



## Analysis and Study of High Strength Self Compacting Concrete by Using Chemical and Mineral Admixtures

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**Abstract:** The development of ordinary concrete with good benefits has led to the invention of Self Compacting Concrete (SCC). It is considered as "the most revolutionary development in concrete construction". It can flow and fill the gaps of reinforcement corners of moulds without any need of vibration and compaction. 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". SCC is an example for High Performance Concrete (HPC) with excellent deformability and segregation resistance. 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 Limestone, Super plasticizer like Poly Carboxylate ester (PC) etc. The original contribution in the field of SCC is attributed to the pioneering work of Nan Su; 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 M<sub>70</sub> Grade.

**Index Terms –** Self Compacting Concrete (SCC), High Performance Concrete (HPC), Sedimentation Resistance, Lime stone, Super Plasticizer, Poly Carboxylate Ester (PC), Packing Factor (PF).

### I. INTRODUCTION

Self-compacting concrete (SCC) is a concrete, which flows and compacts only under gravity. SCC is an innovative form of High Performance Concrete (HPC), which has good deformability and segregation resistance. It termed as a concrete, which can flow freely through and fill the gaps of reinforcement and corners of the mould without any need of external vibration. SCC compacts itself due to its self weight and de-aerates almost completely while flowing in the formwork. It completely fills the mould without any damage and defects. Design of Normal or high strength concrete As per IS: 456-2000, Code of Practice for Plain and Reinforced Concrete. Concretes ranging 25MPa to 55MPa are called standard concretes, while those above 55 MPa can be termed high-strength concrete. Concretes having 120MPa and 150MPa are called ultra-high strength concrete. High strength concrete applied in tall buildings, bridges with long span and buildings in aggressive environments. Usually self-compacting concretes have a compressive strength having a range of 60 to 100 N/mm<sup>2</sup>. By the way, the lower grades can also be obtained and applied depending upon the necessity. High-strength concrete can be obtained from normal concrete. However, 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. The beneficial necessities of a fresh SCC are distinct from those of a vibrated fresh Normal Concrete (NC). Filling of formwork with a liquid suspension requires workability performance like filling ability, passing ability and resistance against segregation.

