Effect of Size of Aggregate on Self Compacting Concrete

A Major Project Report

Submitted to the Rajasthan Technical University

in partial fulfillment of requirements for the award of degree

Bachelor of Technology

in

Civil Engineering

by

Suryabhan Singh

Sarangdevot

20ETCCE011

DEPARTMENT OF CIVIL ENGINEERING

TECHNO INDIA NJR INSTITUTE OF TECHNOLOGY

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CERTIFICATE

This is to certify that the report entitled **Effect of Size of Aggregate on Self Compacting Concrete** submitted by **Suryabhan Singh Sarangdevot** (20ETCCE011), to Department of Civil Engineering in partial fulfillment of the B.Tech. degree in **Civil Engineering** is a bonafide record of the seminar work carried out by him under our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

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DECLARATION

I Suryabhan Singh Sarangdevot hereby declare that the major project report **Effect of Size of Aggregate on Self Compacting Concrete**, submitted for partial fulfillment of the requirements for the award of degree of Bachelor of Technology of the Rajasthan Technical University, Kota, Rajasthan is a bonafide work done by me under supervision of Nishit Jain.

This submission represents my ideas in my own words and where ideas or words of others have been included. I have adequately and accurately cited and referenced the original sources.

I also declare that I have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in my submission. I understand that any violation of the above will be a cause for disciplinary action by the institute and/or the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously formed the basis for the award of any degree, diploma or similar title of any other University.

Suryabhan

Udaipur, Rajasthan

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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 original contribution in the field of SCC is attributed to the pioneering work of Nan Su et al; 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 flowability, self compacting ability and other desired SCC properties.

The present investigation is aimed at developing high strength Self Compacting Concrete of M60 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 and segregation resistance have been verified using slump flow and V funnel tests.

This document contains essential templates required to write technical reports. This template may be used for the preparation of B.Tech final reports of Rajasthan Technical University, Kota, Rajasthan. Also minimum working examples to create equations, include figure, include table, table of contents and bibliographic citation are provided.

ACKNOWLEDGEMENT

I take this opportunity to express my deepest sense of gratitude and sincere thanks to everyone who helped me to complete this work successfully. I express my sincere thanks to **Rakesh Yadav**, Head of Department, Civil Engineering, Techno India NJR Institute of Technology, Udaipur for providing me with all the necessary facilities and support.

I would like to place on record my sincere gratitude to my project guide **Nishit Jain**, Assistant Professor, Civil Engineering, Techno India NJR Institute of Technology for the guidance and mentorship throughout the course.

Finally I thank my family and friends who contributed to the successful fulfilmentof this project work.

Suryabhan Singh Sarangdevot

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CHAPTER 1

Introduction

1.0 General

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 - 60 MPa are called standard concretes while those above 60 MPa can be termed as high strength concrete.

Self-compacting concrete (SCC) is a concrete, which flows and compacts only under gravity. It fills the mould completely without any defects. 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.

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

1. Less noise from vibrators and reduced danger from Hand Arm Vibration Syndrome.
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.
12. Best suited where reinforcement congestion is a problem.

1.1 Mechanism for Achieving Self-Compatibility

Simply increasing the water content in a mix to achieve a flowable concrete like SCC is obviously not a viable option. Instead, the challenge is to increase the flowability of the particle suspension and at the same time avoid segregation of the phases. The main mechanism controlling the balance between higher flowability and stability are related to surface chemistry. The development of SCC has thus been strongly dependent on surface active admixtures as well as on the increased specific surface area obtained through the used fillers.

The frequency of collision and contact between aggregate particles increases as the relative distance between the particles decreases and the internal stress increases when concrete is deformed, particularly near obstacles. It has been revealed that the energy required for flowing is consumed by the increased internal stresses, resulting in blockage of aggregate particles.

Limiting the coarse aggregate content, whose energy consumption is particularly intense, to a level lower than normal proportions is effective in avoiding this kind of blockage.

1.2 Constituents of SCC

1.2.1 Coarse aggregate:

The coarse aggregate chosen for Self Compacting Concrete should be well graded and smaller in terms of the maximum size than that used for conventionally vibrated concrete. For typical conventional concrete the coarse aggregate size may be 20 mm and even more in general. The rounded aggregates and smaller size of aggregate particles improves the flowability, deformability and segregate resistance of SCC. The gradation is an important factor in choosing a coarse aggregate, where, highly congested reinforcement patterns are used and where, very small dimensional elements are to be produced. In case of conventional concrete, the size of the coarse aggregate depends upon the type of the construction.

1.2.2 Fine Aggregate:

All normal river sands are suitable for SCC. Both crushed and rounded sands can be used. Siliceous and calcareous sands can be used for production of SCC. The amount of fines less than 0.125mm is to be considered as powder which is very important for the rheology of SCC. A minimum amount of fines must be maintained to avoid segregation. The amount of fines has a very significant effect on SCC mix proportions. Fine sand requires more water and Super Plasticizer (SP), but less filler than coarse sand. The SP dosage, water content and cement/filler content could be adjusted by treating the fines (>150 um) in sand as part of the filler.

1.2.3 Cement:

All types of cements conforming to Bureau of Indian standards are suitable as per Indian conditions. Selection of the type of the cement is made depending on the over all requirements of SCC such as strength, durability etc. The cement content can be 350 – 450 kg/m3. The usage of cement more than 500 kg/m3 may increase the shrinkage in the hardened state of concrete, where as, the quantity less than 350 kg/m3 may decrease the durability of SCC. Hence, cement content shall be judged properly. Less than 350 kg/m3 may also be used with the inclusion of other fine fillers such as fly ash, Ground Granulated Blast furnace Slag (GGBS) and rice husk ash.

1.2.4 Water:

Potable water shall be used for the production of SCC. In case of conventional concretes (NC), the water is proportionate only with the cement content. It is called as the water-cement ratio. This influences the mix and thereby workability. But, in the case of SCC, instead of water-cement ratio the term water binder-ratio will be used. This means the content of water mixed in the SCC is proportionate to the total binders such as cement, fly ash etc.

1.2.5 Mineral admixtures:

The general advantages of mineral admixture additives are:

1. It increases the hydration process and reduces the porosity of concrete.
2. It fills and closes the pores or adjusts the type of pore structure.
3. It increases hydration products in addition to the filling effect of micro aggregate
4. It adjusts the grading of the components to achieve an optimum compact.
5. It can adjust the cohesiveness and reduce the heat of hydration and reaction rate.
6. It can improve the workability.
7. It can improve the durability and resistance to chemical attack and thus reduce micro cracks in the transition zones.

