EFFECT OF SIZE OF AGGREGATE ON SELF COMPACTING CONCRETE OF M70 GRADE

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Abstract

Concrete is a flexible and frequently used building material. Researcher's have been working to raise the caliber and improve the performance of concrete ever since it was adopted as a building material. Developments in building durability are essential due to recent changes in the construction sector. There is a methodological shift in concrete design from a strength- based concept to a performance-based design . At present, there is a large emphasis on the performance aspect of concrete. One such thought has lead to the development of self- compacting concrete (SCC). It is considered “the most revolutionary development in concrete construction”. High-Performance Concrete (HPC) in the form of SCC is a brand-new type that exhibits exceptional deformability and segregation resistance. Without the requirement for vibration or compaction during the putting process, it may flow through and fill the corners of molds as well as the gaps between the reinforcement. 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”. Other characteristics of the SCC mix proportion include a low water-to-cementitious material ratio, a high powder content, a high paste-to-aggregate ratio, and a low amount of coarse aggregate. Using fine materials like Fly Ash, GGBFS, etc. in addition to cement is one of the frequently used methods to create self-compacting concrete. The goal is to enhance the powder content, or fines, in the concrete.

Key word:-Self Compacting Concrete (SCC) ,High Performance Concrete (HPC) .

1. Introduction :Professor Hajime Okamura first presented the idea of self-compacting concrete in 1986, but it wasn't until 1988 in Japan at the University of Tokyo that Professor Ozawa (1989) first explored the idea. The use of self-compacting concrete (SCC) has become widely accepted in the precast industry as well as in-situ constructions due to the reduction in construction time, noise of construction by eliminating vibration, and good possibility of usage of complex formworks and members with highly congested reinforcement, among other factors, leading to the achievement of a better final product in terms of finish and durability.SCC, or self-compacting concrete, is a type of concrete that only flows and compacts when weight is applied. High-Performance Concrete (HPC) in a novel form called SCC offers good deformability and segregation resistance. It is referred to as concrete if it can fill in reinforcement gaps and mold corners naturally without the aid of external vibration. SCC de- aerates almost entirely as it flows in the formwork and compacts itself due to its weight. It perfectly fills the mould with no imperfections or damage. Designing concrete with a standard or high strength. As per IS: 456–2000 [Code of Practice for Plain and Reinforced Concrete], concretes ranging 25 – 55 MPa are called standard concretes and above 55 MPa called high strength concrete and above 120/150 MPa are called ultra high strength concrete. High strength concrete is used in a wide range of structures, including towering skyscrapers, long-span bridges, and structures in hostile environments. High strength concrete building components are typically heavily reinforced. Congestion caused by the reinforcing causes significant issues when pouring concrete. Concrete that can be easily dispersed between the crowded reinforced concrete pieces can be used to overcome problems with densely reinforced concrete. Such a sort of concrete can provide a highly homogeneous,

evenly dispersed, and dense concrete. SCC, or self-compacting concrete, is a type of concrete that only flows and compacts when weight is applied. Without any flaws, it entirely fills the mould. Self-compacting concrete typically has compressive strengths between 60 and 100 N/mm2. However, depending on the demand, lower grades can also be obtained and utilised. Normal concrete can be used to create high strength concrete. However, these concretes are unable to flow freely on their own in order to fill in all of the reinforcement's gaps and moulded corners.

Vibration and thorough compaction are needed during construction of high strength concrete- based parts. SCC is more advantageous because to its high fluidity, strong segregation resistance, and unique self-compacting ability, which eliminates the requirement for external or internal vibration during the putting process. With no segregation, it may be crushed into every nook and cranny of the formwork using only its own weight.

2. Self- Compacting Concrete

SCC is a particularly coveted accomplishment in the construction sector for resolving the issues with cast-in-place concrete. It is unaffected by the design, placement, and shape of the reinforcement bars. Because there is no segregation, it can be pushed a greater distance.It can be utilised for a variety of construction kinds. Utilising SCC speeds up construction while simultaneously ensuring concrete's durability and quality.

The following are a few benefits of self-compacting concrete:

1. Less vibration noise and less risk of hand-arm vibration syndrome.
2. Safe working environment.
3. Increased placement speed leads to higher production efficiency.
4. simplicity of installation, requiring fewer employees for a specific pour.
5. Improved guarantees of sufficient uniform consolidation. 6.reduced vibrator-related damage to forms.
7. Reduced wear on mixers due to reduced shearing action.
8. improved surface quality, less holes caused by bugs, and less patching.
9. Improved durability.
10. Increased bond strength.
11. less energy is used by vibration equipment.
12. Greater freedom in design.

