# Experimental Investigation of use Polypropylene Fibers in Self-Compacting Concrete

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**Abstract.** *In this study investigates the effects of the use of polypropylene fibers as reinforcement on the mechanical and durability properties of M25 grade self-compacting concrete. Fresh characteristics are evaluated using V-funnel, V-funnel at T5 Min and L-box tests in the laboratory. The hardened properties are tested under compressive strength after 3, 7, 14, 28 and 56 days, Split tensile strength after (28) days, flexural strength after (28) days, acid attack after (28 and 56) days, water permeability, and rapid chloride penetration. The compressive improved maximum increase was 11.6% by use (12) mm length fibers. The split tensile strength by use polypropylene fibers in self-compacting concrete was improved by maximum 17.8% as compared to without Polypropylene fibers with (12)mm lengths of fibers. Polypropylene fibers give better flexural resistance about 15.5% maximum at (12) mm length fibers, as well improvement in surface porosity and water permeability. The acid attack figures also cripple with used polypropylene fibers but when we look at both the results individually we find that they are very low and faring better except in the rapid chloride penetration. Polypropylene fibers have improved mechanical properties of concrete as well as good performance in the durability of concrete*.

**Keywords** *self-compacting concrete; Polypropylene fibers, Compressive strength, Split tensile strength, flexural strength.*

## I. Introduction

Concrete is the requisite engineering material used in most of the structure's engineering. Its vogue as the basic building material in construction is because of; its economy, pretty durability, and the ease with which it can be produced at the site. Self-compacting concrete is described by its height flowability, therefore spreads through full reinforcement, fills all open and closed corners of the form and consolidates only by its have weight [3]. Self-compacting concrete commonly has a higher paste ratio and contains some mineral addition such as silica fume, natural pozzolan, and slag.. Self-Compacting Concrete is a specific type of innovative concrete. it is so flowable and non-segregating concrete and can be placed and compacted under its own self-weight need not demand any mechanical vibration due to its good deformability nature and also as it acquires a property called capability of flowing through thin openings or extremely congested reinforcement structures [5].

The Self-compacting concrete can flow out of and fill the bore of reinforcement also corners of molds without a necessity for any mechanical vibration and compaction during the placing practicability [23, 25]. Apparent superplasticisers are typically using in Self-compacting concrete to minimize the water to binder ratio. Further, supplementary cementitious or inert materials, such as limestone powder, natural pozzolans and fly ash fly ashcan are used to increase the viscosity and fresh concrete workability and reduce the cost of Self-compacting concrete. The use of pozzolanic admixtures provides the hydration reaction and produces perfect micropore structures, resulting in improved durability [16].

The use of fly ash reduces the demands for cement, fine fillers and sand that are required in Self-compacting concrete [17, 24] The fly ash, a by-product of coal power plants has been reported to get better in the mechanical properties, such as freeze–thaw resistance, alkali–silica reaction, sulphate resistance, durability and abrasion resistance, when it is used as a cement surrogate material in mortar and concrete. Also shrinkage and permeability of hardened concrete are decreased due to the filling of micropores by fly ash [18]. Numerous different kinds of fibers, such as metallic, polymeric, coated, uncoated or modified by irradiation, have been used in concrete engineering for their particular advantages [13].

The main objective of this study is to compare the fresh and hardened properties of self-compacting concrete with and without the use of polypropylene fibers. And check the effect of the increase in length and content of fibers through experimental studies also to investigate the influence of Polypropylene fibers in self-compacting concrete.

## II. Material used properties

The following ingredients are used in the concrete specimens throughout this study

### *A.Cement*

It is the basic binding material in concrete the commonly used binder in concrete is cement. The requirements of properties of the cement are given in the following Indian standards. IS: 12269 -1987 (53 grade), IS: 8112-1989 (43 grade), IS: 269-1989 (33 grade), for our study we have chosen Ultratech Cement 53 Grade is selected. The ultratech cement week no.4 and month.1 and year.2016, it was tested as per IS: 4031.