In this study, only fly ash is used as the mineral admixture and an attempt is made to maximize the fly ash content in Self Compacting Concrete. Fly ash or pulverized fuel-ash is a residue from the combustion of pulverized coal collected by mechanical separators, from the fuel gases of thermal plants. The composition of fly ash varies with type of fuel burnt, load on the boiler and type of separation. Fly ash material solidifies while suspended in the exhaust gasses and is collected by electrostatic precipitators or filter bags. Fly Ash consists mostly of silicon dioxide (SiO_2), aluminium oxide (Al_2O_3) and iron oxide (Fe_2O_3), and is hence a suitable source of aluminum and silicon for geopolymers. They are also pozzolanic in nature and react with calcium hydroxide and alkali to form Calcium Silicate Hydrates (C – S – H). The average particle size of fly ash is about 20 microns, which is similar to the average particle size of Portland cement. Particles below 10 microns provide the early strength in concrete, while particles between 10 and 45 microns react more slowly. **Fig.1.1** shows the SEM micrograph of fly ash particles. The specific gravity of fly ash particles ranges between 2.0 to 2.4 depending on the source of coal. The fineness of fly ash is in the range of 250 - 600 m^2/kg.

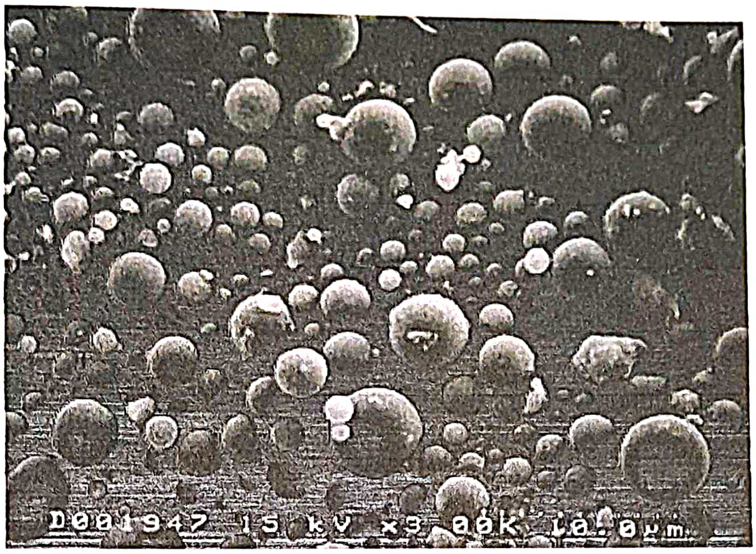

Fig 1.1 SEM Micrograph of fly ash particles

(https://upload.wikimedia.org/wikipedia/commons/6/6f/Fly_Ash_FHWA_dot_gov.jpg)

1.3 Mechanical properties of SCC

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

CHAPTER - 2

Objectives and 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 M60 grade of Self Compacting Concrete. Powder content is the main aspect of a SCC mix design. In the present work, flyash is maximized in the SCC mixes as a filler material.Keeping in view the idea explained above, a detailed and a systematic experimental program is laid down as explained in the next paragraphs. The main objective of the present investigation is: To study the effect of the size of aggregate on the strength and flow of M60 grade of Self compacting concrete.The experimental program is categorized as detailed below: Casting of 27 standard cubes, 27 standard cylinders covering M60 grade of concrete, three aggregate sizes, three periods of curing and three specimens of each type. In this study, high strength (M60) of SCC with three different maximum size of aggregate (20, 12.5, 10 mm) were designed to determine the effective maximum size of aggregate. The grade of concrete and age of curing were the parameters in the study.

CHAPTER – 3

Experimental Program

3.0 General

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.

The experimental program consisted of casting and testing specimens for arriving at the maximum size of aggregate. M60 grade of concrete is considered in this study. In the first stage the effective maximum size of aggregate for M60 grade of concrete was arrived. The mix proportion for M60 grade was arrived, taking the different sizes of aggregate into consideration. The effective size of aggregate was arrived for M60 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 and 27 cylinders of 150 mm diameter and 300 mm height were cast for determining the compressive 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.

3.1 Materials

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.

3.1.1 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. Care has been taken to ensure that the cement of same company and same grade is used throughout the investigation. The cement thus procured was tested for physical properties in accordance with the IS: 12269 – 1987.

Table: 3.1 Physical properties of Ordinary Portland Cement

S. No	Property	Test Method	Test Results
1.	Normal Consistency	Vicat Apparatus (IS: 4031 Part - 4)	28%
2.	Specific gravity	Sp. Gr bottle (IS: 4031 Part - 4)	3.08
3.	Initial setting time Final setting time	Vicat Apparatus (IS: 4031 Part - 4)	92 minutes 256 Minutes
4.	Fineness	Sieve test on sieve no.9 (IS: 4031 Part – 1)	1.3%
5.	Soundness	Le-Chatlier method (IS: 4031 Part – 3)	2 mm

3.1.2 Fine Aggregates

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]. The fine aggregate was tested for its physical requirements such as gradation, fineness modulus, specific gravity and bulk density in accordance with IS: 2386 – 1963 [Methods of test for aggregate for concrete] and is shown in **Table 3.2**. The sand was surface dried before use.

3.1.3 Coarse Aggregates

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. The rounded and smaller aggregate particles provide better flowability and deformability of concrete and also prevent segregation. Graded aggregate is also important particularly to cast concrete in highly congested reinforcement or formwork having small dimensions. Crushed granite metal of sizes 16 mm to 10 mm graded obtained from the locally available quarries was used in the present investigation. These were tested as per IS 383-1970 [Methods of physical tests for hydraulic cement]. The physical properties like specific gravity, bulk density, flakiness index, and elongation index and fineness modulus are shown in **Table 3.2.**

Table: 3.2 Physical properties of Coarse and Fine aggregates

S. No	Property	Method	Fine Aggregate	Coarse Aggregate
1.	Specific gravity	Pycnometer IS:2386 Part 3-1986	2.43	2.62
2.	Bulk Density Loose Compacted	IS:2386 Part 3-1986	1540 kg/m3 1685 kg/m3	1456kg/m3 1610kg/m3
3.	Bulking	IS:2386 Part 3-1986	6% w c	--
4.	Flakiness Index	(IS:2386 Part 2-1963)	--	8.04%
5.	Elongation Index	(IS:2386 Part 2-1963)	--	0%
6.	Fineness Modulus	Sieve Analysis (IS:2386 Part 2-1963)	3.61	6.05

3.1.4 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. Most of the fly ash particles are solid spheres and some particles. The particle sizes in fly ash vary from less than 1 μm to more than 100 μm with the typical particle size measuring less than 20 μm. Their surface area is typically 300 to 500 m2/kg, although some fly ashes can have surface areas as low as 200 m2/kg and as high as 700 m2/kg. Flyash is primarily silicate glass containing silica, alumina, iron, and calcium. The relative density or specific gravity of flyash generally ranges between 1.9 and 2.8 and the color is generally grey.

