Design And Development Of High Strength Self Compacting Concrete With Steel Fibre

A Project Report

Submitted by

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Title Design and development of high strength self Compacting Concrete with fiber.

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ABSTRACT

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 workability and strength of Self-Compacting Concrete (SCC). Tests involving various fiber proportions for a particular mix of SCC. Test methods used to study the properties of fresh concrete were slump test, U – tube, V – funnel and L – Box. The properties like compressive, tensile and flexural strength of SCC were also investigated.

For compressive strength of studies the cube size of 100mmX100mmX100mm were used. The specimens were cured and tested for 7 and 28 days for high compressive strength.

The split tensile strength was studied for the same concrete mix using cylinders size 100mmX200mm. The specimens were cured and tested for 7 and 28 days.

The flexural strength was studied for the same concrete mix using beam of size 100mmX100mmX200mm. The specimens were cured and tested for 7 and 28 days.

The stress-strain relationship was studied for the same concrete mix using cylinders of size 150mmX300mm. The specimens were cured and tested for 7 and 28 days.

Test Results shows that the workability characteristics of SCC are within the limiting constraints of SCC. The variation of different parameters of hardened concrete with respect to various fibre contents were analyzed.

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LIST OF SYMBOLS AND ABBREVIATIONS

ASTM - American Standard for Testing Materials

CA - Coarse Aggregate

FA - Fine Aggregate

SCC - Self Compacting Concrete

ACI - American Concrete Institute

HRWR - High Range Water Reducer

VMA - Viscosity Modifying Agent

CTM - Compression Testing Machine

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Self-compacting concrete (SCC) represents one of the most outstanding advances in concrete technology during the last decade. At first developed in Japan in the late 1980s, SCC meanwhile is spread all over the world with a steadily increasing number of applications. Due to its specific properties, SCC may contribute to a significant improvement of the quality of concrete structures and open up new fields for the application of concrete.

SCC describes a concrete with the ability to compact itself only by means of its own weight without the requirement of vibration. It fills all recesses, reinforcement spaces and voids, even in highly reinforced concrete members and flows free of segregation nearly to level balance. While flowing in the formwork, SCC is able to deaerate almost completely.

The use of SCC offers many benefits to the construction practice: the elimination of the compaction work results in reduced costs of placement, a shortening of the construction time and therefore in an improved productivity. The application of SCC also leads to a reduction of noise during casting, better working conditions and the possibility of expanding the placing times in inner city areas. Other advantages of SCC are an improved homogeneity of the concrete production and the excellent surface quality without blowholes or other surface defects.

Often the materials costs of SCC will be higher than the equivalent material costs of a normal vibrated concrete. However, when SCC is sensibly utilized, the reduction of costs caused by better productivity, shorter construction time and improved working conditions will compensate the higher material costs and, in many cases, may result in more favourable prizes of the final product.

1.2 OBJECT AND AIM OF THE PROJECT:

- Study the mix proportions for SCC materials with steel fibers using standard codes of practice
- Determine the workability of SCC using Slump Cone Test, U Tube Test, L Box Test and V Funnel Test.
- Study the Strength Characters of SCC like Compressive Strength, Flexural Strength, Split Tensile Strength and Stress Strain Characters.
- To study the Strength and behavior of using Steel fibres to the SCC.
- Cost analysis of SCC Design Mixes by trial and error procedures.

1.3 SCOPE OF THE PROJECT:

- ➢ To improve filling capacity through highly congested reinforcement by using the Self Compacting concrete.
- ➢ To reduce the construction time in the project.
- ➢ To effective use of fly ash which is a cheaper material compared to the other ingredients of the concrete can be effectively utilized in the Self Compacting Concrete.

