been on the agenda for more than two decades. As per IS: 456–2000[Code of Practice for Plain and Reinforced Concrete], concretes ranging 25 – 55 MPa are called standard concretes while those above 55 MPa can be termed as high strength concrete. Concretes above 120/150 MPa are called ultra-high strength concrete. High strength concrete has numerous applications worldwide in tall buildings, bridges with long span and buildings in aggressive environments. Building elements made of high strength concrete are usually densely reinforced. This congestion of reinforcement leads to serious problems while concreting. Densely reinforced concrete problems can be solved by using concrete that can be easily placed and spread in between the congested reinforced concrete elements. A highly homogeneous, well spread and dense concrete can be ensured using such a type of concrete.

Some of the advantages of Self Compacting Concrete are as follows:

1. Less noise from vibrators and reduced danger from Hand Arm Vibration Syndrome (HAVS).
2. Safe working environment.
3. Speed of placement, resulting in increased production efficiency.
4. Ease of placement, requiring fewer workers for a particular pour.
5. Better assurances of adequate uniform consolidation.
6. Reduced wear and tear on forms from vibrator.
7. Reduced wear on mixers due to reduced shearing action.
8. Improved surface quality and fewer bug holes, requiring fewer patching.
9. Improved durability.
10. Increased bond strength.
11. Reduced energy consumption from vibration equipment.

II. SCOPE OF THE WORK

Despite its advantages and versatile nature, SCC has not gained much popularity in India, though it has been widely promoted in the Middle East for the last two decades. Awareness of SCC has spread across the world, prompted by concerns with poor consolidation and durability in case of conventionally vibrated normal concrete.

All the researchers have developed SCC taking the CA/FA ratio and also considered the limited content of coarse aggregate and more content of fines. But, there are very limited investigations reported considering the size effect of coarse aggregate content in the development of SCC. Keeping this in view, the present experimental investigation is taken up to study the effect of size of coarse aggregate in the development of M70 grade of Self Compacting Concrete. Powder content is the main aspect of a SCC mix design. In the present work, fly ash is maximized in the SCC mixes as a filler material.

III. EXPERIMENTAL PROGRAM

The materials used in the experimental investigation are locally available cement, sand, coarse aggregate, mineral and chemical admixtures. The chemicals used in the present investigation are of commercial grade.

Cement:

Ordinary Portland cement of 53 grade [IS: 12269-1987, Specifications for 53 Grade Ordinary Portland cement] has been used in the study. It was procured from a single source and stored as per IS: 4032 – 1977.

Fine Aggregate:

The fine aggregate used was locally available river sand without any organic impurities and conforming to IS: 383 – 1970 [Methods of physical tests for hydraulic cement.

Coarse Aggregate:

The coarse aggregate chosen for SCC was typically round in shape, well graded and smaller in maximum size than that used for conventional concrete. The size of coarse aggregate used in self-compacting concrete was between 10mm to 16mm. Crushed granite metal of sizes 16 mm to 10 mm graded obtained from the locally available quarries was used in the present investigation.

Water:

Water used for mixing and curing was potable water, which was free from any amounts of oils, acids, alkalis, sugar, salts and organic materials or other substances that may be deleterious to concrete or steel confirming to IS : 3025 – 1964 part22, part 23 and IS : 456 – 2000 [Code of practice for plain and reinforced concrete]. The pH value should not be less than 6. The solids present were within the permissible limits as per clause 5.4 of IS: 456 – 2000.

Fly Ash:

Fly ash is one of the most extensively used supplementary cementitious materials in the construction field resembling Portland cement. It is an inorganic, noncombustible, finely divided residue collected or precipitated from the exhaust gases of any industrial furnace. Fly ash used in this investigation was procured from Kakatiya Thermal Power Project, Andhra Pradesh, India. It confirms with grade I of IS: 3812 – 1981 [Specifications for fly ash for use as pozzolana and admixture]. It was tested in accordance with IS: 1727 –1967 [Methods of test for pozzolana materials]

S No	Characteristics	Requirements for grade of flyash		Experimental Results
		Grade – I	**Grade – II**	
1.	Fineness by Blain's	320	250	335
2.	Lime reactivity (MPa)	4.0	3.0	9.8
3.	Compressive strength at 28 days as percentage of strength of corresponding plain	Not less than 80%		86%
4.	Soundness by Autoclave expansion			Nil

Super Plasticizer:

High range water reducing admixture called as super plasticizers are used for improving the flow or workability for lower water-cement ratios without sacrifice in the compressive strength. These admixtures when they disperse in cement agglomerates significantly decrease the viscosity of the paste by forming a thin film around the cement particles. In the present work, water-reducing admixture Glenium conforming to IS 9103: 1999 [Specification for admixtures for concrete],ASTMC–494[Standard Specification for Chemical Admixtures for Concrete types F, G and BS 5075 part.3 [British Standards Institution]wasused.