3.1.5 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.

3.1.6 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.

Table: 3.3 Details of Super Plasticizer

S. No.	Property	Result
1.	Form or state	Liquid (sulphonated naphthalene based formaldehyde)
2.	Colour	Brown
3.	Specific gravity	1.220 to 1.225 at 30°C
4.	Chloride content	Nil to IS:456
5.	Air entrainment	Approx. 1% additional air is entrained
6.	Compatibility	Can be used with all types of cements except high alumina cement.
7.	Workability	Can be used to produce flowing concrete that requires no compaction.
8.	Cohesion	Cohesion is improved due to dispersion of cement particles thus minimising segregation and improving surface finish.
9.	Compressive strength	Early strength is increased upto 20%. Generally, there is improvement in strength upto 20% depending upon W/C ratio and other mix parameters.
10.	Durability	Reduction in w/c ratio enables increase in density and impermeability thus enhancing durability of concrete
11.	Dosage	The rate of addition is generally in the range of 0.5 - 2.0 litres /100 kg cement.

3.2 Mix Proportioning

Table: 3.4 Mix Proportion and Quantities of M60 grade of SCC

Size of Graded Aggregate (mm)	Mix Proportion	Cement	Fly Ash	Fine Aggregate	Coarse Aggregate	S.P
20	1: 0.41:1.23:1.195: 0.03	680	278.8	836.4	812.6	20.4
12.5	1:0.42:1.25:1.183 :0.025	680	285.6	850	804.44	17
10	1:0.45:1.26:1.169: 0.021	680	306	856.8	794.92	14.28

3.3 Batching and mixing of SCC

The proportioning of the quantity of cement, cementitious material like Flyash, 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.

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.

3.4 Fresh Properties of SCC

3.4.1 Requirements of Self Compacting Concrete

1. Ability to flow into and completely fill intricate and complex forms under its own weight.

2. Ability to pass through the congested reinforcement under its own weight.

3. High resistance to aggregate segregation

Due to the high powder content, SCC shows more plastic shrinkage or creep than ordinary concrete mixes. These aspects should therefore be considered during designing and specifying the SCC.

By definition of SCC, it is clear that the fresh concrete has to fulfill various properties. The SCC must be adequately free flowing so that the coarse aggregate particles can float in mortar but the air can still rise and escape adequately. Sedimentation of the coarse aggregate particles and upward movement of fine mortar, paste or water before the concrete sets must be avoided. Otherwise, the SCC components will be resulting inhomogeneous compositions that can adversely affect their durability and fitness for use. The paste volume and grading curve must be chosen so that the concrete completely fills the form work and is not held back in front of the gaps between the reinforcement. Suitable test methods by which the corresponding requirements can be verified were developed to ensure that the SCC meets these requirements.

Many 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.

3.4.2 Workability Criteria for the Fresh Concrete

Filling ability, passing ability and segregation resistance are the requirements for judging the workability criteria of fresh SCC. These requirements are to be fulfilled at the time of placing of concrete. Typical acceptance criteria for Self-compacting Concrete with a maximum aggregate size up to 20 mm are shown in **Table 3.5**.

Table: 3.5 Acceptance criteria for Self-compacting Concrete

S No	Method	Unit	Typical range of values	
			Minimum	Maximum
1.	Slump flow test	mm	650	800
2.	T_{50} cm Slump flow	sec	2	5
3.	J – Ring	mm	0	10
4.	V – Funnel	sec	6	12
5.	V – Funnel at T_5 minutes	sec	6	15
6.	L – Box	h_2/h_1	0.8	1.0
7.	U – Box	(h_2-h_1) mm	0	30
8.	Fill Box	%	90	100
9.	GTM Screen stability test	%	0	15
10.	Orimet test	sec	0	5

and upward movement of fine mortar, paste or water before the concrete sets must be avoided. Otherwise, the SCC components will be resulting inhomogeneous compositions that can adversely affect their durability and fitness for use. The paste volume and grading curve must be chosen so that the concrete completely fills the form work and is not held back in front of the gaps between the reinforcement. Suitable test methods by which the corresponding requirements can be verified were developed to ensure that the SCC meets these requirements.

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8.	Fill Box	%	90	100
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3.4.3 Test Methods

It was observed that none of the test methods for SCC has yet been standardized, and neither the tests described are yet perfected or definitive. A brief description of the tests has been presented below.

3.4.3.1 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 under water 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 T_{50} 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. The slump flow test procedure is as shown in **Fig.3.1**. **Slump flow apparatus .**

The mould used is in the shape of a truncated cone with internal dimensions 200mm diameter at the base, 100mm diameter at the top and a height of 300mm. The base plate is of a stiff non-absorbing material of at least 700mm square, marked with center location for the slump cone, and further concentric circle of 500mm diameter.The other apparatus required are trowel, scoop, ruler, and a stop watch.

Procedure

About 6 liters of concrete is needed to perform the test. The base plate and the inside of the slump cone were moistened. The base plate was placed on level stable ground and the slump cone was placed centrally on the base plate and hold down firmly. The concrete was filled into the cone with the scoop without tamping. The excess material on the top of slump cone was removed and leveled with a trowel. The surplus concrete around the base of the cone was removed. The slump cone was raised vertically upwards allowing the concrete to flow out freely. The time taken for concrete to reach the 50cm spread circle was recorded by using the stopwatch. This is the T_{50} time. After the flow of concrete was stopped, the final diameter of concrete in two perpendicular directions was measured. The average of the two measured diameters is called as slump flow in mm.