**Table I** Cement Test Report

| No. | Parameter | Unit | Result | LimitsIS:12269 |
|---|---|---|---|---|
| 1 | Normal Consistency | % | 27.50 | --- |
| 2 | Fineness by dry sieving | % | 2.60 | --- |
| 3 | Initial Setting Time | Min | 180 | 30 min |
| 4 | Final Setting Time | Min | 240 | 60 min |
| 5 | Compressive Strength 3days | N/mm$^2$ | 31.11 | 27 min |
| 6 | Compressive Strength 3days | N/mm$^2$ | 45.61 | 37 min |
| 7 | Compressive Strength 3days | N/mm$^2$ | -- | 53 min |
| 8 | Density | g/cc | 3.11 | --- |
| 9 | Soundness by le-chateliar's method | Mm | 0.50 | 10 max |
| 10 | Fineness by Blaines method | m$^2$/kg | 265 | 225 min |

### *B. Chemical Admixtures*

Superplasticizer using as a chemical admixture in this work we used AUROMIX-400. We used superplasticizer in Self-Compacting Concrete to gives good flowability with a very high slump that is to be used in a heavily reinforced structural member. Fly ash is used as a mineral admixture with specific gravity 2.1.

### *C. Additive or Mineral Admixture*

Fly ash the good suitable mineral admixture, fly ash was important filler used in mix ratio. It was made availed locally class F. Throughout project work; it was kept constant about 10 % to that of the weight of cement added. It helped not only to increase flexibility in SCC but reduced cement as well.

### *D. Coarse Aggregate*

It is the basic building component of concrete, to averting harshness and attaining easiness in mixing we recommended to reduce the coarse aggregate content in the concrete mixture. The general size of coarse aggregate is 10mm and 20mm. The important parameters of coarse aggregate that influence the performance of concrete are its shape, texture and the maximum size. However, the aggregate strength becomes important in the case of high-performance concrete. After finalizing the type of aggregates then the decision was taken to source the aggregates from one of the good source available.In this study used Crushed granite coarse aggregate.

### *E. Fine Aggregate*

Fine aggregate is provided workability and uniformity in the concrete mixture and helps the cement paste to hold the coarse aggregate particle in suspension. Their properties rely on the mineralogical composition of the rock, the environmental exposure to which the rock has been subjected, and the method of crushing employed to get the different sizes. We use fine aggregate these are passing through IS sieve 4.75 mm were used it is acquired from locally existing river sand.

### *F. Water*

It hydrates cement and also makes concrete workable water was chosen for this study and both the sources were checked as the testing procedures of IS:3025 and checked for permissible limits as per I.S.456 - 2000 regarding water for Mixing and Curing Underground water.

**Table II.**Water samples were tested as per IS: 3025 and limits as per IS: 456

| Sr. No. | Parameter | Unit | Used water | LIMITS |
|---|---|---|---|---|
| 1 | pH | -- | 7.6 | 6 min |
| 2 | Chlorides | mg/L | 54 | 500 max |
| 3 | Sulphates | mg/ L | 42 | 400 max |
| 4 | Organic Impurities | mg/ L | 65 | 200 max |
| 5 | Inorganic Impurities | mg/ L | 250 | 3000 max |
| 6 | Suspended Matter | mg/ L | 5 | 2000 max |
| 7 | Alkalinity | Ml | 5.8 | 25 max |
| 8 | Total Hardness | mg/ L | 200 | --- |
| 9 | Acidity | Ml | 0.7 | 5 max |

### *G. Polypropylene fibers*

Another mineral additive in the form of synthetic fibrillated polypropylene fibers was decided to add. There were two types of fibers used in this work (12) mm and (25) mm which complies with ASTM C 1116, ACI committee report 544-1R, European Standard EN 14889-2:2006, Fibers for concrete Part-2: Class 1b and IS:456-2000 Guidelines for Concrete Amendment.