CHAPTER 2

LITERATURE REVIEW

1. **Dr. Rakesh Kumar & M.V. Rao** "The ingredients for SCC are similar to other plastized concrete. It consists of cement, coarse and fine aggregates, water, mineral and chemical admixtures. Similar to conventional concrete, SCC can be affected by physical properties of materials and mix proportioning"

2. **Champion & Jost** "SCC is produced with standard, readily available concrete components. The mix proportioning is based upon creating high degree of flowability while maintaining a low water cement ratio. This can be achieved through the use of new HRWR admixtures combined with stabilizing agents to ensure homogeneity of mixture"

3. **S.Subramanian & D.Chattobadhyay** "In SCC, a major concern is flowability of the concrete without segregation. Therefore the mixture will appear deficient in coarse aggregate. In practice, a unit water content of about 200 to 220 litre will be required even when super plasticizers are used"

4. **Kamal H.Khayat, Patrick Paultre & Stephan Tremblay** "The approach adopted to develop SCC for casting was designed to increase the paste volume to secure the high deformability and decrease the risk of blockage. The water cement ratio was selected in function of targeted compressive strength, incorporating a viscosity enhancing admixtures"

5. **Ghezal & Kamal H. Khayat** " The Self consolidating concrete is high performance that can flow under its own weight to completely fill the formwork and get self consolidated without any mechanical vibration. A range of water reducing admixtures are used to reduce the water content"

6. **Kamal H. Khayat, John Bickley & Michel Lessard** "SCC is highly flowable concrete and used in the case of congested reinforcement locations. SCC is made with 20% of fly ash and 3% of silica fume to be used as filling materials to improve the strength properties of SCC"

7. **Aaron W.Saak, Hamlin M.Jennings & Surendra P. Shah** "SCC is compacted under its own weight without any segregation. It is highly flowable and suitable for placing in thin walled structures ".

8. **Okamura** proposed a mix design method for SCC based on paste and mortar studies for super plasticizer compatibility followed by trail mixes. However, it is emphasized that the need to test the final product for passing ability, filling ability, and flow and segregation resistance is more relevant

9. **Bindiganavile and Banthia** examined two major issues related to impact loading on plain and fiber reinforced concrete. They observed that for cement based materials, the measured impact response is highly dependent on the characteristics of the drop weight impact machine used for testing. The pulse duration was found to depend upon the drop height, with greater drop heights leading to shorter pulses. Results appear to be far less sensitive to the mass of the hammer than to the drop height.

10. **Hajime Okamura and Masahiro Ouchi** made investigation for establishing a rational mix-design method and self-compactability testing methods have been carried out from the viewpoint of making self-compacting concrete a standard concrete. When self-compacting concrete becomes so widely used that it is seen as the "standard concrete" rather than a "special concrete" we will have succeeded in creating durable and reliable concrete structures that require very little maintenance work.

CHAPTER 3

SELF COMPACTING CONCRETE

3.1 SCC – AN EMERGING TREND

Self Compacting Concrete was first developed in Japan around the year 1980. Professor H.Okamura from the University of Tokyo is mainly responsible for initiating the development of such concrete.

Self Compacting Concrete also referred to as Self Consolidation Concrete or silent concrete can be considered as the greatest technical advancement and most revolutionary development in concrete technology over the years, atleast from 1980 till today. This is the concrete for the future. It is reported that in the year 2003 approximately 50% of the total concrete executed in Japan was Self Compacting Concrete. In India it was used for the first time in the year 2003 and the work was executed by Gammon India Ltd.

3.2 BACKGROUND HISTORY OF SCC

This type of concrete was first proposed by Okamura in 1986. The motivation behind this was the gradual reduction of skilled workers in Japan's construction industry which led to a reduction in the quality of construction work. This further, affected adversely the durability of concrete that has been poorly compacted. SCC was developed to counter the problems of compaction and associated poor quality of concrete. It is basically a high flowable concrete. When the construction industry in Japan experienced a decline in the availability of skilled labour in the 1980's a need was felt for a concrete that would overcome the problems of defective workmanship. This led to a development of Self Compacting Concrete, primarily through the work of Okamura. Data indicate that the share of application of SCC, in pre cast concrete industry is more than three times than that in the ready-mixed concrete industry. This is attributed to the higher cost of SCC. The estimated average price of SCC supplied by RMC industry in Japan was 1.5 times that of the conventional concrete in the year 2002, such as in lattice type structures, casting without pump, and tunnel linings. It was developed in order to overcome the following problems in conventional concrete construction:

- Improper consolidation of inaccessible areas (deep lying or in zones of congested reinforcement) it can ensure quality.
- Tremendous waste of energy in vibration-based compaction.
- Vibration-related hearing loss and other injuries to workers.