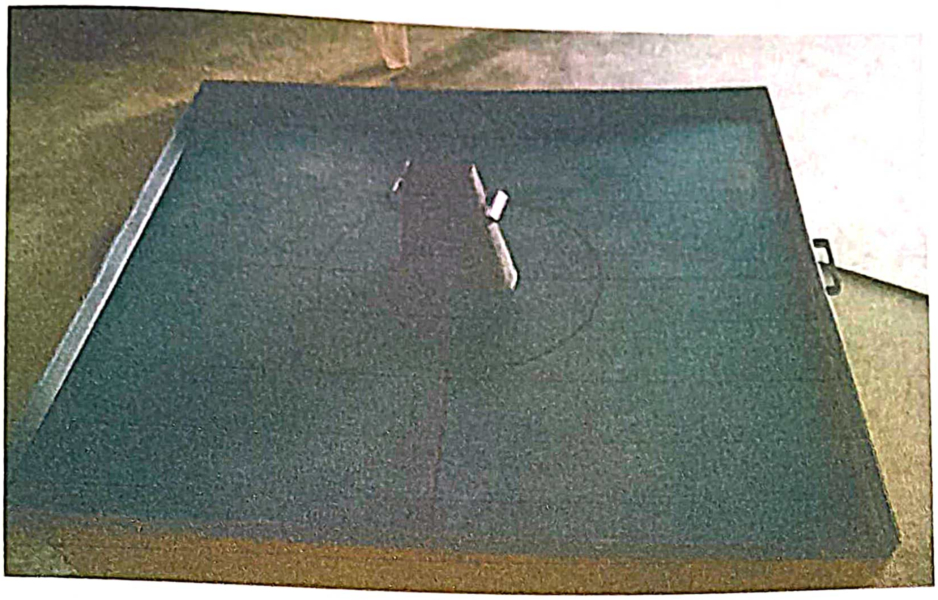

Fig.3.1. Slump flow apparatus
(https://5.imimg.com/data5/SELLER/Default/2023/8/338782653/BJ/ZY/AL/16195802/slump-flow-test-appaaratus.png)

Fig. 3.2 T50 cm test procedure

(https://www.selfconsolidatingconcrete.org/images/testingmeasure.jpg)

3.4.3.2 V- funnel test and V- funnel test at T5 minutes

The equipment consists of a V-shaped funnel, shown in **Fig.3.3**. The V-funnel test is used to determine the filling ability of the concrete with a maximum aggregate size of 20mm. The funnel was filled with about 12 liter of concrete and the time taken for it to flow through the apparatus measured. After this the funnel was refilled concrete and left for 5 minutes to settle. If the concrete shows seggregation then the flow time increases significantly.

a. Procedure for flow time

About 12 liters of concrete was needed to perform this test. The V-funnel apparatus was placed on the firm ground. The inside surfaces of the V – funnel was moistened and the surplus water in funnel was drained through trap door by opening it. Before starting the test, the trap door was closed and a bucket was placed underneath. The V – funnel apparatus was completely filled with concrete without any compaction. The top surface was leveled with the trowel. The trap door was opened and concrete was allowed to flow out under gravity. By using the stopwatch, the time taken for the complete discharge of concrete from the funnel was measured. The whole test has to be performed within 5 minutes.

b. Procedure for flow time at T5 minutes

After measuring the flow time, the trap door of the V-funnel was closed and a bucket was placed underneath. Again the concrete was filled into the apparatus completely without any compaction. The top surface was leveled with the trowel. The trap door was opened after 5 minutes and the concrete was allowed to flow out under gravity. The time for the complete discharge of concrete from the funnel was recovered.

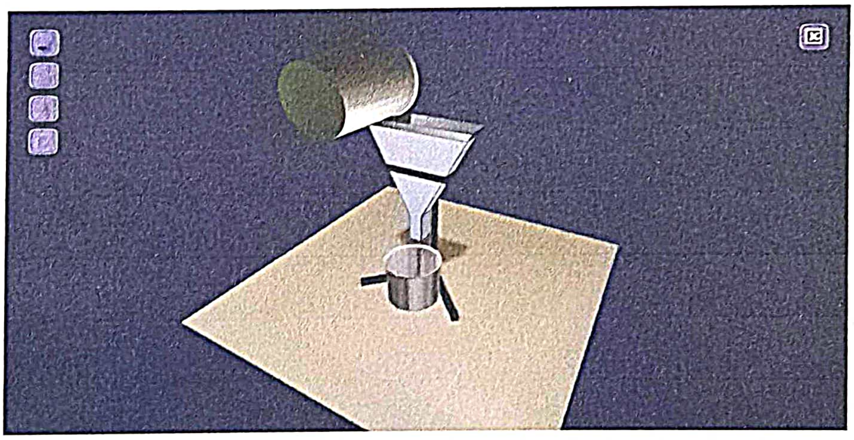

Fig. 3.3 V-funnel test apparatus

(https://sunspire.site/wp-content/uploads/2022/03/scc_L2_003.png)

3.5 Size of test specimen used

The Self Compacting Concrete mixes, after having checked for the satisfaction of the fresh properties of self compacting specifications was cast into cube moulds of size 150 mm x 150 mm, cylindrical moulds of 300 mm height x 150mm diameter. The moulds were fabricated with steel sheets. It is easy for assembling and removing the mould specimen without damage. Moulds were provided with base plates, having smooth surface to support. The mould is filled without leakage. Care was taken to ensure that there were no leakages.

3.6 Curing of test specimens

After 24 hours of casting, the specimens were removed from the moulds and immediately dipped in clean fresh water. The specimens were cured for 3 days, 7 days and 28 days respectively depending on the requirement of age of curing. The fresh water tanks used for the curing of the specimens were emptied and cleaned once in every fifteen days and were filled once again. All the specimens under immersion were always kept well under water and it was seen that at least about 15 cm of water was above the top of the specimens as shown in **Fig.3.4.**

Fig. 3.4 Curing of specimens

(https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcT4IakPrbbS_oc_XoWwp2jEQ2ujNAV9qeOJuazfFiR3rO-sQZTM

3.7 Test on hardened concrete

3.7.1 Compressive Strength

Compressive strength of a material is defined as the value of uniaxial compressive stress reached when the material fails completely. In this investigation, the cube specimens of size 150 mm x 150 mm x 150 mm are tested in accordance with IS: 516 – 1969 [Method of test for strength of concrete]. The testing was done on a compression testing machine of 300 tons capacity. The machine has the facility to control the rate of loading with a control valve. The machine has been calibrated to the required standards. The plates are cleaned; oil level was checked and kept ready in all respects for testing.

