

# An Experimental Study on Rapid Chloride Penetration Test of Self Compacting Concrete

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## ABSTRACT

Self-compacting concrete (SCC) is a very fluid concrete and a homogeneous mixture that solves most of the problems related to ordinary concrete. Self-Compacting Concrete gets dense and compacted due to its own self-weight. An experimental investigation has been carried out to determine different characters like filling ability, passing ability, segregation resistance workability and strength of Self-Compacting Concrete (SCC). And finally determining the chloride penetrability of SCC. Self-Compacted Concrete is generally defined as the "Concrete, which does not need Compaction." Due to these characteristics, SCC is ideally suited for concreting structures, which have heavily congested reinforcement or difficult access conditions. In this project, M40 grade concrete were made using European method. The compressive strength, split tension test obtained at the ages of 7, 14 and 28 days.

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**Keywords:** Self compacting concrete, tensile strength, split tensile test, compressive strength, Rapid chloride penetration test

## INTRODUCTION

Concrete is the most versatile construction material because it can be designed to withstand the harshest environments while taking on the most inspirational forms. Engineers are continually pushing the limits to improve its performance with the help of innovative chemical admixtures and supplementary cementitious materials. Self-compacting concrete (SCC) is an innovative concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened concrete is dense, homogeneous and has the same engineering properties and durability as traditional vibrated concrete.

Self-compacting concrete offers a rapid rate of concrete placement, with faster construction times and ease of flow around congested reinforcement. The fluidity and segregation resistance of SCC ensures a high level of homogeneity, minimal concrete voids and uniform concrete strength, providing the potential for a superior level of finish and durability to the structure. The improved construction practice and performance, combined with the health and safety benefits, make SCC a very attractive solution for both precast concrete and civil engineering construction.

## MATERIALS AND METHODS:

Materials used to produce Self Compacting Concrete for the experimental investigations are, listed below with their physical properties.

**Table 1. Physical properties of self-compacting concrete materials**

Sl. No.	Particulars of Test	Observation
<b>Cement (OPC 53 grade)</b>		
1.	Consistency	36 %
2.	Initial setting time	32 min
3.	Fineness modulus	12.33
4.	Specific gravity	3.14
<b>Fine Aggregate (River sand)</b>		
5.	Specific gravity	2.60
6.	Fineness modulus	2.85
7.	Water absorption	2.5 %
8.	Bulk density	1690 kg/m <sup>3</sup>
<b>Coarse aggregate (Limited to 12 mm)</b>		
9.	Specific Gravity	2.66
10.	Fineness Modulus	3.15
11.	Water absorption	1.0 %
12.	Bulk density	1487.6 kg/m <sup>3</sup>
<b>Fly Ash</b>		
13.	Specific Gravity	2.60
14.	Fineness Modulus	2.85
15.	Water absorption	2.5 %
<b>Super plasticizers (Glenium B 233)</b>		
16.	Chemical base	modified poly carboxylates
17.	Relative density	1.08 kg/l at 30°C
18.	Effect on setting	not retarding
19.	Effect of overdosing	bleeding may occur
<b>Viscosity Modifying Agent (VMA)</b>		
20.	Water-soluble polymers that increase the viscosity of mixing water and enhance the ability of cement paste to retain its constituents in suspension. Cement paste serves as the basis for the workability properties of self-compacting concrete (SCC) and these properties could be assessed by self-consolidating cementitious materials (SCCM).	

**Consumption or dosage of Super Plasticizers:**

For concrete of high workability, very low water/cement ratio and for self-compacting concrete 1.0 to 2.0 % by weight of cement used throughout the project.

**MIX DESIGN AND TESTING:****Self-Compacting Concrete mix Design by European Method (M40)**

The mix design of M40 grade of concrete is done by using the European method by using the test results of the materials known.

**Table 2. Conventional concrete mix design for M 30 grade concrete**

Cement kg/m <sup>3</sup> (90%)	Fly Ash kg/m <sup>3</sup> (10%)	Water	FA kg/m <sup>3</sup>	CA kg/m <sup>3</sup>
447.073	39.55	158.2	955.16	830.06
0.90	0.10	0.35	2.13	1.85

**Mix proportions**

Cement (90%)	= 447.073 kg/m <sup>3</sup>
Fly Ash (10%)	= 39.55 kg/m <sup>3</sup>
Water	= 158.2 liters/m <sup>3</sup>
Fine aggregate	= 955.16 kg/m <sup>3</sup>
Coarse aggregates	= 830.06 kg/m <sup>3</sup>
VMA (0.2%)	= 0.98 kg/m <sup>3</sup>

**Trail mix proportions to obtain SCC**

The various trail mix proportions of different ratios are conducted in the laboratory to achieve the Self Compacting Concrete. By the addition of the super plasticizer of various ratio achieve the various Self Compacting Concrete mix. In this stage the segregation of aggregates are found. The obtained mix proportion satisfies the U-Flow test, V-Funnel test, Fill ability test and L box test. This proportion is used for further work by replacing cement with use of fly ash. After conducting number of trails we found that, the following SCC mix proportions are satisfying the required fresh properties and strength properties as per EFNARC specifications.