3. LITERATURE REVIEW

Dr.VaishaliGVijaya G.S, Ghorpade (2016), in his paper showed results that the compressive strength, split tensile strength, and flexural strength was improved proportionally with the addition of waste plastic fibres up to 1.0% by weight of cement and then decreased. This study dealt with flow and strength characteristics such as compressive strength, split tensile strength, flexural strength, and impact strength of SCC with various percentages of waste plastic fibres and GGBS.Heba (2011), presented an experimental study on SCC with two cement contents; the work involved three types of mixes, the first considered different percentages of fly ash, the seconds used different percentages of silica fumes and the third used mixtures of fly ash and silica fume. It was concluded that higher the percentages of fly ash the higher the values of concrete compressive strength until 30% of FA, however the higher values of concrete compressive strength is obtained from mix containing 15% FA. Dr.H.SudarsanaRao (2017), this paper An outline of a laboratory study on the chloride resistance of SCC reinforced with waste plastic. concrete mixtures that self-consolidate and contain different percentages of recycled plastic fibres. The test findings showed that just 1% of plastic fibres could reach the maximum compressive strength.Miao (2010), conducted research on creating an SCC and analysing its fresh characteristics while replacing cement in all combinations by up to 80%. The results demonstrate that fly ash functions as a lubricant; it does not interact with super plasticizer and produce

a repulsive force, and super plasticizer can only interact with cement. As a result, less super plasticizer is required the more fly ash is present. Vikram.K .Shadi,
M.A. Banarase (2015), In their study evaluated the high performance of concrete incorporating supplemental cementations materials such as Alccofine. The effect of Alccofine on the qualities of self-compacting concrete has been explored in this work. It was discovered that the use of alcofine material significantly increased strength. If the percentage of alcofine rises above that point, it serves as a filler and gives the concrete good workability. And it was understood that the ideal ratio for replacing cement is 10% alcofine.

4. Materials 4.1.Cement

The study made use of ordinary Portland cement of grade 53 (IS: 12269-1987, Specifications for 53 Grade Ordinary Portland cement). It can be kept according to IS: 4032 – 1977. employed the same concrete grade and cement throughout the experiment. According to Table (1), the cement was evaluated for physical qualities in accordance with IS: 12269 - 1987.

Table -1 .Physical properties of Ordinary Portland Cement

Sl. No	Property	Test Method	Test Results	IS Standard
1	Normal Consistency	vicat Apparatus (IS: 4031 Part - 4)	30%	
2	Specific gravity	Sp. Gr bottle (IS: 4031 Part - 4)	3.09	
3	Initial setting time Final setting time	Vicat Apparatus (IS: 4031 Part - 4)	96 minutes 207 minutes	Not less than 30 minutes Not less than 10 hours
4	Soundness	Le-Chatlier method (IS: 4031 Part – 3)	2mm	Not more than 10 mm
5	Finess	Sieve test on sieve (IS: 4031 Part – 1)	1.3%	10%

4.2. Aggregates

4.2.1. Fine Aggregate

Fine aggregate from the river was utilised in accordance with IS: 383 - 1970 [Methods of physical tests for hydraulic cement] and without impurities. According to IS: 2386 - 1963 [Methods of test for aggregate for concrete], the fine aggregate was evaluated for its physical properties, including gradation, fineness modulus, specific gravity, and bulk density. Before use, the sand's surface had dried.

4.2.2. Coarse Aggregate

The coarse aggregate used in SCC is round in shape, properly graded, and smaller in maximum size than that used in traditional concrete because rounde smaller aggregate provides flowability, deformability, and segregation. Graded aggregate is also necessary when casting concrete in severely congested reinforcement or formwork with limited dimensions. In the current study, crushed granite metal of sizes 16 mm to 10 mm graded obtained from locally available quarries was used. These were tested in accordance with IS 383-1970 [Physical testing for hydraulic cement].

Table: 2 . Physical properties of Coarse and Fine aggregate

Sl. No	Property	Method	Fine Aggregate	Coarse Aggregate
1.	Specific gravity	Pycnometer IS:2386 Part 3-(1963)	2.41	2.63
2.	Bulk loose Compacted	IS:2386 Part 3-(1963)	1548 kg/m^3 1680 kg/m^3	1451kg/m^3 1602kg/m^3
3.	Bulking	IS:2386 Part 3-(1963)	6%wc	--
4.	Flakiness Index	IS:2386 Part-1(1963)	--	8.08%
5.	Elongation Index	IS:2386 Part-1(1963)	--	0%
6.	Finess Modulus	Sieve Analysis IS:383(1970)	3.62	6.04

4.3. Water

The water used for mixing and curing was portable water that was devoid of any oils, acids, alkalis, salts, organic compounds or other substances according to IS: 3025 - 1964 part22, part 23 and IS: 456 - 2000 [Code of practise for plain and reinforced concrete]. The pH level should not be lower than 6. The solids present were within the acceptable limits specified in IS: 456 - 2000 clause 5.4.