3.3 DEFINITION OF SCC

Self Compacting Concrete is a flowable concrete mixture that is able to consolidate under its own weight. It does not require any external vibration for compaction. The highly fluid nature of SCC makes it suitable for placing in difficult conditions and in sections with congested reinforcement SCC does not show segregation, bleeding and has revolutionized concrete pavement.

Self Compacting Concrete is ideally suited for the concreting of the structures, which have heavily congested reinforcement or wherein the access for concrete is difficult. Self Compacting Concrete mixes contain a combination of ingredients that enhances the flow but maintains segregation resistance. Maintaining the right balance between fluidity and resistance to segregation the apparently opposing characteristics – is the key to the successful design of SCC. These characteristics of SCC mix are achieved by using higher powder content, optimizing water to powder ratio, a high volume of fine aggregate as compared to coarse aggregate, high dosage of super plasticizer.

Self Compacting Concrete generally possesses a high powder content which keeps the concrete cohesive with a high flowability. For achieving economy, a substantial part of this powder could contain fly ash. In such cases, early age strength development may prove to be reused. India has an abundant supply of low calcium fly ash, with its sources well distributed across the country in the form of about ninety coal based thermal power stations. Recent upsurge in the interest about its utility in Self Compacting Concrete in the country has opened a new area for its potential uses.

3.4 INDIAN SCENARIO OF SCC

In India, during the last few years, attempts were made in the laboratories and in the field to develop and use SCC. However, large scale uses have been rare. Some pioneering efforts have been made in Delhi Metro projects in association with L&T and MBT. The Delhi Metro project have used SCC in large scale for dome construction tunnel lining, column casting etc, and used about 10,000 m^3 of SCC in as many as forty locations during the year 2004. This is by far the biggest use of SCC in India.

Hindustan Construction Company have also carried out considerable studies on the use of High Volume Fly ash SCC for domes, walls in turbine building in Rajasthan Power Project, and Concrete for piers in Bandra-Worli Sea Link Projects. Based on their extensive trials, they used High Volume Fly ash Self Compacting Concrete in the above projects and in many other works.

3.5 ADVANTAGES OF USING SCC

SCC has got many advantages over normal concrete. It can even be cheaper than normal concrete if fly ash is locally available and a suitable viscosity modifying agents is used.

Advantages of SCC over NC are as follows:

- Faster construction.
    - By using SCC, the production of concrete can be more industrialized. The evolving ready mix concrete is easily possible by using the property pump ability.
- Reduction in site man power.
    - The man power used for the vibration and for compaction of concrete is saved.

- Better surface finishes.
  - The Self Compacting Concrete has a high percentage of fines, and the property of fallibility enables the concrete to give a better surface finish.
- Easier placing.
  - The SCC unlike the normal conventional concrete can be placed easily. The SCC can also be poured inside the reinforcement.
- Reduced noise levels in work site.
  - The noise produced by the compactors and vibrators is avoided. This enables better communication in the work site.
- Safer working environment.
  - As there is less man power required in the site, the problems resulting from congestion etc.., are reduced, this results in a safer working environment.
- Economical construction.
  - In SCC the cementitious materials like fly ash can be used, which is a waste product in thermal power plant. Fly ash costs very less compared to other building materials, ultimately resulting in economical construction.
- Improved filling capacity through highly congested reinforcement.
  - The SCC has a higher filling and flowing ability when compared to the conventional concrete thereby it enables to fill through the congested reinforcement. This eliminates the difficulty of vibrating through the congested reinforcement.
- Time of construction is minimized.
  - As the production of SCC can be industrialized, the time required for the construction is reduced.

3.6 APPLICATION AREAS OF SCC

SCC may be used in pre-cast applications or for concrete placed on site. It can be manufactured in a site batching plant or in a ready mix concrete plant and delivered to site by truck. It can then be placed either by pumping or pouring into horizontal or vertical structures. In designing the mix, the size and the form of the structure, the dimension and density of reinforcement and cover should be taken in consideration. These aspects will all influence the specific requirements for the SCC.