After 28 days of curing, cube specimens were removed from the curing tank and cleaned to wipe off the surface water. The specimens were transferred on to the swiveling head of the machine such that the load was applied centrally. The smooth surfaces of the specimen are placed on the bearing surfaces. The top plate was brought in contact with the specimen by rotating the handle. The oil pressure valve was closed and the machine was switched on. A uniform rate of loading 140 kg/cm2/min was maintained. The maximum load to failure at which the specimen breaks and the pointer starts moving back was noted. The test was repeated for the three specimens and the average value was taken as the mean strength. The test set up is shown in Fig.3.5.

In the present investigation, the compressive strength test has been conducted on concretes with different sizes of coarse aggregate. M 60 grade of SCC at 3, 7 and 28 day were tested.

Fig. 3.5 Compressive Strength test setup

(https://velosiaims.com/pk/wp-content/uploads/sites/15/2023/09/compressive-strength-test-3.jpg)

3.7.2 Split tensile strength

This is also some times referred as "Brazilian Test" as this test was developed in Brazil in 1943. This comes under indirect tension test methods. The test was carried out by placing a cylindrical specimen horizontally between the loading faces of a compression testing machine and the load was applied until failure of the cylinder, along the vertical diameter as shown in **Fig.3.6**. A concrete cylinder of size 150mm diameter and 300mm height was subjected to the action of a compressive force along two opposite edges. The cylinder was subjected to compression near the loaded region and the length of cylinder is subjected to uniform tensile stress.

Horizontal tensile stress=2P/Π D L

Where P= Compressive load on the cylinder.

L= Length of cylinder.

D= Diameter of cylinder.

In the present investigation, the split tensile strength test has been conducted on concrete with different sizes of coarse aggregate for M 60 grade of SCC at 3, 7 and 28 days.

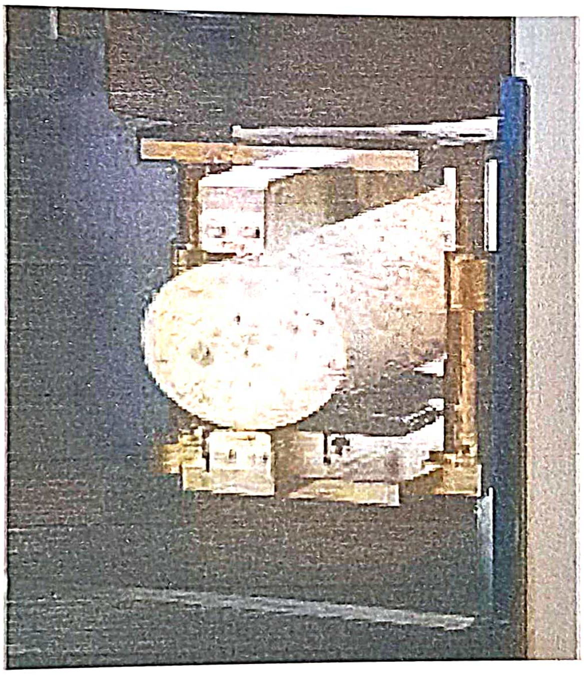

Fig. 3.6 Split tensile strength test

(https://media.licdn.com/dms/image/D5612AQEzhrCyswlhOA/article-cover_image-shrink_600_2000/0/1685968761705?e=2147483647&v=beta&t=E56r39a4XBFOR9GiowTcXZNYl8iMvMMrh_dtXx1q2q8)

CHAPTER – 4

Experimental Results and Discussion

4.1 Discussion on mix proportions adopted for SCC

As described earlier, Nan Su method of mix design [2001] was adopted to design the SCC mix for M60 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 flowability, self-compacting ability and other desired SCC properties. The packing factors assumed on the basis of better compactability and strength. From Nan Su method of mix design for SCC, the density, compactability 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.

4.2 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 M60 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 M60 grade of concrete.

4.3 Mix proportions for SCC

The mix proportion of M60 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, **Table 4.1**, 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 (F/T) for various aggregate sizes.

Table 4.1 Parameters of M60 grade SCC mix proportions

Size of aggregate (mm)		A/C	w/c	CA/FA	F/T
10		2.43	0.39	0.927	0.519
12.5		2.43	0.37	0.946	0.514
20		2.42	0.36	0.973	0.507

4.4 Fresh properties of SCC

Table 4.2 Fresh properties of M 60 SCC

S. No	Size of Aggregate	Slump Flow value	T_{50}	V-Funnel	V-Funnel at T5 Minutes
1.	20 mm	720 mm	5 Sec	9 Sec	12 Sec
2.	12.5 mm	725 mm	5 Sec	6 Sec	8 Sec
3.	10 mm	735 mm	5 Sec	7 Sec	9 Sec

4.5 Mechanical Properties of SCC with different sizes of aggregate with their effects

4.5.1 Compressive Strength

Grade of concrete, maximum size of aggregate and age of curing are the variables of investigation. The details of the compressive strengths of M60 grades are shown in **Tables 4.3**. From the results it was noted that, as the grade of concrete increased the effective maximum size of the aggregate has decreased. In the above cases, the cement content was 680 kg/m3 for M60 grades. The three effective sizes for the above three mixes have been arrived and the same was adopted in the further study

Table: 4.3 Compressive Strength of M60 grade SCC

Size of Aggregate	3 Days	7 Days	28 Days
20 mm	27.4	40.3	63.7
12.5 mm	31.2	43	67.5
10 mm	33.8	43.7	69.9