4.4. Fly Ash

Fly ash, similar to Portland cement, is one of the most often utilised supplementary cementitious materials in the building industry. It is a finely split inorganic, non-combustible residue collected or precipitated from the exhaust gases of any industrial furnace. The majority of fly ash particles are solid spheres, with some being hollow cenospheres and some being plerospheres, which are spheres with smaller spheres inside. Fly ash particle sizes range from less than 1 m to more than 100 m, with the median particle size being less than 20 m. Their surface area ranges from 300 to 500 m2/kg on average, however certain fly ashes can have surface areas as low as 200 m2/kg and as high as 700 m2/kg. Flyash is mostly silicate glass, which contains silica, alumina, iron, and calcium. Fly ash has a relative density or specific gravity that ranges between 1.9 and 2.8 and is grey in hue. The flyash used in this study came from the Kakatiya Thermal Power Project in Andhra Pradesh, India. It complies with IS: 3812 -1981 [Specifications for flyash for use as pozzolana and admixture] grade I. It was tested in accordance with IS: 1727-1967 [Test Methods for Pozzolanamaterials].Table .3. shows a typical oxide content of Indian fly ash. Table.4. and Table.5. provide the chemical composition and physical parameters of the fly ash employed in this study.

Table: 3. Typical Oxide Composition of Indian fly ash.

S No	Characteristics	Percentage
1.	Silica	49-67
2.	Alumina	16-28

3.	Iron oxide	4-10
4.	Lime	0.7-3.6
5.	Magnesia	0.3-2.6
6.	Sulphar Trioxide	0.1-2.1

Table: 4. Chemical requirements of fly ash

S No	**Characteristics**	**Fly Ash Requirements (% by weight)**	**Fly Ash used (% by weight)**
1.	SiO2,Al2O$_3$ +Fe2O3	70 (minimum)	94.46
2.	SiO2	35 (minimum)	62.94
3.	MgO	5 (max.)	0.60
4.	SO3	2.75 (max.)	0.23
5.	Na2O	1.5 (max.)	0.05
6.	Loss on ignition	12 (max.)	0.30
7.	Chlorides		0.009

Table: 5. Physical requirements of fly ash

S No	**Characteristics**	**Requirements for grade of flyash(IS:3812-1981)**		**Experimental Results**
		Grade-I	**Grade-II**	
1.	Finess by Blain’s apparatus in m$^{2/}$kg	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 cement mortar cubes	Not less than 80%		86%
4.	Soundness by Autoclave expansion			Nil

4.5. Super Plasticizer

Super plasticizers are water-reducing admixtures with a high water-cement ratio that are used to increase flow or workability for lower water-cement ratios without sacrificing compressive strength. When these admixtures disperse in cement agglomerates, they reduce paste viscosity significantly by forming a thin film around the cement particles. This study used the water- reducing additive Glenium and complies with IS 9103: 1999 [Specification for admixtures for concrete], ASTM

C - 494 [Standard Specification for Chemical Admixtures for Concrete] types F, G, and BS 5075 part.3 [British Standards Institution]. The super plasticizer used is described in Table .6.

Table: 6.Details of Super Plasticizer

SL. NO.	**PROPERTY**	**RESULT**
1.	Form or state	Liquid (sulphonated naphthalene based formaldehyde)
2.	Colour	Broun
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. Conplast SP430 is compatible with other types of Fosroc admixtures when added seperately to the mix
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

4.6. Viscosity Modifying Agent

These admixtures raise water viscosity and eliminate bleeding and segregation in fresh concrete to the fullest extent possible. VMA is a neutral, biodegradable liquid chemical ingredient meant to reduce bleeding, segregation, shrinkage, and cracking in high water/cement ratio concrete mixes. VMA also aids in the stabilisation of SCC blends prone to segregation in high slump ranges. The VMA in this experiment was Glenium stream-2, a product of BASF construction chemicals. VMA's features are listed in Table.7.

Table: .7.Details of Viscosity Modifying Agent

Sl.No.	**Property**	**Results**
1 .	Aspect	Colourless free flowing liquid
2.	Relative density	1.01

3.	pH	≥6
4.	Chloride ion content	< 0.2%
5.	Compatibility	Can be used with all types of cements
6.	Incompatible	use with naphthalene sulphonate based superplasticiser admixtures
7.	Mechanism of action	It consists of a mixture of water soluble copolymers which is adsorbed onto the surface of the cement granules, thereby changing the viscosity of the water and influencing the rheological properties of the mix
8.	Dosage	50 to 500 ml/100 kg of cementitious material.

4.7. MIX PROPORTIONING

The Nan Su technique [2001] was used for mix proportioning. Table .8. shows the mix proportion for various aggregate sizes.