Due to the flowing characteristics of SCC it may be difficult to cast to a fall unless contained in a form. SCC has made it possible to cast concrete structures of a quality that was not possible with the existing concrete technology.

3.7 CHARACTERISTIC OF SCC

3.7.1 Characteristic Of Fresh SCC

The main characteristics of SCC are the properties in the fresh state. In order to flow, fill through the dense reinforcement the SCC must pose certain properties like flow ability, fill ability, resistance for segregation.

The major properties of SCC are:

- Passing ability (confined flow ability).
- Filling ability (unconfined flow ability).
- Resistance to Segregation (segregation resistance).

3.7.1.1 Passing Ability

- The ability of SCC to flow through tight openings such as spaces between steel reinforcing bars without segregation or blocking.
- The flow ability of the mix is tested by the slump flow, T_{50} slump flow, V funnel.
- The flow ability of the mix is increased by having a suitable w/p ratio.
- The use of super plasticizers helps to increase the work ability of the concrete.

3.7.1.2 Filling Ability

- This property of fresh concrete is related entirely to the mobility of the concrete
- The ability of SCC to flow into and fill completely all spaces within the formwork, under its own weight.
- This property is achieved by addition of super plasticizers and by optimizing the packing of fine particles by adding fillers.
- This property is tested by the Slump flow test and V- funnel test.

3.7.1.3 Resistance to Segregation

- The mix has to maintain its stability under high flow conditions i.e. it should not segregate and should remain homogenous in composition during transport and homogeneity.
- The normal concrete mix when it shows signs of segregation, a percentage of coarse aggregate is replaced by fine aggregate.
- In this study the stability of the SCC is maintained by using cementitious fines, fly ash in place of coarse aggregate.
- This property of the Self Compacting Concrete is tested by V – funnel test and V- funnel at T_5 minutes test.

3.7.2 Characteristic of Hardened SCC

In normal concrete, during vibration, water tends to migrate to the surface of the coarser particles causing porous and weak interfacial zones to develop. In case of well designed SCC the homogeneity, mobility, cohesiveness helps placing concrete in formwork without compaction. This helps in better interface between coarse aggregate and mortar paste as minimal interfacial zone develops. The microstructure of SCC can be therefore expected to be superior, promoting strength, impermeability, durability and ultimately longer service life of concrete.

The performance of hardened concrete of SCC and normally vibrated concrete does not show much of a difference.

Variation in strength across depth of structure, between creeps and drying shrinkage, strength and statistic modulus is also the same. Durability is better for SCC while early age shrinkage and cracking is higher for SCC.

3.8 INGREDIENTS FOR SCC

3.8.1 Cement

Portland Pozzolana Cement can be used.

3.8.2 Aggregates

The maximum size of aggregate is generally limited to 20mm. Aggregate of size 10 to 12mm is desirable for structures having congested reinforcement. Wherever possible size of aggregate higher than 20mm could also be used. Well graded cubical or rounded aggregates are desirable. Aggregates should be uniform quality with respect to shape and grading.

Fine aggregates can be natural or manufactured. The grading must be uniform throughout the work. The moisture content or absorption characteristics must be closely monitored as quality of SCC will be sensitive to such changes.

Particles smaller than 0.125 mm size are considered as FINES which contribute to the powder content.

3.8.3 Mixing Water

Water quality must be established on the same line as that for using reinforced concrete or prestressed concrete.

3.8.4 Admixtures

Super plasticizers are an essential component of SCC to provide necessary workability. The new generation super plasticizers termed poly-carboxylated ethers (PCE) are particularly useful for SCC.

Other types may be incorporated as necessary, such as Viscosity Modifying agents (VMA) for stability, air entraining agents to improve freeze-thaw resistance, and retarders for control of setting.