**Table III.** Polypropylene fibers properties

| No. | Name | properties |
|---|---|---|
| 1 | Length | 12 mm and 25 mm |
| 2 | Specific Gravity | 0.92 gm/cc |
| 3 | Absorption | Nil |
| 4 | Salt Resistance | High |
| 5 | Alkali Resistance | Full |
| 6 | Acid Resistance | High |

## III. Mix design

Mix design has been done using the Specifications of BIS 10262:2009 and the ACI 211.1-91 guidelines. Mix design objective to obtain perfect quality concrete at site economically. A concrete grade 25 mixture was designed in the laboratory according to IS method of mix design IS 10262 assuming a good quality control with mild exposure for designing a mix. Based on the material properties of the ingredients the following mix proportion (SP.23, 1982) was arrived. Ten mixture compositions for each cubic meter of concrete are defined in table (4)

Designed compressive strength = 25 MPa
Air content = 1.5 %
Max size of aggregate = 10 mm
Super Plasticizer dosage= 0.8%
The volume ratio of fine aggregates (S)to the total aggregates (a) =S/a= 54%
Specific gravity of Cement = 3.12
Specific gravity of Coarse Aggregate = 2.68
Bulk density of Coarse Aggregate = 1265 Kg / m3
Bulk density of Fine Aggregate = 1595 Kg / m3
Specific gravity of Fine Aggregate = 2.61
Specific gravity of Fly ash = 2.1
Specific gravity of water = 1.0
Polypropylene fibers=0%, 1% and 2% of the weight of cement

**Table IV.** Mix proportions.

| Quantity of materials per $m^3$ | |
|---|---|
| W/C | 0.55 |
| Cement | 300kg |
| Fine Aggregate | 895.19kg |
| Coarse Aggregate | 604.69kg |
| Superplasticizer | 3.70kg |
| Water | 240.41L |
| Fly ash | 167.59kg |

## IV. Concrete samples preparation

I prepared five mixes for this study content polypropylene fibers1% and 2% of the weight of cement. As already stated the mixes with and without fibers are chose 12 mm and 25 mm fiber length For each specimen in the form of cubes with sides 150 mm, cylinders of dimension(300 mm x150 mm), and beams of dimension (700 mm x150 mm x150 mm) were prepared. Experimental specimens in the form of cubes, beams, and cylinders were tested to determine the compressive strength, the tensile strength, and the flexural strength, respectively. All the samples were moulded after 24 hours of casting and subsequently kept in the air at room temperature until the testing age was attained.Along with this cubes were also cast to conduct the water permeability, acid attack, and RCPT tests. It was decided to calculate RCPT for multiple environments and hence three solutions were finalized 3.33% HCl solution of market available HCL of 30% concentration. Thus effective concentration reaches 1% of fully concentrated HCl. This was done to study the acid attack phenomenon, 28-day immersion 5% NaCl solution in order to give the effect of seawater environment and 28-day immersion in 5% MgSO4 solution in order to study the sulphate attack.

**Table V.** Casting specimens

| No. | Test | specimens |
|---|---|---|
| 1 | Compressive strength test | 75 cubic |
| 2 | Split tensile strength test | 15 cylinder |
| 3 | Flexural strength test | 10 beams |
| 4 | Acid attack | 30 cubic |
| 5 | Water permeability | 15 cubic |
| 6 | RCPT | 60 cubic |
| Total specimens | | 205 |

## V. Test method for evaluating the fresh properties of self compacting concrete

### *A. Slump Flow Test*

The slump height and slump diameter of the five concrete mixed tested using Abraham's slump cone, the slump observed to completely collapse type. It is observed the required flowability with the little signal of segregation.

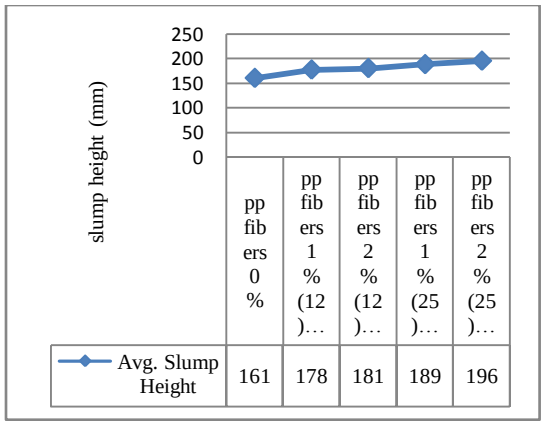



**Figure I.** Average of slump height (mm)

From above Graph, the slump height obtained for different concrete mix used in the study. The slump found favorable , height slump flow is 196 mm in this test by used 2% (25) mm polypropylene fibers.