**Table 3. Proportion of Constituents of SCC**

S.No.	SCC mix	Cement	Fly ash	F.A	C.A	W/P	S.P	VMA
1	SCC 1	0.90	0.10	2.00	1.74	1.00	1.00%	1.00%
2	SCC 2	0.90	0.10	2.00	1.74	1.00	1.25%	1.00%
3	SCC 3	0.90	0.10	2.00	1.74	1.00	1.50%	1.00%
4	SCC 4	0.90	0.10	2.00	1.74	1.00	1.75%	1.00%
5	SCC 5	0.90	0.10	2.00	1.74	1.00	2.00%	1.00%
6	SCC 6	0.90	0.10	2.00	1.74	1.00	2.25%	1.00%
7	SCC 7	0.90	0.10	2.00	1.74	1.00	2.50%	1.00%
8	SCC 8	0.90	0.10	2.00	1.74	1.00	2.75%	1.00%

**Test on Fresh concrete:**

The following tests are carried out to determine the properties of fresh concrete mix. These typical requirements shown against each test method are based on current knowledge and practice.

Values outside these ranges may be acceptable if the producer can demonstrate satisfactory performance in the specific conditions, e.g., large spaces between reinforcement, layer thickness less than 500 mm, short distance of flow from point of discharge, very few obstructions to pass in the formwork, etc. Special care should always be taken to ensure no segregation of the mix is likely as, at present, there is not a simple and reliable test that gives information about segregation resistance of SCC in all practical situations.

**Table4. Acceptance Criteria for SCC**

Property measured	Test method	Material	Recommended values
Flow ability / Filling ability	Slump flow	Concrete	650 – 800 mm Average flow diameter
	T <sub>50</sub>	Concrete	2 – 5 sec Time to flow 500 mm
	V – funnel	Concrete / mortar	6 – 12 sec Time for emptying of funnel
Passing ability	U – box	Concrete	0 – 30 mm Difference in heights in two limbs
	L – box	Concrete	0.8 – 1.0 Ratio of heights at beginning and end of flow
Segregation resistance	V – funnel at T5 mins	Concrete	0 – 3 mm
	Settlement column test	Concrete	> 0.95 Segregation ratio
	Sieve stability test	Concrete	5 – 15% sample passing through 5 mm sieve
	Penetration test	Concrete	Penetration depth < 8 mm

**Tests on hardened concrete:**

**1. Compression test:**

The cube specimen is of the size 15 x 15 x 15 cm. If the largest nominal size of the aggregate does not exceed 20 mm. Cylindrical test specimens have a length equal to twice the diameter. They are 15 cm in diameter and 30 cm long. Smaller test specimens may be used but a ratio of the diameter of the specimen to maximum size of aggregate, not less than 3 to 1 is maintained.



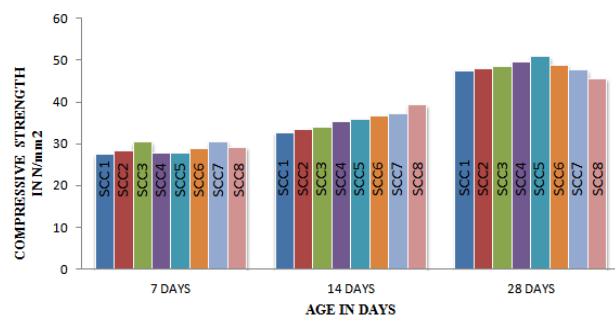
**Fig1. Compression Test Setup**

Compression test develops a rather more complex system of stresses. Due to compression load, the cube undergoes lateral expansion owing to the Poisson's ratio effect.

It has been found that the lateral strain in the steel plates is only 0.4 of the lateral strain in the concrete. The compression test specimens were tested on a compression testing machine of capacity 2000 kN. Load is applied gradually as the rate of 14 N/mm<sup>2</sup>/min or 320 kN/min.

**Table5. Compressive Strength of Cubes**

S.No	Trail Mix	Compressive Strength (N/mm <sup>2</sup> )		
		7 Days	14 Days	28 Days
1.	SCC 1	27.51	32.67	47.56
2.	SCC 2	28.22	33.54	48.14
3.	SCC 3	30.45	34.12	48.64
4.	SCC 4	27.87	35.31	49.71
5.	SCC 5	27.77	35.98	50.94
6.	SCC 6	29.02	36.81	48.69
7.	SCC 7	30.59	37.12	47.63
8.	SCC 8	29.23	39.31	45.69



**Fig2. Comparison of cube compressive strength at 7days, 14 days and 28days**

**2. Split tensile test:**

Tensile strengths are based on the indirect splitting test on cylinders. This is also sometimes referred as, “Brazilian Test”. This test was developed in Brazil in 1943. At about the same time this was also independently developed in Japan.