## II. LITERATURE REVIEW

- [1] Arabi N.S. Alqadi; Kamal Nasharuddin Bin Mustapha; Sivakumar Naganathan, Qahir N.S. Al-Kadi (2012), "Development of self-compacting concrete using contrast constant factorial design" The highest compressive strength is obtained when cement contents, w/p, FA contents are high and SP is low. Complete factorial design needs to add center point to handle the curvature from second order effects and have to allow an independent estimate of error to be obtained.
- [2] D. Indu; R.Elangovan (2016), "Optimum Mix Proportioning of High Strength Self Compacting Concrete", The test results of fresh concrete are within the limits of SCC. The concrete have been casted for M<sub>30</sub> to M<sub>80</sub> in order to check the Compressive strength, Split tensile strength and Flexural strength.
- [3] G.J. Prasanna Venkatesh, S.S.Vivek, G.Dhinakaran (2018), "Study on Strength Characteristics of Binary Blend Self Compacting Concrete Using Mineral Admixtures", The rheological behaviour of SCC was developed by slump flow & T<sub>500</sub> tests in which MK 20% has yielded better results. From the cube compressive strength results, GGBS 20% have obtained better performance than CVC, control SCC and other binary blended SCC mixes.
- [4] M. Chandrakanth, Prof C.Sashidhar, G.Hemalatha(2020), "Study on Fresh and Hardened Properties of Self Compacting Concrete Using Macro Synthetic Fibers and Manufacture Sand", The reference mix possesses the least compressive strength. An increases in compressive strength by 23.3% has been achieved in mix with 25% FA, 5% SF, 5%GGBS and 1.5% of fiber as compared to the reference mix. Addition of mineral admixtures, results in increase of tensile strength.
- [5] Mallikarjuna Reddy V, Seshagiri Rao M V, Srilakshmi P, Sateesh Kumar B (2013), "Effect of W/C Ratio on Workability and Mechanical Properties of High Strength Self Compacting Concrete (M<sub>70</sub> Grade)", Required minimum strengths are achieved for a w/c ratio 0.27 with optimum slump for M<sub>70</sub> grade high strength self compacting concrete. For water cement ratio 0.25 fresh and hardened state properties of high strength self-compacting concrete are moderate.
- [6] Mohammad Kasim, Amir, Shiwani Bharti(2017). "Effect of Size of Aggregate on Self Compacting Concrete of M<sub>70</sub> Grade", on experimental study conducted on SCC mixes with an aim to develop performance mixes, the following are the arrived. The mixes designed using the lower size of aggregate yielded better fresh properties than higher size of aggregates. As the strength of concrete increases, the effective size of aggregate has decreased.
- [7] N. Ramanjaneyulu, M. V. Seshagiri Rao, V. Bhaskar Desai(2019), "Behavior of Self Compacting Concrete Partial Replacement of Coarse Aggregate with Pumice Lightweight Aggregate". The compressive strength and flexural strengths of pumice aggregate self compacting concrete (PASCC) are found to be optimum for 20% replacement of pumice aggregate. Pumice aggregate absorbs additional water when compared to the normal coarse aggregate reducing workability.
- [8] P. Ramanathan, I. Baskar, P. Muthupriya and R. Venkatasubramani (2013), "Performance of Self-Compacting Concrete Containing Different Mineral Admixtures", All the self-compacting concrete mixes had a satisfactory performance in the fresh state. Among the mineral admixtures considered, the Blast furnace slag series had a good workability properties compared to Fly ash and Silica fume series. The results of the mechanical properties (compressive, split and flexure) had shown significant performance differences and the higher compressive strength has been obtained for Silica fume series.
- [9] Ram Prasanth, S.Karthik, J.ShriIndhu (2017), "Influence of Mineral Admixture on strength Aspects of Self Compacting concrete" The test results of fresh concrete are within the limits of SCC i.e., flow ability, passing ability and resistance against segregation, Compressive strength of Self-compacting concrete of M<sub>80</sub> grade at 7 days is 47.7MPa and at 28 days is 81.0MPa has been obtained with a water-cement ratio of 0.26.
- [10] Saleema Begum R (2016), "Studies on the characteristics of high strength self compacting concrete of M<sub>70</sub> grade using flyash and microsilica", The results of compressive strength of fly ash concretes when replaced with 15% of cement are more than 12.87% compared to Conventional concrete at the end of 28 days. It is observed that compressive strength and split tensile strength less 17.97% at higher rate for 7 days strength when compared to 28 days strength.

## III. MATERIALS AND METHODOLOGY

### I. 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(CC). the coarse aggregate size may be 20 mm and even more in general. Highly congested reinforcement patterns of grades are used and where, very small dimensional elements are to be produced. Like in case of conventional concrete(CC), size of aggregate has a key note to play in SCC designs also. Hence, studies are needed to assess the maximum size of aggregate for a particular grade of concrete. Usually, the maximum size of the coarse aggregate used in production of SCC, ranges approximately between 10mm and 20mm. Well graded with maximum size 20mm, ranges approximately between 10mm and 20mm Tested as per IS: 383-1970.

Sl. No.	Tests Carried Out	IS Code	Result
1	Impact Value	Tested as per IS : 383-1970	5.21
2	Specific Gravity		2.6
3	Flackiness Index		57.6%
4	Elongation Index		34.32%

## 2. Fine Aggregate

All normal river sands are suitable for SCC. Both crushed and rounded sands, M sand 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. 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.

Sl. No.	Tests Carried Out	IS Code	Result
1	Finess Test	IS Code : 383-1970	2.54%
2	Specific Gravity		2.61

## 3. Cement

All types of cements conforming to Bureau of Indian standards are suitable as per Indian conditions. The cement content can be 350 – 450 kg/m<sup>3</sup>. The usage of cement more than 500 kg/m<sup>3</sup> may increase the shrinkage, and the quantity less than 350 kg/m<sup>3</sup> may decrease the durability of SCC. Less than 350 kg/m<sup>3</sup> may also be used with the inclusion of other fine fillers such as fly ash, Ground Granulated Blast furnace Slag (GGBFS) and rice husk ash. Portland Pozzolana Cement(PPC) of 53 grade with codal provision IS: 1489- 1991(Part I).

Sl. No.	Tests Carried Out	Result
1	Setting Time of Cement a) Initial Setting Time = 31min b) Final Setting Time = 10hr	
2	Consistency	36%
3	Specific Gravity	3.15

## 4. Water

Potable water shall be used for the production of SCC. In case of conventional concretes (CC), 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. Portable water with pH value not be less than 6, with code as per IS: 3025-1964 Part 22 & Part 23.