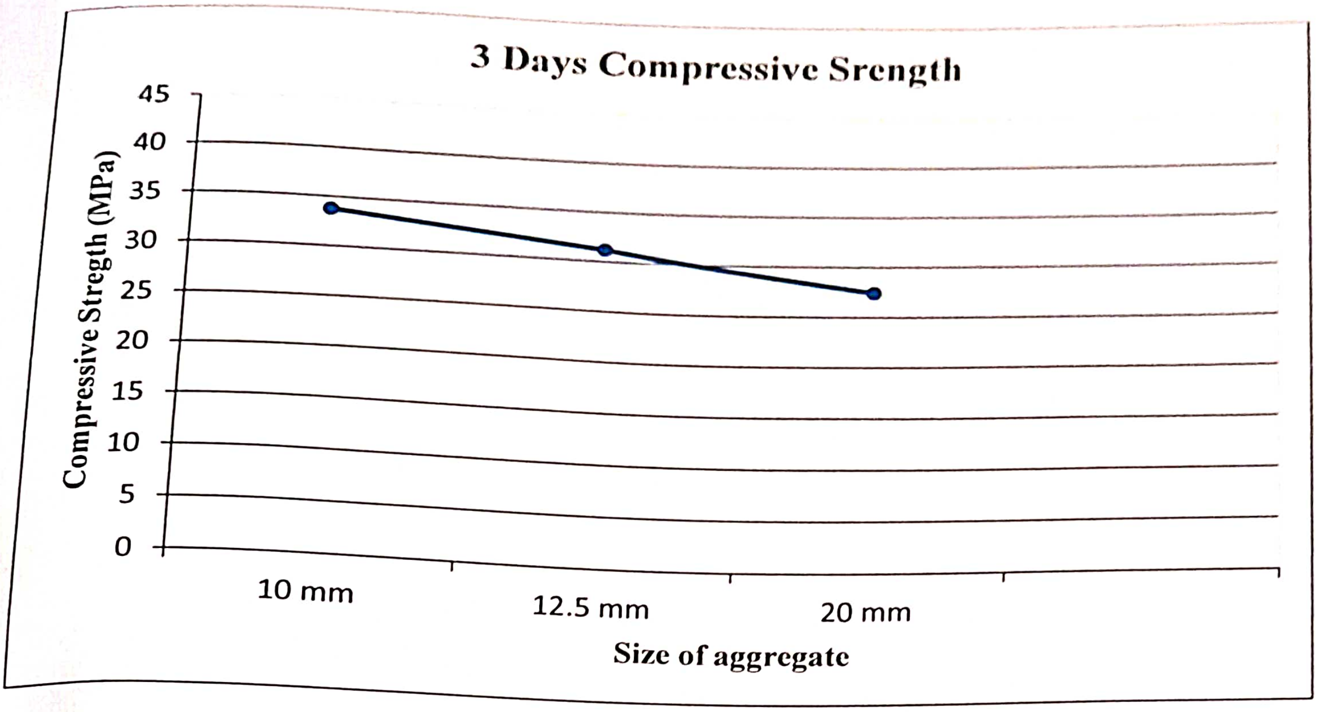

Fig. 4.1 3 Days Compressive strength with various sizes of aggregates

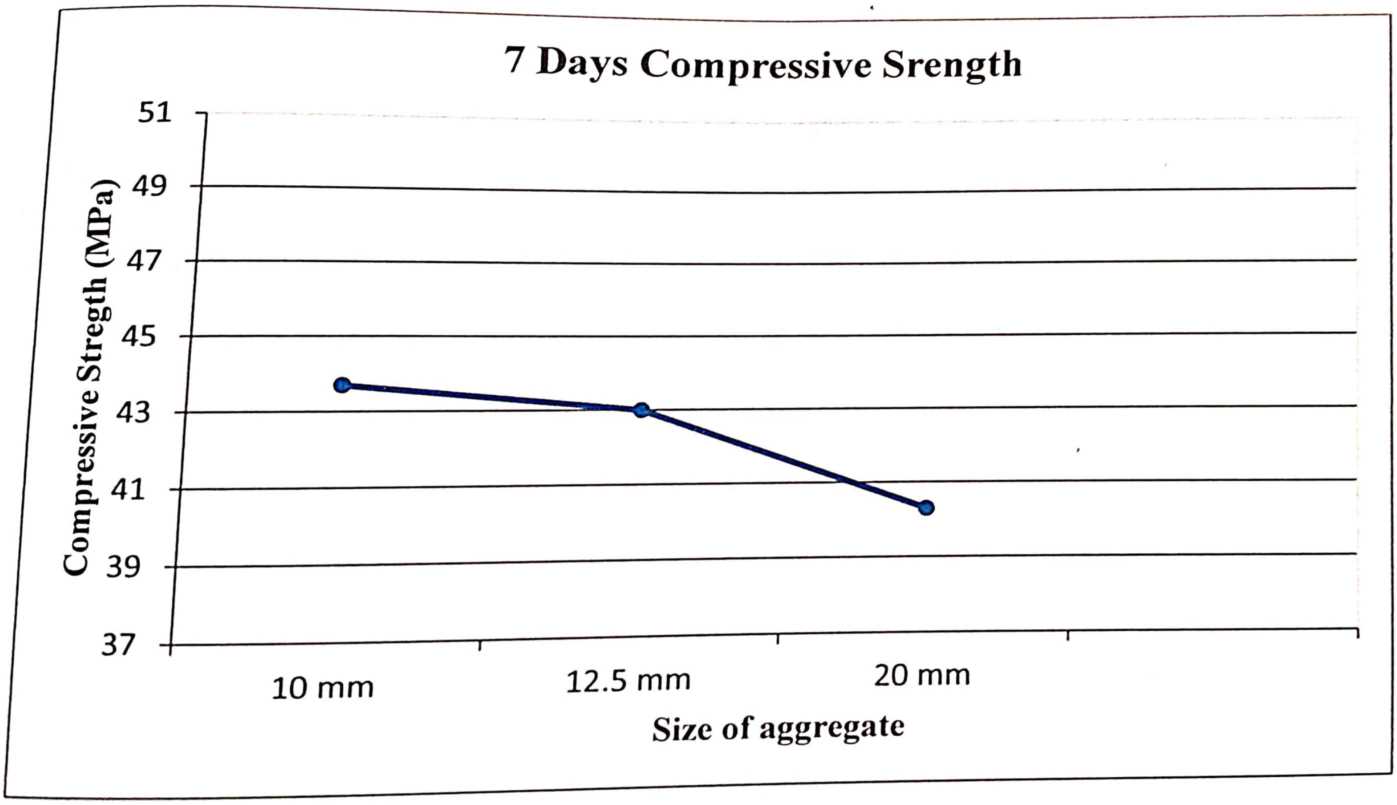

Fig. 4.2 7 Days Compressive strength with various sizes of aggregates

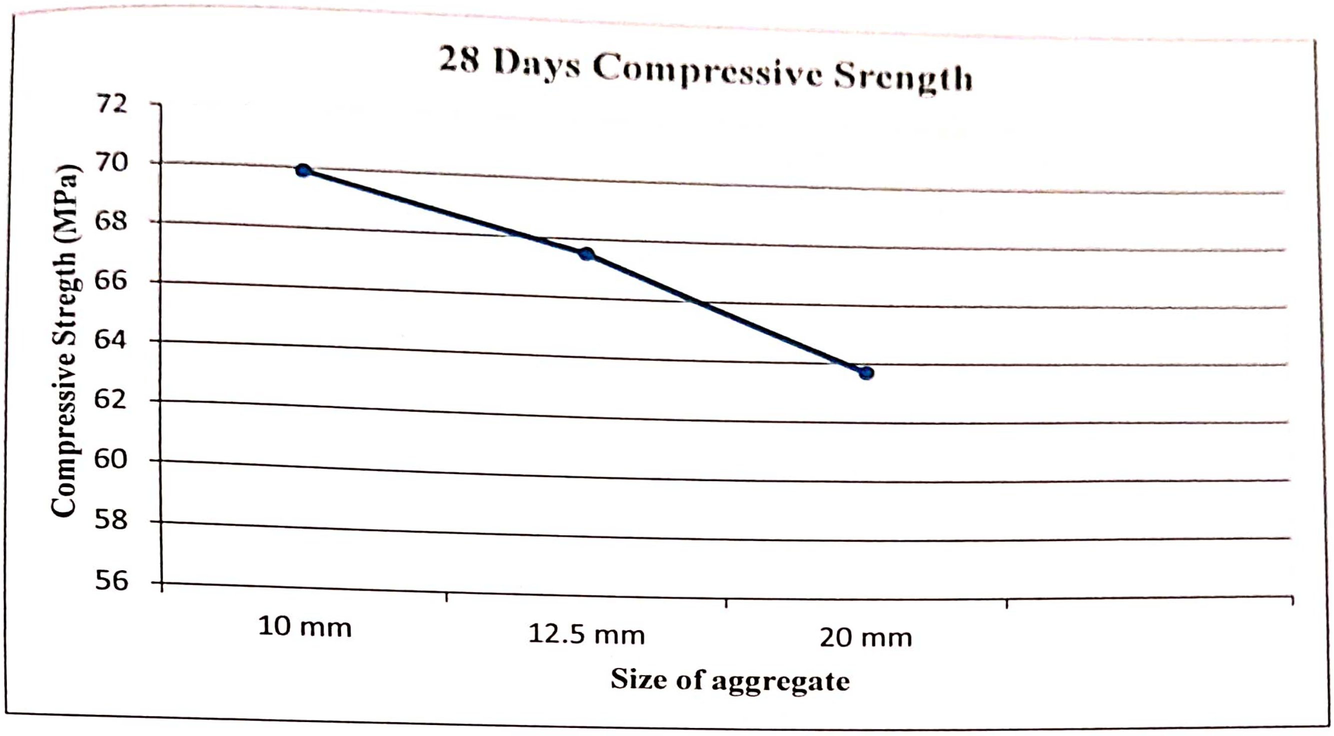

Fig. 4.3 28 Days Compressive strength with various sizes of aggregates

4.5.2 Split tensile strength

Table 4.4 shows the details of the split tensile strength of M 60 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: 4.4 Split tensile strength of M60 grade SCC

Size of Aggregate	3 Days	7 Days	28 Days
20 mm	1.91	5.35	8.7
12.5 mm	2.13	5.5	8.9
10 mm	2.42	5.83	9.2