***B. Flow Table Test.***

For the five mixes are tested immediately on flow table test tools which gives a better average. Spread diameter after 15 sequential blows. The average spread diameter is calculated in all these directions. Finally, the percentage of the flow is calculated use:

$$flow\ percent = \frac{spread\ \ D\ in\ cm - 25}{25} \times 100\% \qquad (1)$$

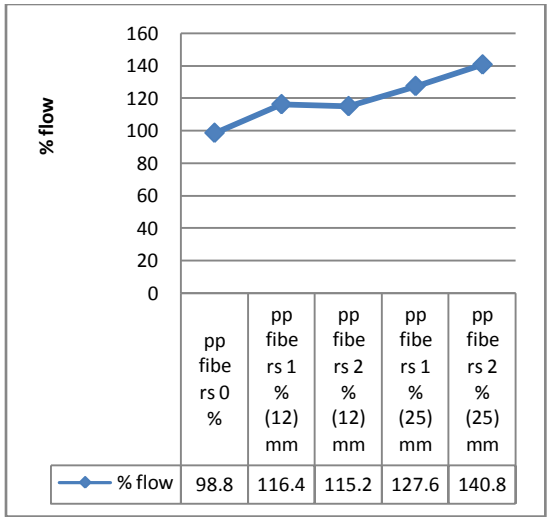



**Figure II**. Flow for different mixes

The concrete % flow calculated and found to be improved by used 2% (25) mm polypropylene fibers.

***C. V-funnel Test and -V-funnel at T5 Min Test***

The time required to empty the funnel completely after filling V- Funnel is tacked carefully using a stopwatch.

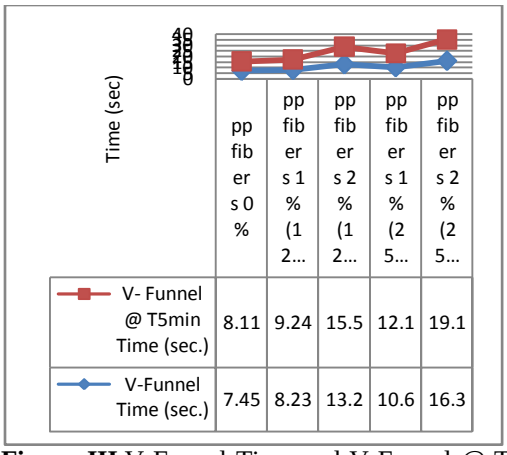



**Figure III.**V-Funnel Time and V-Funnel @ T5 Min results

Due to the addition of polypropylene fibers, we show both V-Funnel Time test and V-Funnel T5 Min test found increasing. It has been also observed that when fiber content and length of fibers increases, the concrete mixture become harsh and fibrous.

***D. L-box tests in the laboratory Test***

The effect of fibers on passing ability of prepared self-compacting concrete mixes checked by using L-Box test apparatus. The results obtained are done on all types of mixes. The time measured for reaching 20 and 40 cm mark also found to be affected. The results obtained are reported in Table 5 represents all about calculated H2/H1 as blocking ratios for different ratio and content of polypropylene fibers.

**Table VI.**L-box tests in the laboratory Test

| | | 12mm | | 25mm | |
|---|---|---|---|---|---|
| Fibers% | 0% | 1 % | 2% | 1% | 2% |
| $T_{20}$ Time (sec.) | 2.42 | 3.53 | 3.72 | 3.62 | 5.41 |
| $T_{40}$ Time (sec.) | 3.85 | 4.17 | 6.12 | 8.28 | 10.06 |
| Height H1(mm) | 150 | 150 | 150 | 150 | 150 |
| Height H2(mm) | 127 | 123 | 107 | 121 | 98 |
| Blocking RatioH2/H1 | 0.84 | 0.82 | 0.73 | 0.81 | 0.65 |

The above values show that fibers greatly affect the flow by reducing flowability.