3.9 MIX COMPOSITION OF SCC IN COMPARISON WITH NORMAL VIBRATED CONCRETE

The basic components for the mix composition of SCC are the same as used in conventional concrete. However, in SCC a higher proportion of ultra fine materials and the incorporation of chemical admixtures, in particularly effective super plasticizers, are necessary. Filler materials like fly ash, limestone powder, blast furnace slag, silica fume and quartzite powder are used in SCC.

A comparison of a typical mix design of SCC and conventional concrete is shown in fig 1.

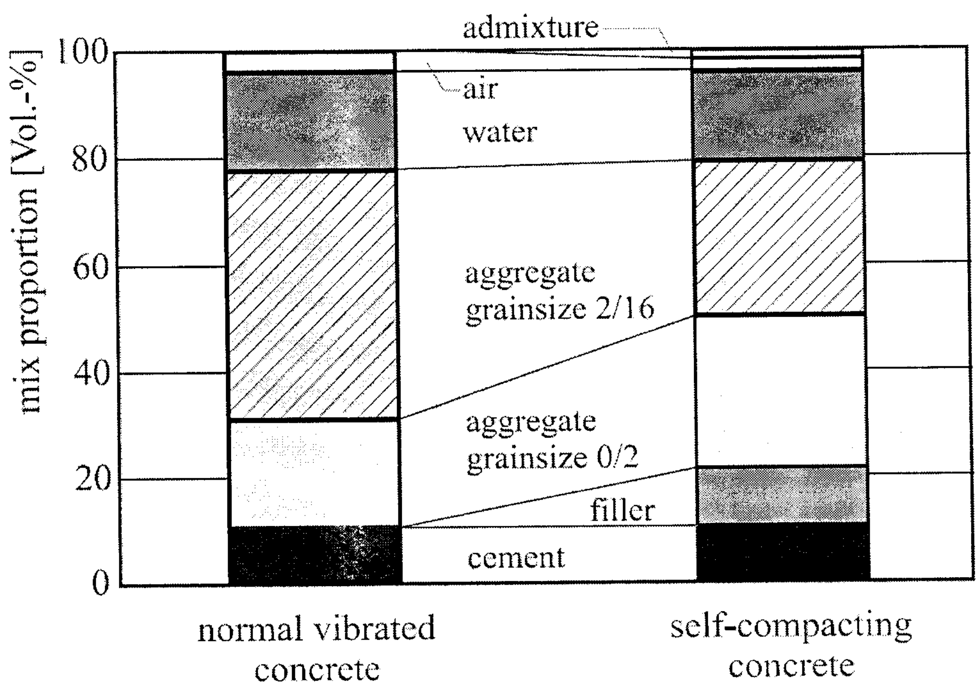

Fig. No:3.1 Mix composition of SCC over normal vibrated Concrete.

3.10 TEST METHODS FOR SCC

The guidelines for testing the fresh Self Compacting Concrete has none been Standardized to date. So far no single method or combination of methods has achieved universal approval and most of them have their adherents. The constant search for finding more appropriate field testing methods has led to the emergence of few empirical methods in the past few years.

The filling ability, passing ability and resistance to segregation are the distinguished properties of SCC which is not common to conventional concrete and, therefore the tests for SCC are handled through special tests.

EFNARC, making use of broad practical experiences of all members of European federation with SCC, has drawn up specification and guidelines for testing the SCC and also specified the limiting values to obtain SCC. It also provides a framework for design and use of high quality SCC. Some of the important test that has to be carried out in order to satisfy the requirements of Self Compacting Concrete is listed below.

3.10.1 Slump Flow Test and T_{50} Slump Flow Test

Aim:

Slump flow is used to assess the horizontal free flow of SCC in the absence of obstructions.

Principle:

The slump flow test aims at investigating the filling ability of SCC. It measures two parameters: flow spread and flow time T50. The former indicates the free, unrestricted deformability and the latter indicates the rate of deformation within a defined flow distance.

Equipment:

- Base plate of size at least 900 × 900 mm, made of impermeable and rigid material (steel or plywood) with smooth and plane test surface (deviation of the flatness not exceed 3mm), and clearly marked with circles of Ø200mm and Ø500mm at the centre, as shown in Fig 2.