Table: .8. Mix Proportion and Quantities of M70 grade of SCC

Size of Graded Aggregate (mm)	**Mix Proportion**	**w/b**	**Cement**	**Fly-ash**	**Fine aggregate**	**Coarse aggregate**	**S.P**	**VMA**
20	1: 1.42: 4.49: 3.76: 0.043	0.455	210	300	944	791	9.12	1.75
12.5	1:0.425:1.250:1.181 :0.024	0.257	680	289.28	850.30	803.17	16.82	1.75
10	1:0.425:1.250:1.181 :0.024	0.269	680	305.50	850.30	795.65	15.85	1.75

5. Mix design for M 70 grade of SCC

5.1 Mix design using 20 mm size graded aggregates:

Characteristic strength = 70 MPa.

Target mean strength = 70 + 1.65 x 6 = 80 Mpa. = 11428.5 psi. Maximum size of graded aggregate = 20mm

Specific gravity of coarse aggregate, Gg = 2.63 Specific gravity of fine aggregate, Gf = 2.41

Bulk density of loose coarse aggregate = 1451kg/m3 Bulk density of loose fine aggregate = 1548 kg/m3 Specific gravity of cement, Gc = 3.09

Specific gravity of fly ash = 2.19

Specific gravity of super plasticizer = 1.22 Volume of fine/coarse aggregate ratio = 58/42

Volume ratio of fine aggregates to total aggregates(s/a) = 58/100

Determination of Coarse aggregate:Assume P.F = 1.12

Amount of coarse aggregate, Wg = P.F x WgL (1-s/a) = 1.12 x 1451 x (1-0.58)

= 682.55 kg/m3

Determination of fine aggregate:

Amount of fine aggregates, Ws = P.F x WsL (s/a) = 1.12 x 1548 x (0.58) = 948.42 kg/m3

Determination of cement:
C = f’c /20
Given 0.14Mpa = 20 psi
Hence C = 80/.14 =571.42 kg/m3
Determination of water:
Water/cement ratio for 26.6 Mpa = 0.25
Hence quantity of water required = 571.42 x 0.25= 142.85 kg/m3
Determination of fly ash:
Vpf+ Vpb = 1- Wg / (1000 x Gg)- Ws/(1000 x Gf)-C/ (1000 x Gc)-Wwc/ (1000 x Gw)-Va
=1-682.55/ (1000 x 2.63) 948.42/ (1000 x 2.41)-571.42/ (1000 x 3.09)-142.85/ (1000 x 1) - 0.015 = 0.0485 kg/m3

Total weight of Pozzolanic material(Wpm):
Vpf+ Vpb = (1+W/F) x A% x Wpm/ (1000 x Gf)W pm = (Vpf + Vpb) x (1000 x Gf)/((1+W/F) x A%)
= 0.0485 x (1000 x 2.19)/ (1+0.25)
= 8.50 kg/m3
Determination water required for fly ash(Wwf):
Wwf = W/F x Wpm = 0.25 x 8.50= 2.125 kg/m3
Determination of S.P dosage (Wsp);
S.P dosage =1.8% of (571.42+8.50) =10.44kg/m3Water content in S.P = (1-0.4) x 10.44= 6.26 kg/m3
Total water content = 142.85+2.125 – 6.26 = 138.715 kg/m3 Water binder ratio (W/B) = 138.715/ (571.42+8.50) = 0.24

	Cement	Fly ash	Fine aggregate	Coarse aggregate	S.P	Water, w/b
Quantity (kg/m3)	571.42	8.5	948.42	682.55	10.44	138.715
Proportions	1	0.015	1.66	1.20	0.018	0.24

Following a series of testing, the following SCC mix proportions satisfy the required fresh characteristics according to EFNARC requirements.

	Cement	Silica fume	Fly ash	Fine aggregate	Coarse aggregate	S.P	VMA	Water,w/b
Quantity (kg/m3)	680	34	344.7	915.71	750.04	19.34	1.75	241.85
Proportions	1	0.05	0.507	1.346	1.103	0.028	0.0025	0.236

5.2 Mix design using 12.5 mm size graded aggregates:

	Cement	Fly ash	Fine aggregate	Coarse aggregate	S.P	Water, w/b
Quantity (kg/m^3)	571.42	35.46	850.17	803.17	10.92	145.16
Proportions	1	0.062	1.48	1.40	0.019	0.239

Following a series of testing, the following SCC mix proportions satisfy the required fresh characteristics according to EFNARC requirements.

	Cement	Silica fume	Fly ash	Fine aggregate	Coarse aggregate	S.P	VMA	Water,w/b
Quantity (kg/m^3)	680	34	289.3	850.3	803.3	16.82	1.75	249.1
Proportions	1	0.05	0.425	1.250	1.181	0.024	0.0025	0.257

5.3 Mix design using 10 mm size graded aggregates:

	Cement	Fly ash	Fine aggregate	Coarse aggregate	S.P	Water, w/b
Quantity (kg/m^3)	571.42	40.02	850.65	795.65	11.00	146.3
Proportions	1	0.07	1.48	1.48	0.019	0.239

Following a number of trials, the following SCC mix proportions satisfy the required fresh characteristics as per EFNARC requirements.