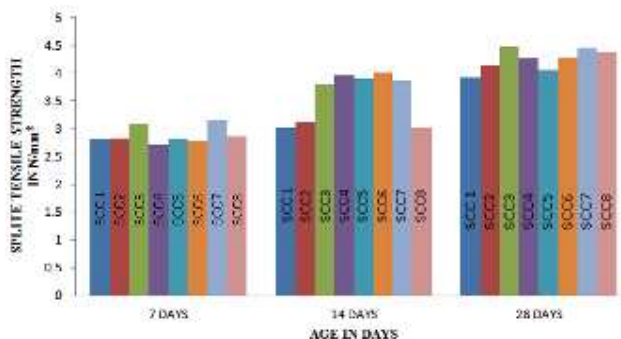


**Fig3. Split Tensile Test**

The test is carried out by placing a cylindrical specimen horizontally between the loading specimen of a compression testing machine and the load is applied until failure of the cylinder, along the vertical diameter. The tensile strength is one of the basic and important properties of the concrete. The concrete is not usually expected to resist, the direct tension because of its low tensile and brittle in nature. However the determination of tensile strength of concrete is necessary to determine the load at which the concrete members crack. The cracking is a form a tensile failure.

**Table6. Split-Tensile strength at 7 days, 14days, 28days**

S.No	Trail Mix	Split Tensile Strength (N/mm <sup>2</sup> )		
		7 Days	14 Days	28 Days
1.	SCC1	2.80	3.01	3.92
2.	SCC2	2.82	3.12	4.14
3.	SCC 3	3.10	3.80	4.47
4.	SCC 4	2.72	3.95	4.26
5.	SCC 5	2.80	3.90	4.05
6.	SCC 6	2.78	4.01	4.28
7.	SCC 7	3.15	3.87	4.46
8.	SCC 8	2.86	3.01	4.38



**Fig4. Comparison of split tensile strength at 7days,14 days and 28days**

**3. Cylinder compressive strength test:**

The cylinder are cast and tested in the same position the standard size of cylinder is 15 cm diameter and 30 cm height in actual structures in the field the casting and loading is similar to that of the cylinder and not like the cube therefore the use of cylinder is more popular particularly in the research laboratories.

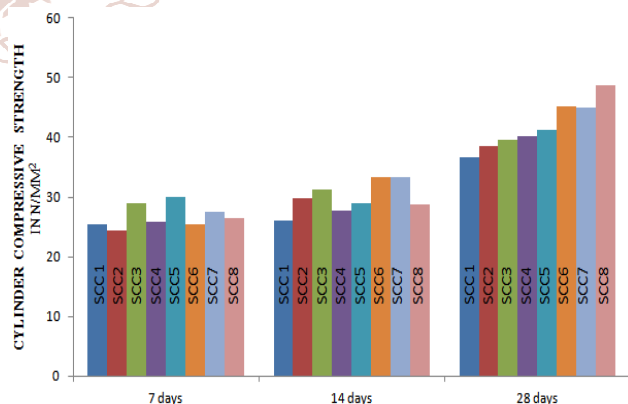


**Fig.5. Cylinder compressive test**

Cylinder compressive strength = Ultimate load / Area of cylinder

**Table7. Cylinder compressive strength at 7 days, 14days, 28 days**

S. No.	Trail Mix	Compressive Strength (N/mm <sup>2</sup> )		
		7 Days	14 Days	28 Days
1	SCC 1	25.50	26.05	36.75
2	SCC 2	24.45	29.88	38.45
3	SCC 3	28.95	31.33	39.50
4	SCC 4	25.88	27.66	40.25
5	SCC 5	30.05	28.98	41.20
6	SCC 6	25.45	33.32	45.28
7	SCC 7	27.43	33.43	45.00
8	SCC 8	26.56	28.78	48.75



**Fig6. Comparison of cylinder compressive strength at 7 days and 28 days**

**4. Rapid chloride penetration test**

Accelerated chloride permeability tests were conducted on standard cylindrical specimens (100 mm dia, 50mm thick) of self compacting Concrete. The test conducted after different periods of curing, as per **ASTM C1202-1994**. All the results of total charge passed through standard specimens in 6 hours (the RCPT values), taken as a measure of the chloride permeability.