- Abrams cone with the internal upper/lower diameter equal to 100/200 mm and the height of 300 mm, as shown in Fig.
- Stop watch with 0.1sec accuracy, ruler graduated in mm, bucket.

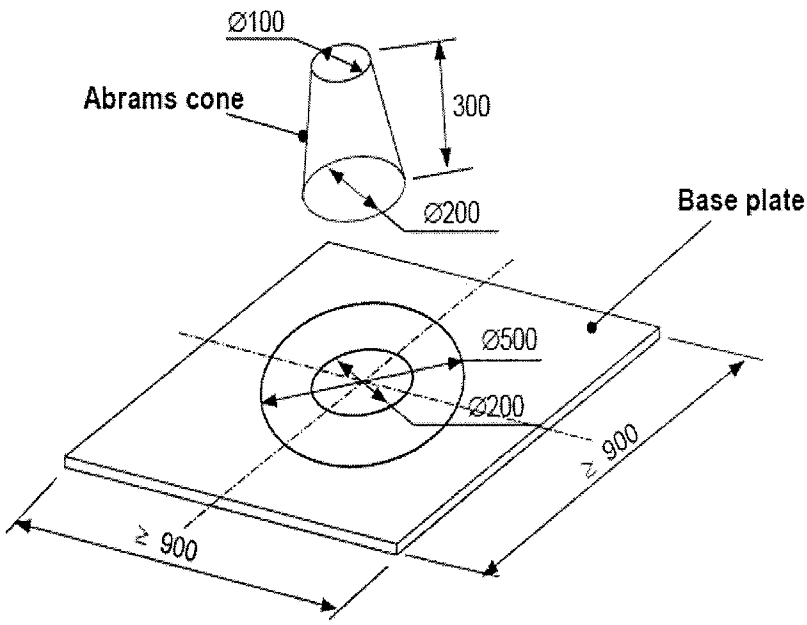

Fig.No:3.2 Slump test apparatus

Procedure:

- The base plate should be kept horizontal and should have smooth surface. The concentric diameter of 50 cm is marked on the plate.
- The surface is cleaned and the slump cone is placed centrally on the plate.
- Fill the slump cone with concrete while pressing the slump cone to the plate.
- Ensure that the slump cone is lifted vertically. Start timing when the lifting of slump cone.
- The diameter of the flow is measured and also the time for the concrete to reach 50 cm diameter is also noted.

Interpretation of Test Results:

The higher the flow value, the greater its ability to fill formwork under its own weight. A value of at least 650 mm is required for SCC. In case of severe segregation, most coarse aggregate will remain in the centre of the pool of concrete and mortar and paste at the periphery of concrete.

3.10.2 V – Funnel Test and V – Funnel At T_5 Min Test

Aim:

V – Funnel test is used to determine the filling ability (flow ability) of the SCC.

Principle:

The V-funnel flow time is the period a defined volume of SCC needs to pass a narrow opening and gives an indication of the filling ability of SCC provided that blocking and/or segregation do not take place; the flow time of the V-funnel test is to some degree related to the plastic viscosity.

Equipments:

- V-funnel, as shown in Fig 3, made of steel, with a flat, horizontal top and placed on Vertical supports, and with a momentary releasable, watertight opening gate.
- Stopwatch with the accuracy of 0.1 second for recording the flow time.
- Straightedge for leveling the concrete.
- Buckets with a capacity of 12 to 14 litres for taking concrete sample.

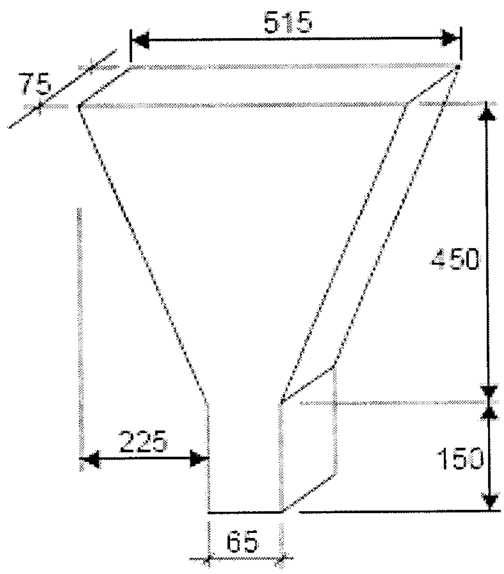

Fig.No:3.3. V – funnel test apparatus

Procedure:

The V – funnel is mounted vertically, the fresh concrete is filled in the V – funnel.