	Cement	Silica fume	Fly ash	Fine aggregate	Coarse aggregate	S.P	VMA	Water,w/b
Quantity (kg/m^3)	680	34	289.3	850.3				
Proportions	1	0.05	0.425	1.214				

6. Test Method :

It was discovered that none of the SCC test techniques have yet been standardised, and the tests presented are neither perfected nor definitive. A brief summary of the tests is provided below. They are mostly improvised approaches developed expressly for SCC.These are the following. T50 CM

6.1. Slump Flow Test:

The slump cone is used with typical concretes in this test, as stated in ASTM C 143 [Standard Test Method for Slump of Hydraulic-Cement Concrete]. The fundamental distinction between the Slump Flow Test and the ASTM C 143 [Standard Test Method for Slump of Hydraulic-Cement Concrete] is that the Slump Flow Test evaluates the spread or flow of the concrete sample after the cone is lifted as opposed to the typical slump (drop in height) of the concrete sample. During the Slump Flow Test, the T50 test is also determined. It is just the time it takes for the concrete to flow to a diameter of 50 centimetres. Fig.1. depicts the slump flow test process.

Figure.1. Slump flow test and T50 cm test procedure (SCC mixes)

6.2. V – funnel test and V – funnel test at T5 minutes:

Ozawa et al. [1989] developed and used this test in Japan. The apparatus is a V-shaped funnel, as shown in Fig.3.3. The V-funnel test is used to measure the concrete's filling ability with a maximum aggregate size of 20mm. The funnel was filled with approximately 12 litres of concrete, and the time it took for the concrete to flow through the apparatus was measured. Following that, the funnel was refilled with concrete and left for 5 minutes to settle. If the concrete segregates, the flow time increases dramatically.

Figure.2. Funnel test apparatus (SSC Mixes)

6.3. J – Ring test

The University of Paisley invented the J - Ring test. The test is performed to determine the concrete's ability to pass. A rectangular portion (30mm x 25mm) open steel ring is drilled vertically with holes to accommodate threaded sections of reinforcement bar. These bar sections can be of varying diameters and positioned at varying intervals in accordance with standard reinforcement concerns.The ring of vertical bars has a diameter of 300mm and a height of 100mm. The J - Ring can be combined with the Slump flow test. These combinations assess the concrete's flowing and passing capacity. To evaluate flow properties, the slump flow spread was measured. The J - Ring bars can be put at any spacing to apply a more or less rigorous test of the concrete's passing ability. Following the test, the height difference between the concrete inside and just outside the J - Ring is measured. This is an indication of passing ability, or the degree to which concrete can pass between the bars.

6.4. U – Box test :

The Taisei Corporation's Technology Research Centre in Japan created this test. This test is also known as the box-shaped test. It is used to assess the filling capacity of self-compacting concrete. The equipment consists of a jar separated into two halves by a central wall. R1 and R2 represent two compartments in Figure.3.Between the two portions, an aperture with a sliding gate was installed. Reinforcing bars with nominal diameters of 13 mm and centre-to- centre spacings of 50 mm are fitted at the gate. This results in a clear space of 35 mm between the bars. About 20 litres of concrete were poured into the left hand part. The gate was raised, and the concrete now flows upwards in the opposite part. The height of the concrete is measured in both parts.

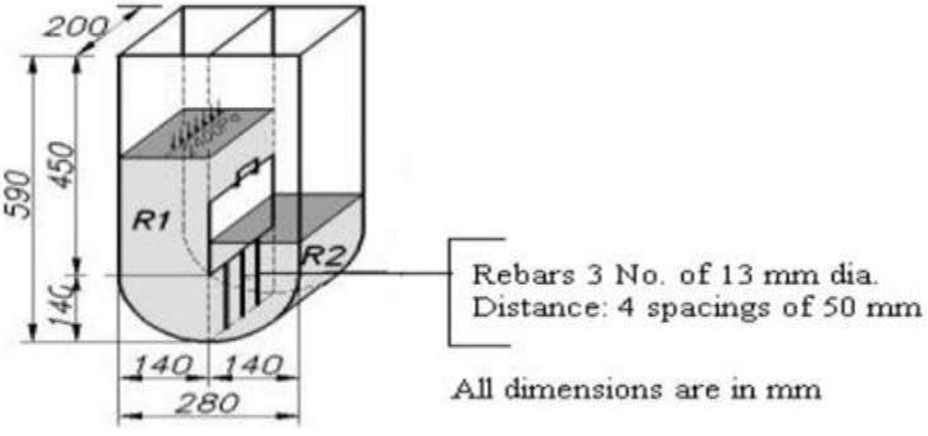

Figure.3.U-box apparatus (SSC Mixes)

7. Tests on hardened concrete

Hardened concrete testing is essential for controlling and confirming the quality of self compacting concrete.