## VI. Mechanical Properties of hardened self-compacting concrete

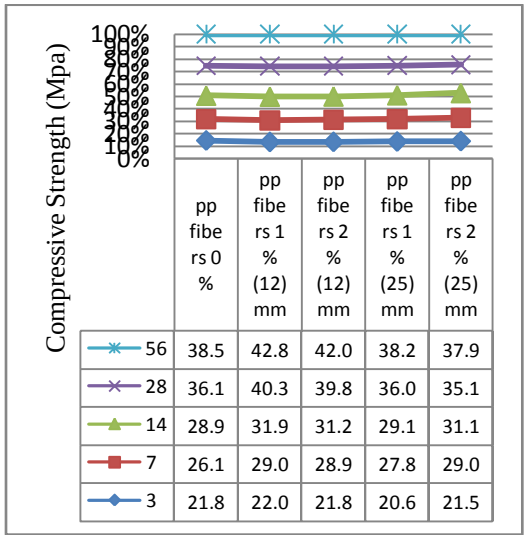
### *A. Compressive strength test*

The compression strength test was conducted according to IS 516; the specimen's cubes150mm for each side were kept in water for curing for 3, 7, 14, 28 and 56 days. The compressive strength of cured cubes tested under compression testing machine the IS procedure is strictly followed during this test so as to analyze variation in strength. The loading is given at a rate of 4 ton/ minute and failure is observed; which is indicated by a reverse moment of a black pointer in CTM dial gauge. Every time the weight is shown by red or dummy pointer is noted carefully in particular observations. The compressive strength is then calculated in MPa by:

$$\sigma_c = \frac{P}{A} \qquad (2)$$

Where P is failure load (N) and A is the surface area under compression $mm^2$

These testing results of compressive strength of cubes under CTM are summarized in Figure 4 below.




| | pp fibers 0 % | pp fibers 1 % (12) mm | pp fibers 2 % (12) mm | pp fibers 1 % (25) mm | pp fibers 2 % (25) mm |
|---|---|---|---|---|---|
| 56 | 38.5 | 42.8 | 42.0 | 38.2 | 37.9 |
| 28 | 36.1 | 40.3 | 39.8 | 36.0 | 35.1 |
| 14 | 28.9 | 31.9 | 31.2 | 29.1 | 31.1 |
| 7 | 26.1 | 29.0 | 28.9 | 27.8 | 29.0 |
| 3 | 21.8 | 22.0 | 21.8 | 20.6 | 21.5 |

**Figure IV.**Compressive strength for the different SCC mixtures

It was observed maximum improvement in compressive strength when used 1% polypropylene fibers length (12) mm.

### *B. Split tensile strength test*

The tensile strength test was calculated according to IS 5816. The size of the cylinder is 300 mm length with 150 mm diameter, the specimen were kept in water for curing for 28 days the resistance to the tensile forces is tested under DUTM, In this two different cut length fibers 12and 25 mm are used. The load transferred through loading device resulted in a split of the cylinder to two parts. To find split tensile strength following equation:

$$Split\ tensile\ strength = \frac{2p}{\pi dL} \qquad (3)$$

Where:

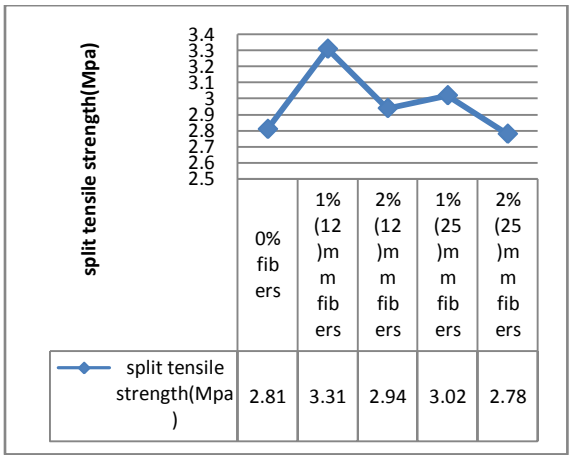
P = maximum applied load indicated by the testing machine (N)

L = length in (mm)

d = diameter in (mm)

As per IS: 456, split tensile strength of concrete is assumed to be $0.7f_{ck}$

These testing results of compressive strength of cylinders under DUTM are summarized in Figure 5.




| | 0% fibers | 1% (12)mm fibers | 2% (12)mm fibers | 1% (25)mm fibers | 2% (25)mm fibers |
|---|---|---|---|---|---|
| split tensile strength(Mpa) | 2.81 | 3.31 | 2.94 | 3.02 | 2.78 |

**Figure V.** Split tensile strength test for the different SCC mixtures

The results refer to a max improvement in Split tensile strength when used 1% polypropylene fibers length (12) mm.