Viscosity Modifying Agent:

These admixtures enhance the viscosity of water and eliminate the bleeding and segregation phenomena in the fresh concrete as much as possible. VMA is a neutral, biodegradable, liquid chemical additive designed to reduce the bleeding, segregation, shrinkage and cracking that occur in high water/cement ratio concrete mixes. VMA also contribute to stabilization for SCC mixes that are susceptible to segregation at high slump ranges. The VMA used in this investigation was Glenium stream-2 which is a product of BASF construction chemicals.

MIX PROPORTIONING

The mix proportioning was done based on the Nan Su approach [2001] for different aggregate sizes.

Test Methods:

Different test methods have been developed in an attempt to characterize the properties of SCC. So far, no single method or combination of methods has achieved universal approval and most of them have their adherents. Similarly, no single method has been found which characterizes all the relevant workability aspects. Each mix design should be tested by more than one test method for different workability parameters.

Table 1: List of test methods for workability properties of SCC:

S.NO	Method	Property
1	Slump flow test	Filling ability
2	T50cm Slump flow	Filling ability
3	V-funnel test	Filling ability
4	V-Funnel at T5 minutes	Segregation resistance
5	L-Box test	Passing ability
6	U – Box test	Passing ability
7	Fill box apparatus test	Passing ability
8	J-Ring	Passing ability
9	Orimet test	Filling ability
10	GTM screen stability test	Segregation resistance

Table 2: Acceptance criteria for Self-compacting Concrete:

S No	Method	Unit	Typical range of values	
			Minimum	Maximu
1.	Slump flow test	mm	650	800
2.	T50 cm Slump flow	sec	2	5
3.	J – Ring	mm	0	10
4.	V – Funnel	sec	6	12

5.	V – Funnel at T5	sec	6	15
6.	L – Box	h2/h1	0.8	1.0
7.	U – Box	(h2-h1) mm	0	30
8.	Fill Box	%	90	100
9.	GTM Screen stability	%	0	15
10.	Orimet test	sec	0	5

IV.EXPERIMENTAL RESULTS

Mix proportions for SCC: The mix proportion of M70 grade of concrete designed on the basis of Nan Su method for different maximum sizes of aggregates 10, 12.5 and 20 mm.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 3: Parameters of M70 grade SCC 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

TABLE 4: FRESH PROPERTIES OF M 70 GRADE SCC

S. No	Size of Aggregate	Slump Flow value	T50	V-Funnel	V-Funnel at T5 Minutes	L-Box H2/H1 (blocking ratio)
1.	20 mm	720mm	**5 Sec**	**9 Sec**	**12 Sec**	1.00
2.	12.5 mm	725mm	**5 Sec**	**6 Sec**	**8 Sec**	1.00
3.	10 mm	735mm	**5 Sec**	**7 Sec**	**9 Sec**	1.00

Mechanical properties of SCC with different sizes of aggregate:

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 70 grade of concrete, three maximum sizes of aggregate and three different ages of curing are the variables of investigation.

Table 5: Compressive strength of M 70 grade SCC

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

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Table 6: Split tensile strength of M 70 grade SCC

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

Table 7: Flexural strength of M 70 grade SCC

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

V.INTERPRETATION AND DISCUSSION OF TEST RESULTS

Effect of size of aggregate on fresh properties of SCC:

Based on the fresh properties of SCC for different sizes of aggregates, it can be noted that M70 grade of concrete with all the different maximum sizes satisfied the required EFNARC specifications [2005]. The fresh properties have improved with the increase in powder content. Also the lower size of aggregate yielded better results in M70 grade of concrete.

Effect of size of aggregate on the mechanical properties of SCC:

Compressive strength:

From the results it was noted that, as the grade of concrete increased the effective maximum size of the aggregate has deceased. In the above cases, the cement content was 680 kg/m^3 for M70 grades. The three effective sizes for the above three mixes have been arrived and the same was adopted in the further study.