7.1 Compressive Strength

The compressive strength of a material is defined as the value of uniaxial compressive stress reached when the material fails completely. Cube specimens of 150 mm x 150 mm x 150 mm are examined in this study in accordance with IS: 516 - 1969 [Method of test for concrete strength]. The compression testing equipment with a capacity of 300 tonnes was used for the tests. The machine's control valve allows you to control the rate of loading. The machine has been calibrated to meet the required specifications.Everything is ready for testing now that the plates have been cleaned and the oil level has been verified. After 28 days, the cube specimens were taken from the curing tank and cleaned to remove any surface water. The specimens were put on the machine's swivelling head with the weight applied in the centre. The flat surfaces of the specimen are placed on the bearing surfaces. The top plate came into contact with the specimen when the handle was rotated. When the oil pressure valve was closed, the machine was turned on. The loading rate was maintained at 140 kg/cm2/min. The maximum load to failure was measured when the specimen broke and the pointer began to move backwards.The test was repeated for each of the three specimens, and the average value was used to calculate the mean strength. Fig.3.7 depicts the test setup. The compressive strength test was performed on concretes with varying coarse aggregate sizes in the current study. M 70 SCC grade was examined at 3, 7, and 28 days.

Figure.4. Compressive strength test setup

7.2. Flexural Strength

The standard beam test (Modulus of rupture) was performed on beams of size 100 mm x 100 mm x 500 mm in accordance with IS: 516 [Method of test for concrete strength], with the material assumed to be homogeneous. The beams were evaluated on a 400 mm span for a 100 mm specimen using two equal loads placed at third points.A central point load was given to a beam supported on steel rollers placed at the third point to get these loads, as shown in Fig.3.8. For 100 mm specimens, the loading rate is 1.8 kN/minute, and the load was raised until the beam failed. The flexural tensile strength of the sample was calculated based on the kind of failure, appearance of fracture, and fracture force. As previously stated, the flexural strength test was performed on concretes with varying sizes of coarse aggregate M 70 grade of SCC at 3, 7, and 28 days in the current experiment.If 'a' is the distance between the line of fracture and the nearest support, then following instances should be considered when calculating the modulus of rupture.

i. When a > 133 mm for 100 mm specimen fcr = PL/bd2, where P = total load applied on the beam

ii. When 110 mm < a < 133 mm, fcr = 3Pa/bd2

iii. When a < 110 mm, the result should be discarded.

Figure .5. Flexural strength test

7.3. Split tensile strength

This test is also known as the "Brazilian Test" because it was developed in Brazil in 1943. This falls under the heading of indirect tension test procedures. The test was performed by placing a cylindrical specimen horizontally between the loading faces of a compression testing machine and applying a load along the vertical diameter until the cylinder failed, as shown in Fig.3.10. A compressive force was applied to two opposing edges of a concrete cylinder 150mm in diameter and 300mm in height. The cylinder was squeezed near the loaded region, and consistent tensile stress was applied along its length.

Horizontal tensile stress=2P/Π D L

Where P= Compressive load on the cylinder. L= Length of cylinder.

D= Diameter of cylinder.

The split tensile strength test was performed on concrete with different sizes of coarse aggregate for M 70 grade of SCC at 3, 7, and 28 days in the current study.

Figure.6. split tensile strength test

8. Experimental Results

The mechanical properties of the material, such as compressive strength, split tensile strength, and flexural strength, have been thoroughly examined. This chapter highlights the findings of the aforementioned experimental investigation.

8.1. Mix proportions for SCC

The mix proportion of M70 grade concrete designed on the basis of the Nan Su technique for different aggregate maximum sizes of 10, 12.5, and 20 mm. Table 4.1 highlights the details of several parameters such as 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 for the mix proportions determined.

Table .9.- Parameters of M70 grade SCC mix proportions

Size of aggregate(mm)	**A/C**	**w/c**	**w/p**	**CA/FA**	**S/a**
20	2.45	0.365	0.236	0.820	0.550
12	2.43	0.366	0.257	0.914	0.514
10	2.45	0.38	0.269	0.935	0.520

8.2. Compressive strength

The mechanical properties obtained from specimens evaluated according to Indian standard test procedures (IS: 516) are discussed. The variables under research are M 70 grade concrete, three maximum aggregate sizes, and three different curing ages. The Table .10.- shows the compressive strengths of the M70 grade.

Table:10. Compressive strength of M 70 grade SCC

Size of Aggregate(in mm)	**3 Days**	**7 Days**	**28 Days**
20	31.80	46.30	74.00
12.5	36.20	49.00	7.10
10	38.33	49.66	79.30

According to the findings, the effective maximum size of the aggregate dropped as the concrete grade increased. In the preceding samples, the cement content was 680 kg/m3 for M70 grades. The three effective sizes for the three combinations described above were found and used in the future study.