### *C.Flexural strength test*

The flexural strength test was calculated according to IS 516; load shall be applied is 400 kg/min to find flexural strength following equation:

$$\sigma_p = \frac{1.5\,wl}{bd^2} \qquad (4)$$

Where,

[b] Is the width of specimen (mm)

[d] Is the failure point depth (mm)

[l] Is the supported length (mm)

[w] Is the max. Load (kg)

All observations are stated as given in figure 6 below.

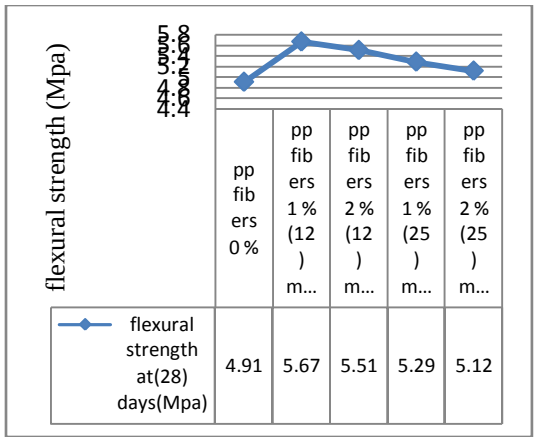



**Figure VI.**Flexural strength test for the different SCC mixtures

Flexural strength tests results are show in the figure, when compared the concrete without polypropylene fibers, the flexural strength of fiber reinforced concretes is significantly higher, the highest value seen for mixture content 1% polypropylene fibers length (12) mm.

## VII. durability Properties of hardened Concrete

### *A. Acid attack test*

For acid attack test concrete used the cube of size 150 mm ×150 mm ×150 mm ,used three cubes for each mix are prepared for all the specimen are moulded and kept in curing tank of acid for 28 days and 56 days. The acid solution was 1% as a whole for curing tank. These testing results of acid attack test are summarized in Figure 6 below.

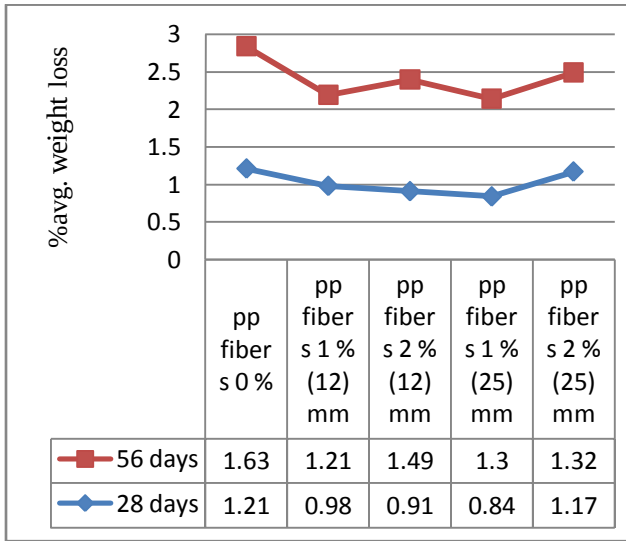



**Figure.6** Acid attack test for the different SCC mixtures

The best acid attack value seen for mix content 1% polypropylene fibers length (25)mm.

### *B.Water permeability test*

The test is carried out according to BS EN 12390-8 and DIN 1048 the German standard on the concrete specimens of size (150) mm for each side testing the depth of penetration under water pressure, are tantamount tests that measure the depth of water penetration into concrete samples undergo (0.5)Mpa of hydrostatic pressure during time three days. Concrete samples are cast and cured at 28 days after that samples are put in the test device where they are undergo hydrostatic pressure the test cell composition being used had the provision for testing three to six cubes at a time.