## 5. Mineral Admixtures

Mineral admixtures are added to concrete as a part of the cementitious material. Here we are using Lime stone as mineral Admixture. They may be used as an addition to or as a part replacement of Portland cement in concrete. This depends on the properties of materials and the desired effect of concrete. Pozzolonas are also used to produce high performance concrete in terms of strength, workability and durability. It is also cost effective.

## 6. Chemical Admixtures

Chemical admixtures are used in Self Compacting Concrete as ingredients which can be added to the concrete mixture immediately before or during mixing. The use of chemical admixtures such as water reducers, retarders, high-range water reducers or Super Plasticizers (SP), is necessary in order to improve the fundamental characteristics of fresh and hardened concrete.

### • Super Plasticizers

Generally, in order to increase the workability, the water content is to be increased provided a corresponding quantity of cement is also added to keep the water cement ratio constant, so that the strength remains the same. To avoid the use of excess quantity of water and cement, SP is used to increase the fluidity of the mix and improve the workability of concrete. When plasticizers are used, they get absorbed on cement particles and that charged polymer on cement particle creates particle to particle repulsive forces, which over come the attractive forces. This repulsive force is called zeta potential which depends on the base, solid contents and quality of super plasticizer used. In this project, superplasticizer Polycarboxylate Ether (PCE) Admixture used.

#### IV. TESTS ON CONCRETE

According to Indian Standard Code of practice for plain and reinforced concrete (fourth revision), [2000]. Slump flow test, L-box test, V-funnel test, U-box test, Orimet test & GTM Screen test are recommended by EFNARC [European Federation of Producers and Applicators of Specialist Products for Structures, May 2005] for determining the properties of SCC in fresh state. Nan Su method of mix design [2001] was adopted to arrive at the suitable mix proportions. The mix proportion for M70 grade was arrived, taking the different sizes of aggregate into consideration. A total of 27 cubes of standard size 150 mm x 150 mm x 150 mm, 27 prisms of standard size 100 mm x 100 mm x 500 mm and 27 cylinders of 150 mm diameter and 300 mm height were cast for determining the compressive strength, flexural strength and split tensile strength respectively.

##### 1) Tests on Fresh SCC

###### a) Slump Flow Test and $T_{50}$ cm Test

Slump Flow is used to find filling ability of SCC. 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 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. About 6 liter of concrete is needed to perform the test. The base plate and the inside of the slump cone were moistened, placed on level stable ground. The slump cone was placed centrally on the base plate and hold down firmly. The concrete was filled without tamping. The excess material was removed and leveled with a trowel. The slump cone was raised vertically upwards allowing the concrete to flow out freely. The time taken for concrete to reach the 500 mm 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.

###### b) L - Box Test

The apparatus consists of a rectangular-section box in the shape of an 'L', with a vertical and horizontal section, separated by a moveable gate. About 14 liters of concrete is needed to perform the test. The apparatus was placed on the level ground. It was ensured that the sliding gate can open and close freely. The inside surfaces of the apparatus were moistened and surplus water was removed. The vertical section of the apparatus was filled with the concrete sample. The sliding gate of the vertical section was lifted and concrete has allowed flowing out into the horizontal section. The time taken for concrete to reach the 200 and 400 mm marks in the horizontal section was measured by stopwatch. The distances  $H_1$  and  $H_2$  were measured, when the concrete stops flowing and the blocking ratio  $H_2/H_1$  is calculated and noted. The maximum time required for performing this L-box test is 5 minutes.

###### c) V-Funnel Test and V-Funnel Test at $T_5$ Minutes

The equipment consists of a V-shaped funnel used to determine the filling ability with a maximum aggregate size of 20mm. 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. 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. 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 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.

###### d) J – Ring Test

It is done to determine passing ability. The J-Ring test apparatus having a rectangular section with a dimension of 30mm x 25mm along with a open steel ring, drilled vertically with holes to accept threaded sectionS. It can be of different diameters and spaced at different intervals. The vertical bar diameter is 300mm, and its height is 100 mm, the mould used is in the shape of a frustum of cone with the base 100mm diameter, internal dimension 200mm diameter and at top height of 300mm. The base plate is a square of at least 700mm, marked with its center location for the slump cone, and concentric circle of 500mm diameter. The J – Ring can be used in combination with the Slump flow test and they will discuss about the flowing ability and the passing ability, the slump cone was placed and the J – ring was placed centrally inside. About 6 liters of concrete was filled into the cone with the scoop without any compaction but levelled. The slump cone is vertically raised upwards to allow the concrete to flow out freely through the rings. The difference in height between the concrete just inside and outside the bars was measured and the average of the difference in height at four locations was measured.