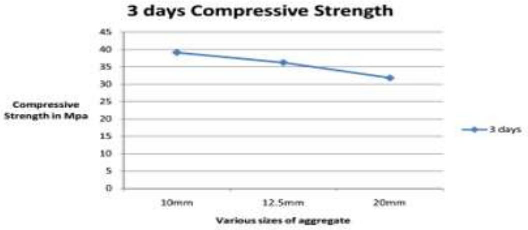

Figure. 7 : 3 days Compressive strength with various sizes of Aggregates

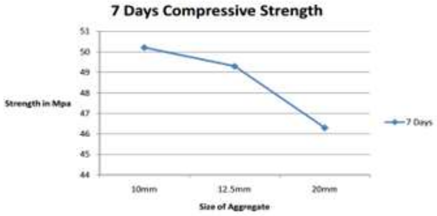

Figure.8 : 7 days Compressive strength with various sizes of Aggregates

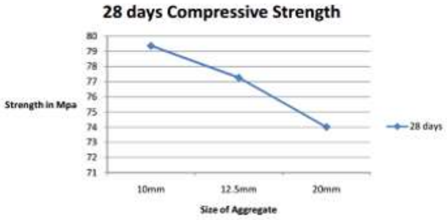

Figure.9 : 28 days Compressive strength with various sizes of Aggregates

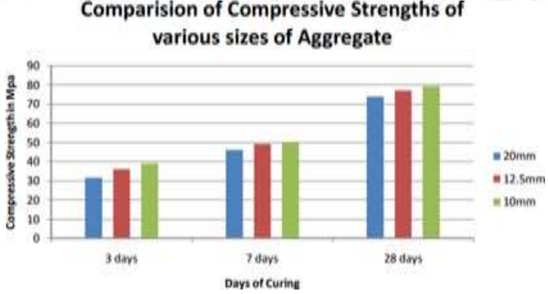

Figure.10 :Bar Diagram of Compressive Strength with various sizes of Aggregates

8.3. Split tensile strength

The split tensile strength of three types of concrete for various aggregate sizes is shown in Table 4.4.

Table: 11. Split tensile strength of M 70 grade SCC

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

In terms of aggregate size, a similar tendency to that of compressive strength was seen. This was true throughout the three stages of curing.

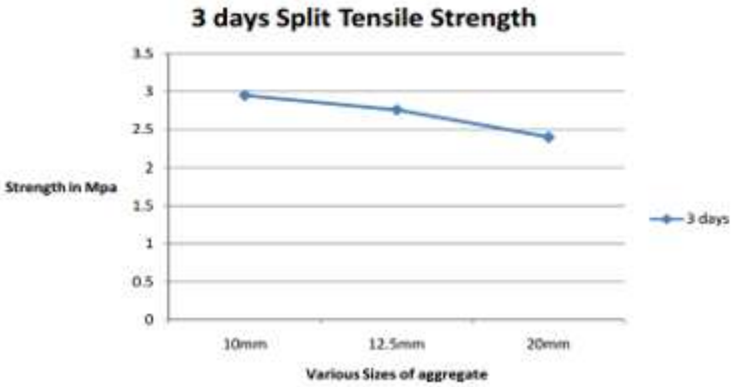

Figure .11 : 3 days Split Tensile strength with various sizes of Aggregates

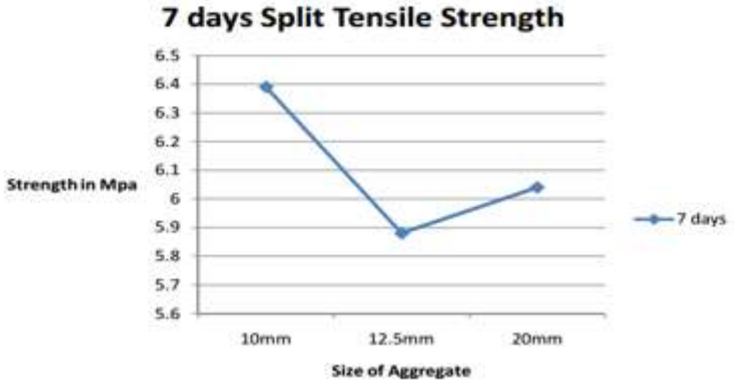

Figure .12: 7 days Split Tensile strength with various sizes of Aggregates

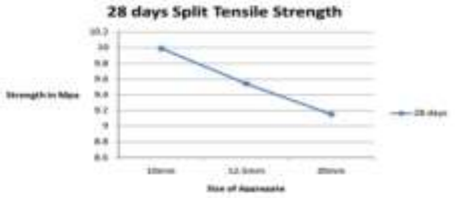

Figure .13 : 28 days Split Tensile strength with various sizes of Aggregates

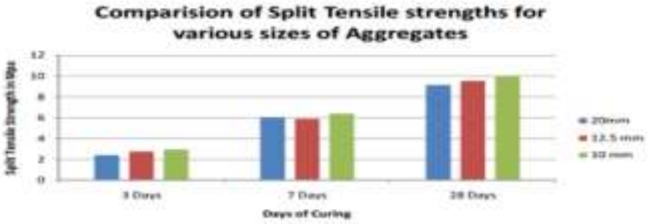

Figure.14: Bar Diagram of Split Tensile Strength with various sizes of Aggregates