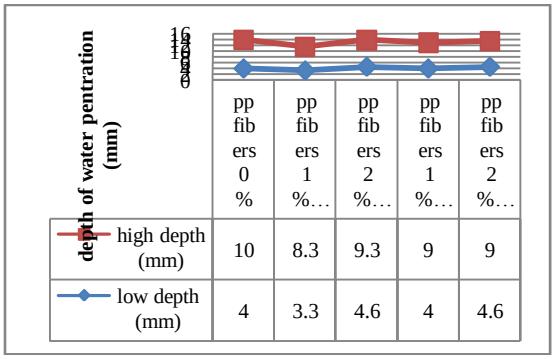



**Figure VII.**Water permeability test for the different SCC mixtures

It was observed with mix content 1% polypropylene fibers length (12) mm we get the lower depth of penetration.

### *C. Rapid Chloride Penetration Test (RCPT)*

According to standard method of test for rapid AASHTO T277 determination of the chloride permeability of concrete and rapid chloride permeability test ASTM C1202. The test method includes obtaining a 100 mm diameter core or cylinder pattern from the concrete being tested. A 50 mm specimen is cut from the sample. The side of the cylindrical specimen is covered with epoxy after that it put in a vacuum chamber for three hours. The specimen is vacuum saturated for one hour after that placed on the test device. The left-hand side (negative) of the test cell is filled with a 3% the NaCl solution. The right-hand side (positive) of the test cell is filled with 0.3N NaOH solution. The system is then connected and a 60-volt potential is applied for 6 hours. The readings are taken every 30 minutes. At the end of 6 hours the sample is extracted from the cell and the number of coulombs passed over the

specimen is calculated. All results of RCPT test are summarized in Figure 6 below.

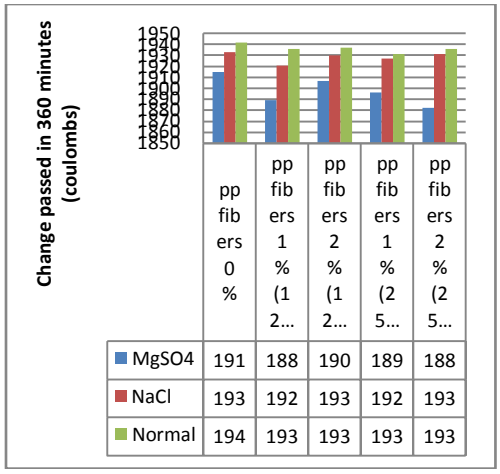



**Figure VIII.**Rapid Chloride Penetration Test results

all consequence of the rapid determination of chloride permeability of concrete test, the results look low permeability but it is noticeable to see that the sample cast with 10% polypropylene fibers 12 mm is seen to perform better.If the flowability of mixture of Self-Compacting Concrete gets reduced. Therefore, the addition of fibers should be at an optimum level to avoid the more viscous flow. The filling ability of Self-Compacting Concrete remains unaffected showing better segregation resistance at lesser length and proportion of fibers in it.

## VIII. Conclusion

Depending on the experimental results and discussions given in this paper the next conclusions can be drawn. Fibers decrease workability but it can be maintained using mineral and chemical admixtures. Fly ash content in self-compacting concrete helps to reduce cement requirement up to certain extent and improves workability. Chemical admixture gives flowable concrete and increases segregation and bleeding. Hence, it is recommended to use short length polypropylene fibers. Adding polypropylene fibers to concrete has increased the compression strength of concrete maximum 11.6%.When polypropylene fibers are used the maximum increased of Splitting tensile strength is 17.8% for specimen have 1% polypropylene fibers length (12) mm.The polypropylene fibers beams grant preferable flexural resistance is 15.5% maximum at shorter length fibers and decreased 1% with the addition 2% of length (25) mm fibers. The sample cast with polypropylene fibers is faring better except in the RCPT and the lower depth of penetration when used polypropylene fibers. The acid attack figures also cripple the sample cast polypropylene fibers but when we look at both the results individually, we find that they are very low, only in case of comparative observation the results tend to be more in favor of without polypropylene fibers. It is proposed to use polypropylene fibers 1% of cement in Self-Compacting Concrete. It is also recommended to use 12 mm fibers length.

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