###### e) U-Box Test

This test is also called as box-shaped test. It is used to measure the filling ability of self-compacting concrete. The apparatus consists of a vessel that is divided by a middle wall into two compartments, shown by  $R_1$  and  $R_2$ . An opening with a sliding gate was fitted between the two sections. Reinforcing bars with nominal diameters of 13 mm are installed at the gate with centre-to-centre spacings of 50 mm. This creates a clear spacing of 35 mm between the

bars. The left hand section was filled with about 20 liters of concrete. The gate was lifted and the concrete flows upwards in the other section. The height of the concrete in both sections is measured.

### 1) Tests on Hardened SCC

#### a) Compressive Strength Test

Compressive strength is defined as the compressive stress reached when the material fails completely. The cube specimens of size 150 mm x 150 mm x 150 mm are tested in accordance with IS: 516 – 1969. It was done in compression testing machine of 300 tons capacity. After 7<sup>th</sup>, 14<sup>th</sup>, 28<sup>th</sup> days of curing, cube specimens were removed from the curing tank. The specimens were transferred on to the swiveling head of the machine such that the load was applied centrally. The top plate brought in contact with the specimen by rotating the handle. The oil pressure valve was closed and switched on. A uniform rate of loading 140 kg/cm<sup>2</sup>/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 specimens.

#### b) Flexural Strength

Standard beam test (Modulus of rupture) was carried out on the beams of size 100 mm x 100 mm x 500 mm as per IS: 516 [Method of test for strength of concrete]. The beams were tested on a span of 400 mm for 100 mm specimen by applying two equal loads placed at third points. For this a central point load has applied on a beam supported on steel rollers placed at third point. The rate of loading is 1.8 kN/minute for 100 mm specimens and the load was increased until the beam failed. Depending the failure, appearance of fracture and fracture load. The flexural strength test has been conducted on concretes with different sizes of coarse aggregate M 70 grade of SCC at 7<sup>th</sup>, 14<sup>th</sup> and 28<sup>th</sup> days.

#### c) Split Tensile Strength

This is also some times referred as “Brazilian Test”. By placing a cylindrical specimen horizontally between the loading faces of a compression testing machine and the load was applied until failure, along the vertical diameter. A cylinder of size 150mm diameter and 300mm height was subjected to the action of a compressive force along two opposite edges, near the loaded region and the length of cylinder is subjected to uniform tensile stress.

## V. Results of SCC

### 1) Test Results In Fresh SCC

Sl.No	Method	Property	Unit	Typical range of values		Results
				Minimum	Maximum	
1	Slump flow test	Filling Ability	mm	650	800	721
2	T <sub>50</sub> cm Slump flow	Filling Ability	sec	2	5	4
3	J – Ring	Passing Ability	mm	0	10	7.6
4	V – Funnel	Filling Ability	sec	6	12	9
5	V – Funnel at T <sub>5</sub> minutes	Segregation Resistance	sec	6	15	9
6	L – Box	Passing Ability	h <sub>2</sub> /h <sub>1</sub>	0.8	1.0	0.9
7	U – Box	Passing Ability	(h <sub>2</sub> -h <sub>1</sub> ) mm	0	30	28
8	Fill Box	Passing Ability	%	90	100	95.4
9	GTM Screen stability test	Segregation Resistance	%	0	15	13.2
10	Orimet test	Filling Ability	sec	0	5	4