8.4. Flexural strength

Table .12. details the flexural strength of various aggregate sizes and the M 70 grade of concrete.

Table.12: Flexural strength of M 70 grade SCC

Size of Aggregate(in mm)	**3 Days**	**7 Days**	**28 Days**
20	4.03	6.75	8.50
12.5	4.60	7.47	9.13
10	5.35	7.65	9.35

The effective size of aggregate at 3, 7, and 28 days was 10 mm for M 70 grade, as indicated below.

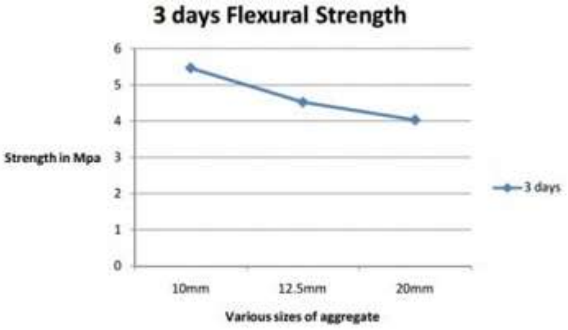

Figure.15 : 3 days Flexural strength with various sizes of Aggregates

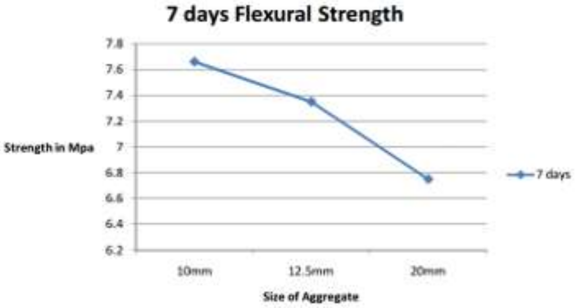

Figure.16: 7 days Flexural strength with various sizes of Aggregates

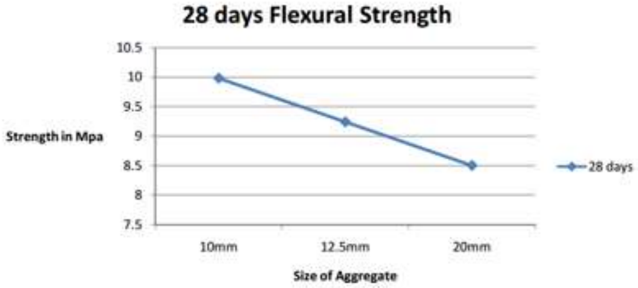

Figure.17 :28 days Flexural strength with various sizes of Aggregates

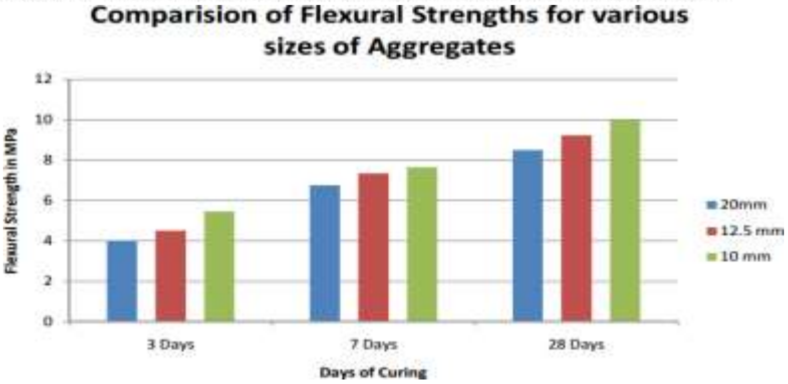

Figure.18 : Bar Diagram of Flexural Strength with various sizes of Aggregates

9. Conclusions

The following results were reached based on a comprehensive and detailed experimental examination on SCC mixes with the goal of developing performance mixes.

1. Mixtures created with smaller aggregate sizes produced greater fresh characteristics than mixes designed with larger aggregate sizes.
2. The effective size of aggregate has reduced as the strength of concrete has increased.

Significant project contribution: The current study has revealed the effect of aggregate size on the compressive strength and other mechanical parameters of self-compacting concrete.

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