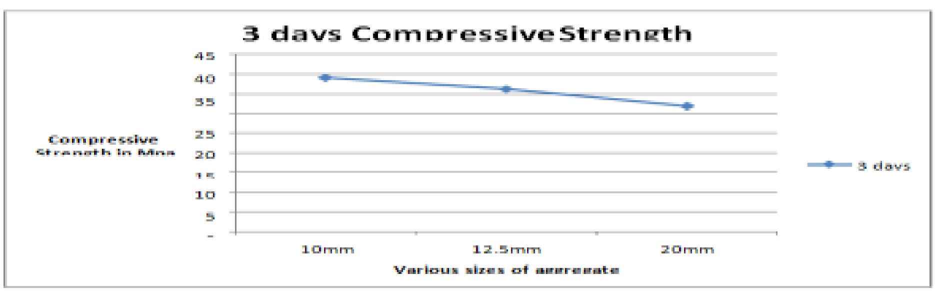

FIGURE 1. 3 DAYS COMPRESSIVE STRENGTH WITH VARIOUS SIZES OF AGGREGATES

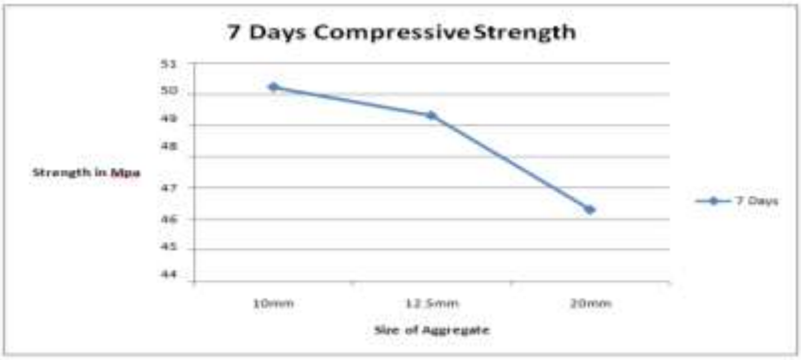

Figure 2. 28 days Compressive strength with various sizes of Aggregates

Split tensile strength:

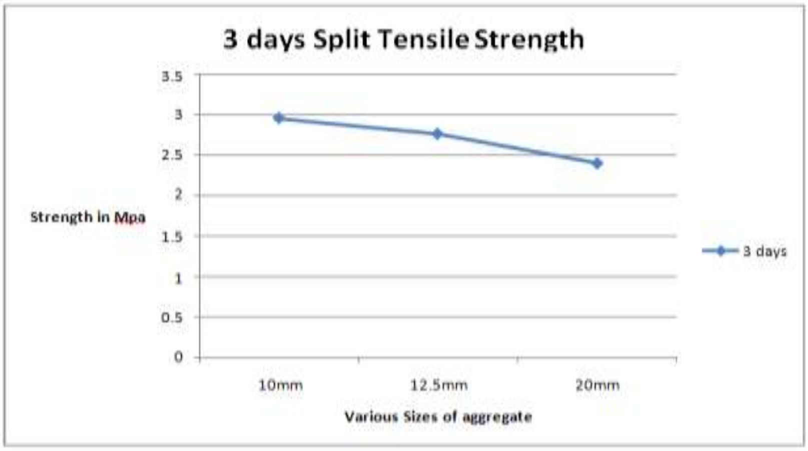

Figure3. 3 days Split Tensile strength with various sizes of Aggregates

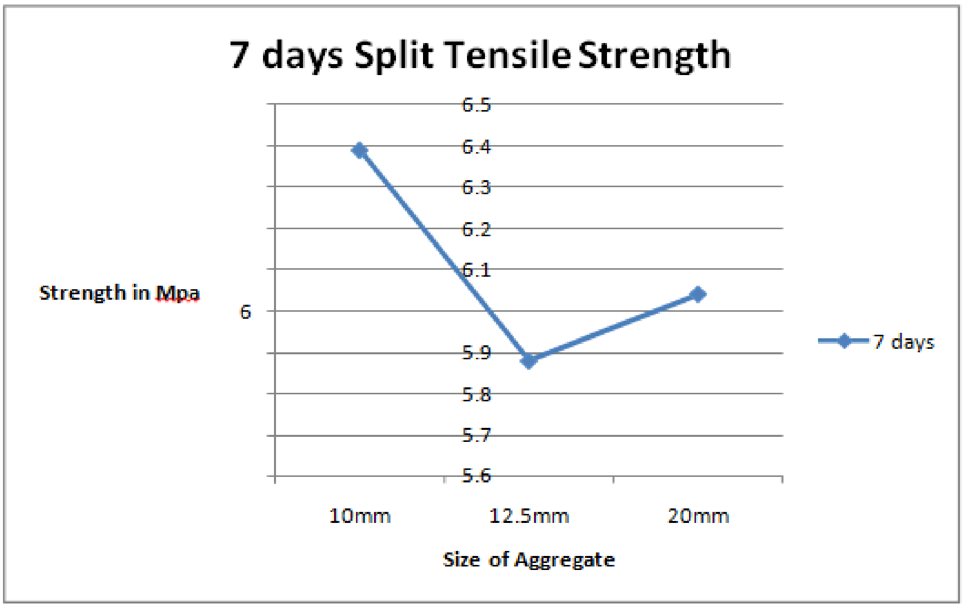

FIGURE 4. 7 DAYS SPLIT TENSILE STRENGTH WITH VARIOUS SIZES OF AGGREGATES

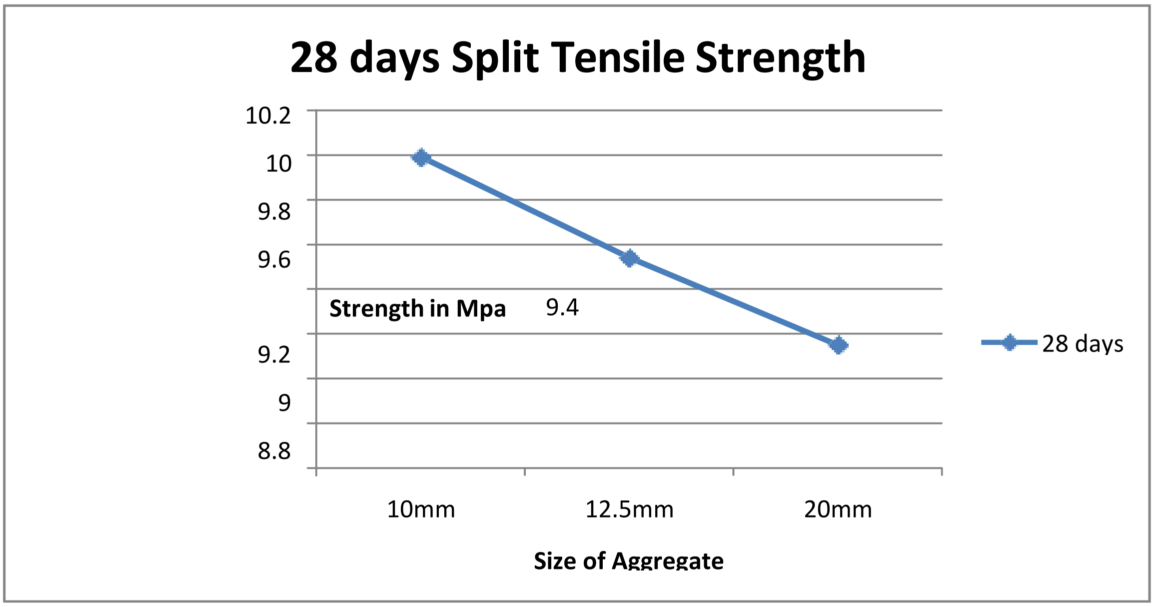

FIGURE 5. 28 DAYS SPLIT TENSILE STRENGTH WITH VARIOUS SIZES OF AGGREGATES

Flexural strength:

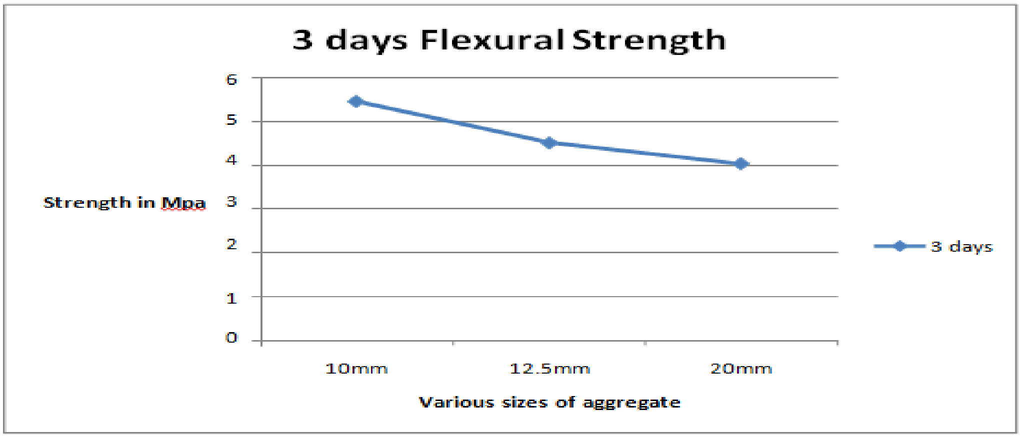

Figure 6.3 days Flexural strength with various sizes of Aggregates

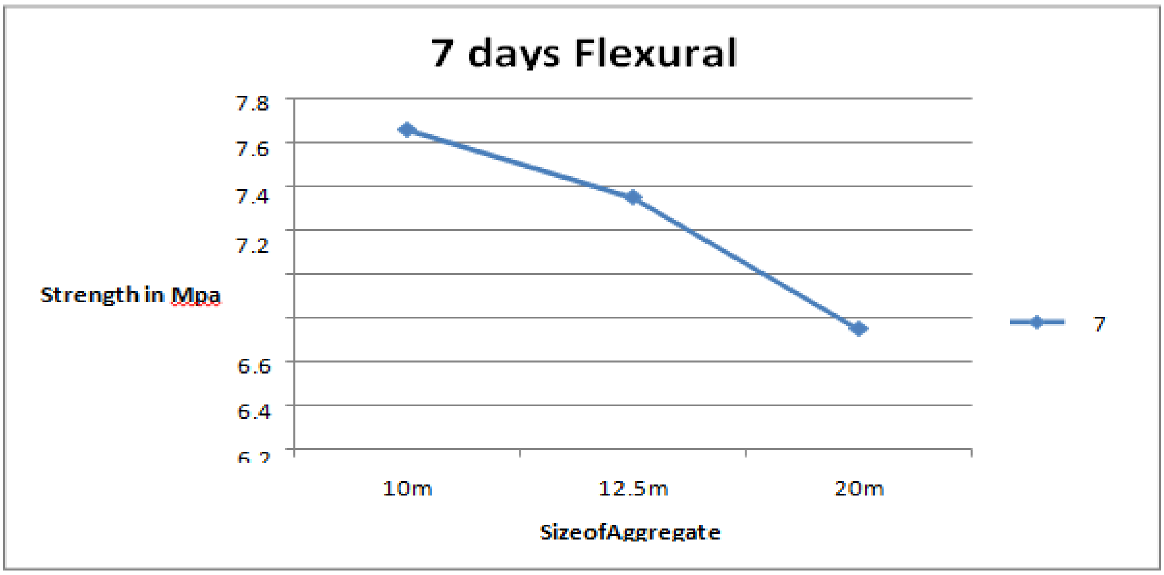

Figure 7. 7 days Flexural strength with various sizes of Aggregates

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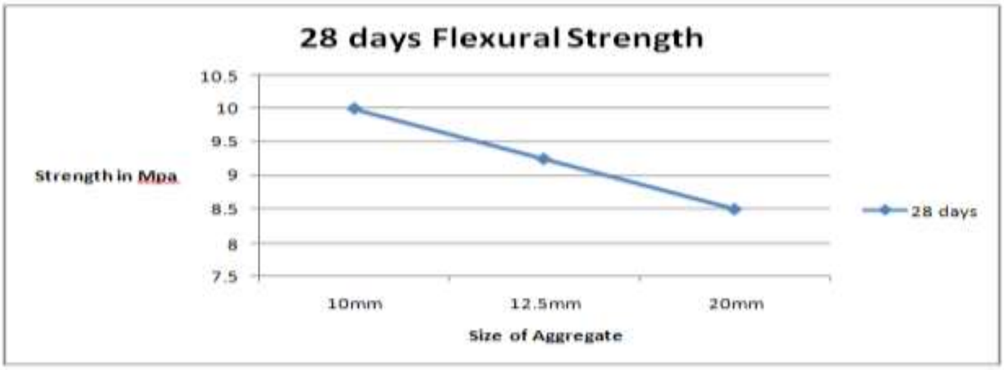