- The shutter gate is opened. The concrete will now flow out of the V – funnel.
- The time taken for the flow of concrete from the V – funnel is noted.
- The concrete is then poured into the V – funnel, the concrete is allowed to set for 5 minutes, after that the shutter gate is opened. The time taken for flow of concrete is noted.

Interpretation of Test Results:

This test measures the ease of flow of the concrete; shorter flow times indicate greater flow ability. For SCC a flow time of 10 seconds is considered appropriate. The inverted cone shape restricts flow, and prolonged flow times may give some indication of the susceptibility of the mix to blocking. After 5 minutes of settling, segregation of concrete will show a less continuous flow with an increase in flow time.

3.10.3 U – Box Test

Aim:

U - box test is used to measure the filling ability (flow ability) and segregation properties of the SCC.

Principle:

In this test, the degree of compatibility can be indicated by the height that the concrete reaches the other part of box after flowing through an obstacle. The test measures filling and segregation properties of Self Compacting Concrete.

Equipments:

- U - Box, as shown in Fig 4, made of steel, with a flat, horizontal top and placed on Vertical supports, and with a momentary releasable, watertight sliding gate.
- The apparatus consists of vessel that is divided by a middle wall into two compartments as shown by R1 and R2 in fig.
- An opening with a sliding gate is fitted between the two compartments. Reinforcement bars with normal diameter of 12mm are installed at the gate with centre to centre distance of 50mm. this creates a clear spacing of 35mm between the bars.

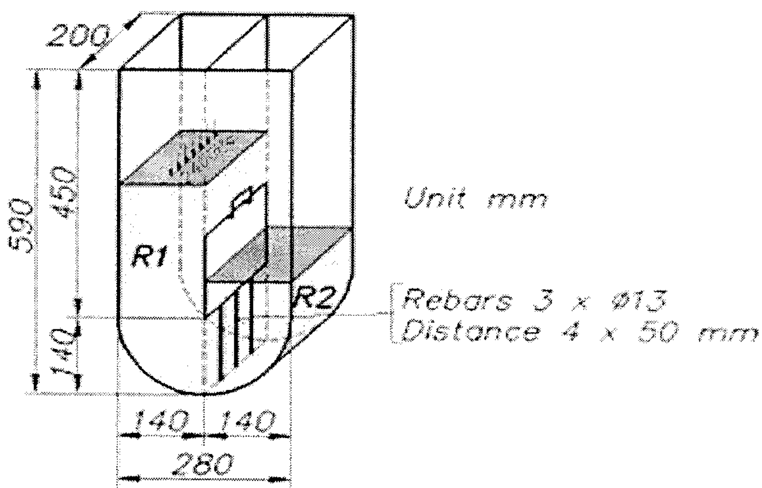

Fig.3.4 U – box apparatus.

Procedure:

- The U - box is mounted vertically and the central door is closed
- The fresh concrete is filled in the left compartment of U - box.
- The gate is opened. The concrete will now flow out from one compartment to another.
- The difference in height between the concrete surfaces on either compartment is measured. This difference in height indicates the self leveling ability and passing ability of self compacting concrete.

Interpretation of Test Results:

If the concrete flows as freely as water, at rest it will be horizontal, so H1 - H2 = 0. Therefore the nearer this test value, the 'filling height', is to zero, the better the flow and passing ability of the concrete.

3.11 ACCEPTANCE CRITERIA FOR SCC

Typical acceptance criteria for Self-compacting Concrete with a maximum aggregate size up to 20 mm are shown in Table 1.

Typical ranges of values indicated in Table No1. are based on the current practice and will undergo changes with respect to the future developments. Values outside these ranges may also be acceptable if it can be demonstrated that satisfactory performance is obtained 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, very simple design of formwork, etc.