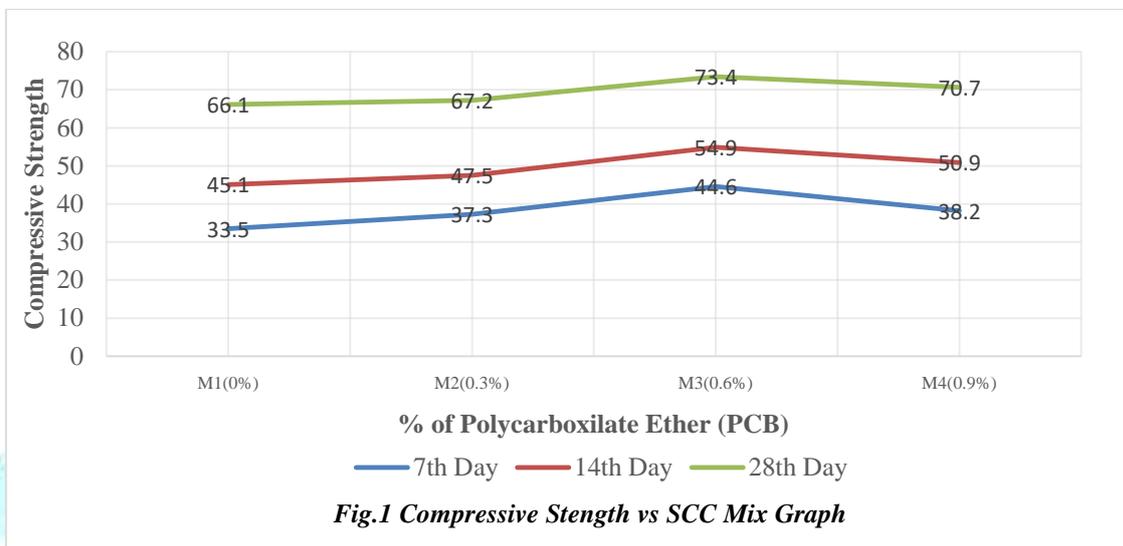
Table 1 : Test Results in Fresh SCC

2) Test Results In Hardened SCC

a) Compressive Strength Test Result

SI. No.	Mix In % of Superplasticizer	7 <sup>th</sup> DAY	14 <sup>th</sup> DAY	28 <sup>th</sup> DAY
1	M1 (0%)	33.5	45.1	66.1
2	M2 (0.3%)	37.3	47.5	67.2
3	M3 (0.6%)	44.6	54.9	73.4
4	M4 (0.9%)	38.2	50.9	70.7

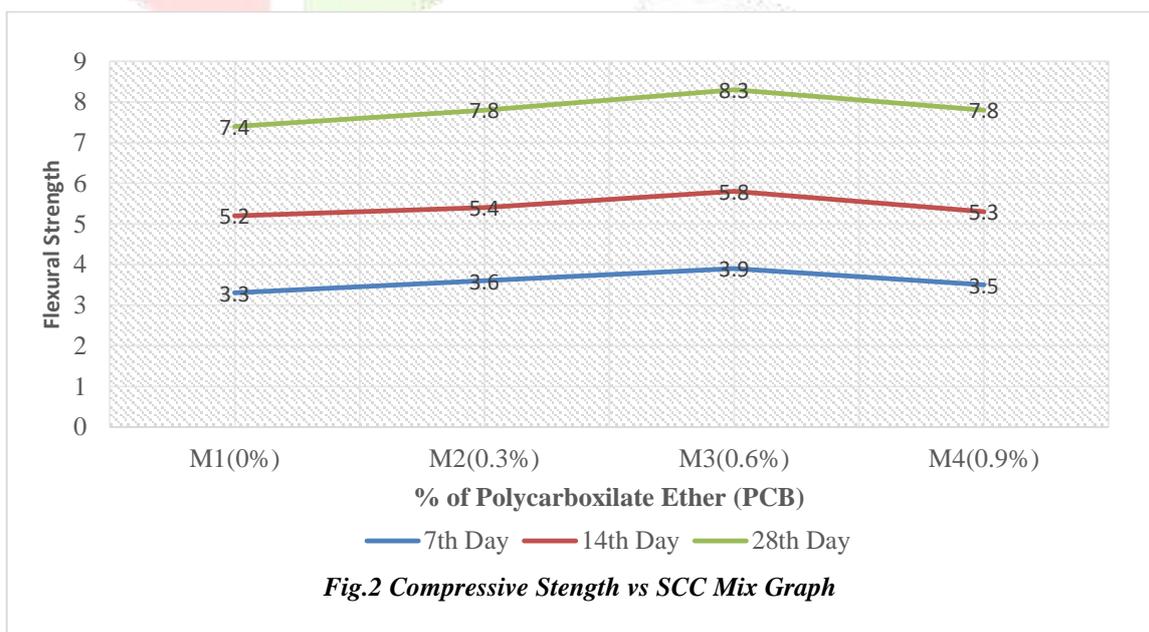
Table 2 : Test Result in Compressive Strength



b) Flexural Strength

SI. No.	Mix In % of Superplasticizer	7 <sup>th</sup> DAY	14 <sup>th</sup> DAY	28 <sup>th</sup> DAY
1	M1 (0%)	3.3	5.2	7.4
2	M2 (0.3%)	3.6	5.4	7.8
3	M3 (0.6%)	3.9	5.8	8.3
4	M4 (0.9%)	3.5	5.3	7.8