Figure 8. 28 days Flexural strength with various sizes of Aggregates

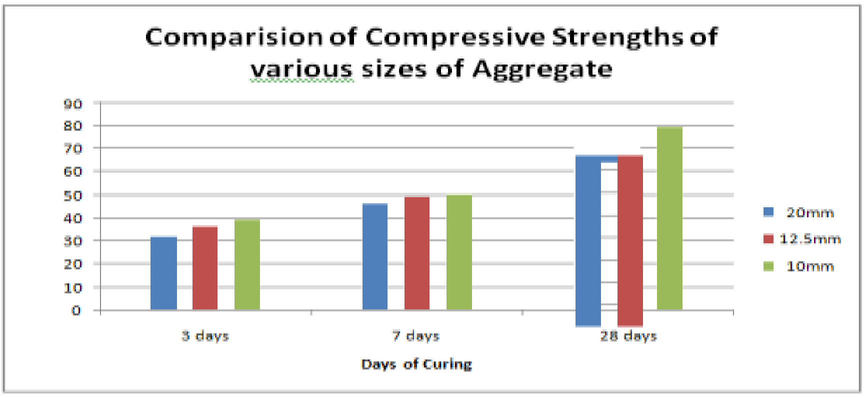

Figure 9. Bar Diagram of Compressive Strength with various sizes of Aggregates

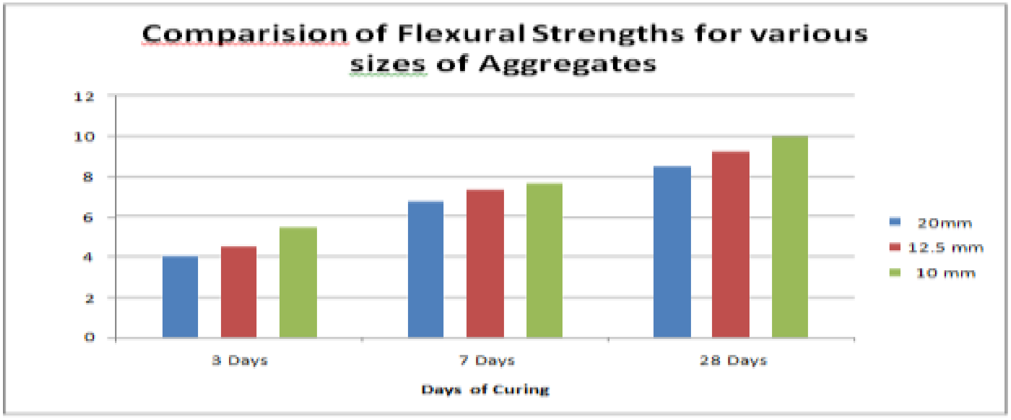

FIGURE 10. BAR DIAGRAM OF FLEXURAL STRENGTH WITH VARIOUS SIZES OF AGGREGATES

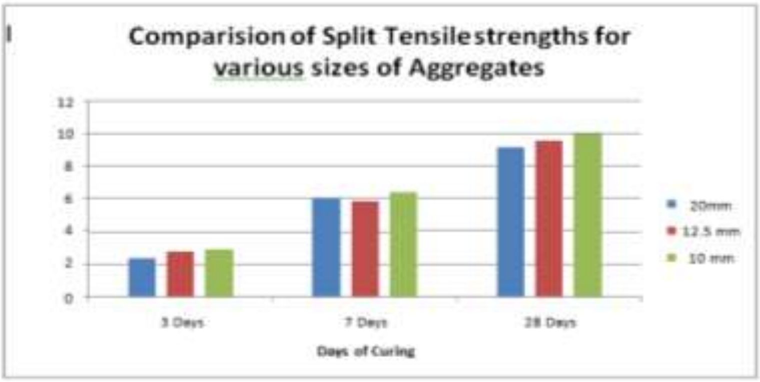

FIGURE 11. BAR DIAGRAM OF SPLIT TENSILE STRENGTH WITH VARIOUS SIZES OF AGGREGATES

VI. CONCLUSIONS

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.

1. The mixes designed using the lower size of aggregate yielded better fresh properties than higher size of aggregates.
2. As the strength of concrete increases, the effective size of aggregate has decreased.

1) Significant contribution of the Project:

The present investigation has brought out explicitly the effect of size of aggregate on the compressive strength and other mechanical properties of self-compacting concrete.

2) Scope of the future work:

1. The simplified mix design methodology was presented may be extended to the more number of concrete strength ranges.
2. The investigations may be conducted with different mineral admixtures like Rice Husk Ash and GGBS apart from fly ash.

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