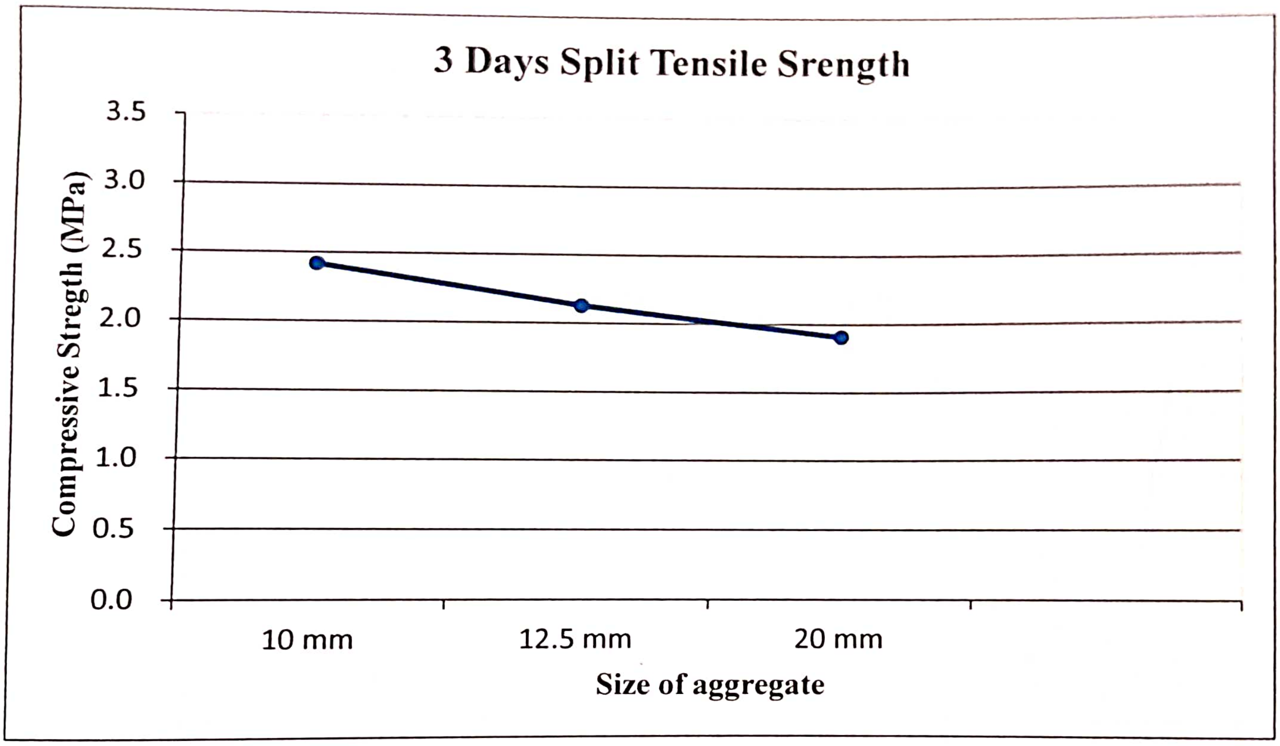

Fig. 4.4 3 Days Split tensile strength with various sizes of aggregates

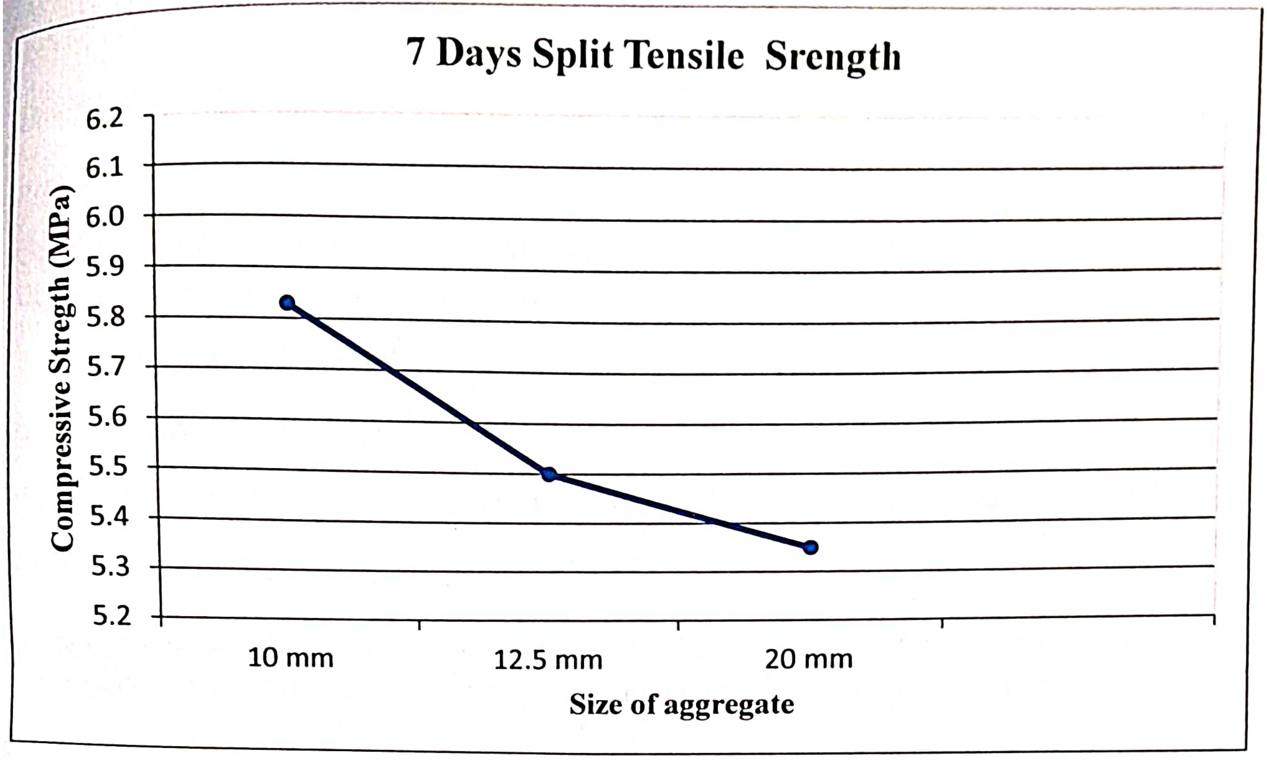

Fig. 4.5 7 Days Split tensile strength with various sizes of aggregates

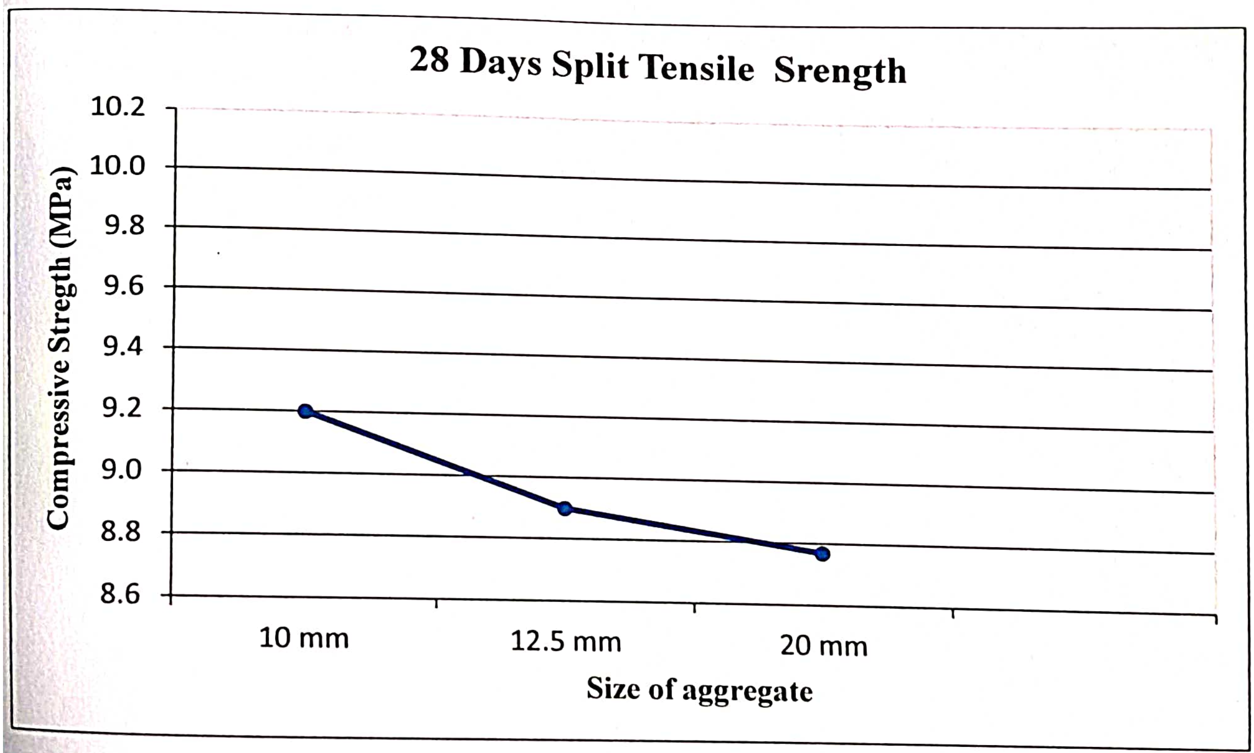

Fig. 4.6 28 Days Split tensile strength with various sizes of aggregates

CHAPTER – 5

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.

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.

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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