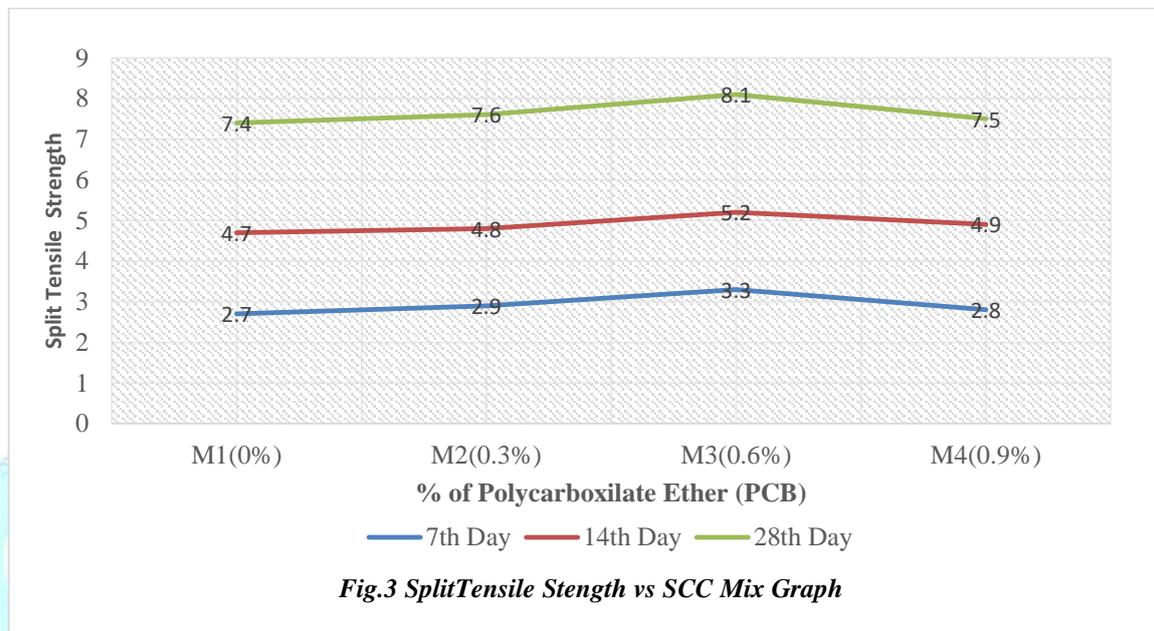
Table 3 : Test Result in Flexural Strength



## c) Split Tensile Strength

Sl. No.	Mix In % of Superplasticizer	7 <sup>th</sup> DAY	14 <sup>th</sup> DAY	28 <sup>th</sup> DAY
1	M1 (0%)	2.7	4.7	7.4
2	M2 (0.3%)	2.9	4.8	7.6
3	M3 (0.6%)	3.3	5.2	8.1
4	M4 (0.9%)	2.8	4.9	7.5

Table 4 : Test Result in Split Tensile Strength



## VI CONCLUSION

This project helps to conclude the high performance of M70 Self Compacting Concrete achieved by using M Sand, and chemical admixture like super plasticizer Poly Carboxylate Ester (PCE) and Mineral admixture limestone. Simply we can say according to the application of PCE and Limestone will help to improve the strength of SCC at 0.6% to 0.9% of the PCE gives the maximum result. Limestone kept constant as 1%. We can use this technology to future construction works and it will helps to improve the work quality and it will ensure the easiness of works. It ensures the other factors like Less noise from vibrators and reduced danger from Hand Arm Vibration Syndrome (HAVS), Safe working environment, speed of placement, resulting in increased production efficiency, ease of placement, requiring fewer workers for a particular pour, better assurances of adequate uniform consolidation, reduced wear and tear on forms from vibrator, reduced wear on mixers due to reduced shearing action, improved surface quality and fewer bug holes, requiring fewer patching, improved durability, increased bond strength, reduced energy consumption from vibration equipment and it best suited where reinforcement congestion is a problem.

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