**Table8. Rating of chloride permeability of concrete**

Chloride Permeability	Charge passing Coulombs	Typical concrete type
High	> 4000	High w/c ratio (> 0.6) Conventional PC concrete
Moderate	2000 to 4000	Moderate w/c ratio (0.4 to 0.5) Conventional PC concrete
Low	1000 to 2000	Low w/c ratio (> 0.4) Conventional PC concrete
Very Low	100 to 1000	Latex-modified concrete, Internally sealed concrete
Negligible	< 100	Polymer impregnated concrete, Polymer concrete

The diffusion cell consists of two chambers. NaCl solution concentration 2.4M and NaOH solution concentration 0.3 M is prepared. NaCl solution concentration 2.4M is filled in one chamber and in another chamber 0.3 M NaOH solution is taken.

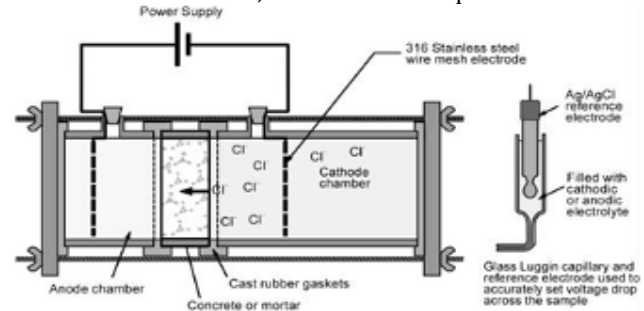
**Reason of conduct RCPT**

Corrosion of reinforcing steel due to chloride ingress is one of the most common environmental attacks that lead to the deterioration of concrete structures. Corrosion related damage to concrete structures is a major. This durability problem has received widespread attention in recent years because of its frequent occurrence and the associated high cost of repairs.

Chlorides penetrate crack-free concrete by a variety of mechanisms: capillary absorption, hydrostatic pressure, diffusion, and evaporative transport of these, diffusion is predominant. Diffusion occurs when the concentration of chloride on the outside of the concrete member is greater

than on the inside. This results in chloride ions moving through the concrete to the level of the rebar. When this occurs in combination with wetting and drying cycles and in the presence of oxygen, conditions are right for reinforcement corrosion.

The rate of chloride ion ingress into concrete is primarily dependent on the internal pore structure. The pore structure in turn depends on other factors such as the mix design, degree of hydration, curing conditions, use of supplementary cementitious materials, and construction practices.



**Fig. 7. Reaction of chlorine during RCPT**

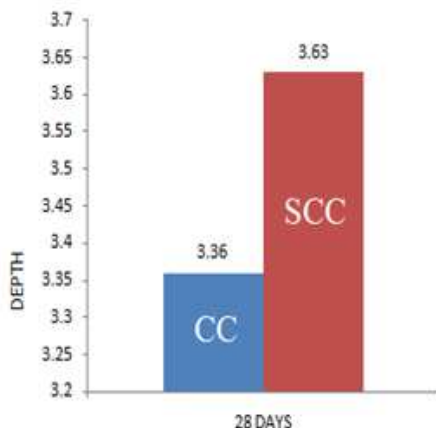
The chloride ions were forced to migrate through the centrally placed vacuum saturated concrete specimen under an impressed DC voltage of 60 Volts. It can also be observed that the total charge passed decreases with the increase in the curing period, measured herein up to 90 days, in specimens of all the mix compositions.



**Fig.8. RCPT test apparatus**

**Table8. RCPT – test result**

TEST DURATION	SCC (in mm)			CC (in mm)			SCC-Avg. (in mm)	CC-Avg. (in mm)
	1	2	3	1	2	3		
<b>28 DAYS</b>	3.4	3.3	3.4	3.5	3.9	3.5	<b>3.36</b>	<b>3.63</b>



**Fig.9. Graphical representation of RCPT test results**

**ADVANTAGES:**

1. It is relatively quick- can be used for quality control
2. Has simple and convenient set up and procedures
3. Provides results that are easy to interpret

**DISADVANTAGES:**

1. May not represent the true permeability for concrete that contains supplementary cementitious material or chemical admixtures
2. May allow measurements before a steady state is achieved
3. Can cause physical and chemical changes in the specimen, result in unrealistic values
4. Has low inherent repeatability and productivity

**CONCLUSION:**

The fundamental tests were conducted for all ingredients of SCC and the results were tabulated. The flow properties were checked by conducting the preliminary tests like slump flow, U box, V funnel, L box tests. The mix SCC5 gives the optimum results of filling ability, passing ability and segregation resistance. It also gives the optimum cube compression strength, split tensile strength, chloride resistance strength.

From these results, it was observed 1% of super plasticizer and 0.4% of viscosity modifying admixtures give better fresh and mechanical properties of SCC. The optimum dosage of super plasticizer was found to be 2% and viscosity modifying agent was found to be 1% by weight of binder. From the experimental investigation, it was observed that the SCC mix satisfied the acceptance criteria of fresh property and mechanical property. From the test result, SCC has high resistance power to the permeability of chloride than conventional concrete.

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