Table No: 3.1 Acceptance criteria for SCC.

Test Methods	Unit	Minimum	Maximum
Slump flow	mm	600	800
T_{50} cm Slump flow	Sec	2	5
V – funnel test	Sec	6	12
V – funnel test at T_5 min	Sec	0	+3
U – box test	mm	0	30

CHAPTER 4

EXPERIMENTAL PROGRAMME

The experimental programme consists of three stages. First the constituent of materials used for making the concrete were tested and the results are furnished. With the test data of the materials known the concrete mix design for M40 grade of concrete is designed by using ACI method. In the second stage the mix was further modified by fine tuning the relative proportions of coarse and fine aggregates so that all the requisite fresh concrete parameters of SCC such as those obtained from slump flow, U- box and V – funnel that are satisfied completely. That particular mix which satisfied all the parameters was taken as the reference SCC mix. Then the Steel fibre is added to the achieved SCC of various proportions of 0.25%, 0.5%,0.75% and 1.0%. The fresh concrete tests for SCC with addition of steel fibre also tested and achieved the SCC properties by the varying different high range water reducing admixture and viscosity modifying agent content to it.

4.1 MATERIALS USED AND THEIR PROPERTIES

The materials used in this study were ordinary Portland cement of 43 grade conforming to IS: 8112, natural river sand conforming to zone II, locally available crushed siliceous stone coarse aggregate of maximum size 12.5mm, fly ash from Mettur thermal power plant station, high range water reducing admixture of type Glenium B233, viscosity modifying agent of type Glenium stream2, portable tap water available in the laboratory. The properties of these materials used in this project are explained below.

4.1.1 Cement

The Portland pozzolana cement of 43 grade conforming to IS: 8112 1989 was used for the present experimental study. The important properties of this cement have been tested and given below:

Specific gravity of Cement = 3.16.

Normal Consistency Of Cement = 34%.

Initial Setting Time Of Cement = 35 minutes.

Fineness modulus cement = 1.75

4.1.2 Fly Ash

4.1.2.1 Physical Properties of Fly Ash

Table No: 4.1 physical properties of fly ash

Sl.No.	Properties	Values
1	Fineness modules (passing through 45μ),%	78.60
2	Specific Gravity	2.10

4.1.2.2 Chemical Properties of Fly Ash:

Table No: 4.2 chemical properties of fly ash

Sl.No.	Properties	Values in %
1	Silica	59.62
2	Alumina	26.43
3	Iron oxide	6.61
4.	Calcium oxide	1.2
5.	Magnesium oxide	0.76
6.	Sulphur tri oxide	0.58
7.	Titanium oxide	1.56
8.	Loss of ignition	1.76

4.1.3 Fine Aggregate

Natural river sand with fraction passing through 4.75mm sieve and on 150μm sieve was used and tested as per IS:2386 - 1983. The important properties tested for fine aggregate are given below:

Specific gravity of fine aggregate	=	2.72.
fineness modulus of fine aggregate	=	2.85.
bulk density of fine aggregate	=	1487.6 kg/m^3.

4.1.4 Course Aggregate

Crushed granite coarse aggregate of size 12.5mm was used and tested as per IS: 2386 - 1983. The important properties tested for coarse aggregate are given below:

Specific gravity of coarse aggregate	=	3.02.
Bulk density of fine aggregate	=	1652.89 kg/m^3.

4.1.5 Water

Portable tap water available in laboratory with pH value of 7.0 ± 1 and confirming to the requirement of IS: 456-2000 was used for mixing concrete and curing the specimens as well.

4.1.6 Admixtures

Glenium B233 and Glenium Stream 2 are confirming to the requirement of IS: 9103-1979 as a high range water reducing admixture and viscosity modifying agent was used in this study.

4.1.7 Steel Fibres

The steel fibres used in the project are of steel fibre of 60 mm in length and 0.75 mm in thickness. The advantages of using steel fibre to the Self Compacting Concrete is as follows:

- Improves the flexural strength and toughness.
- Improves post cracking performance in the hardened state.
- Reduces segregation.
- Increases the durability.

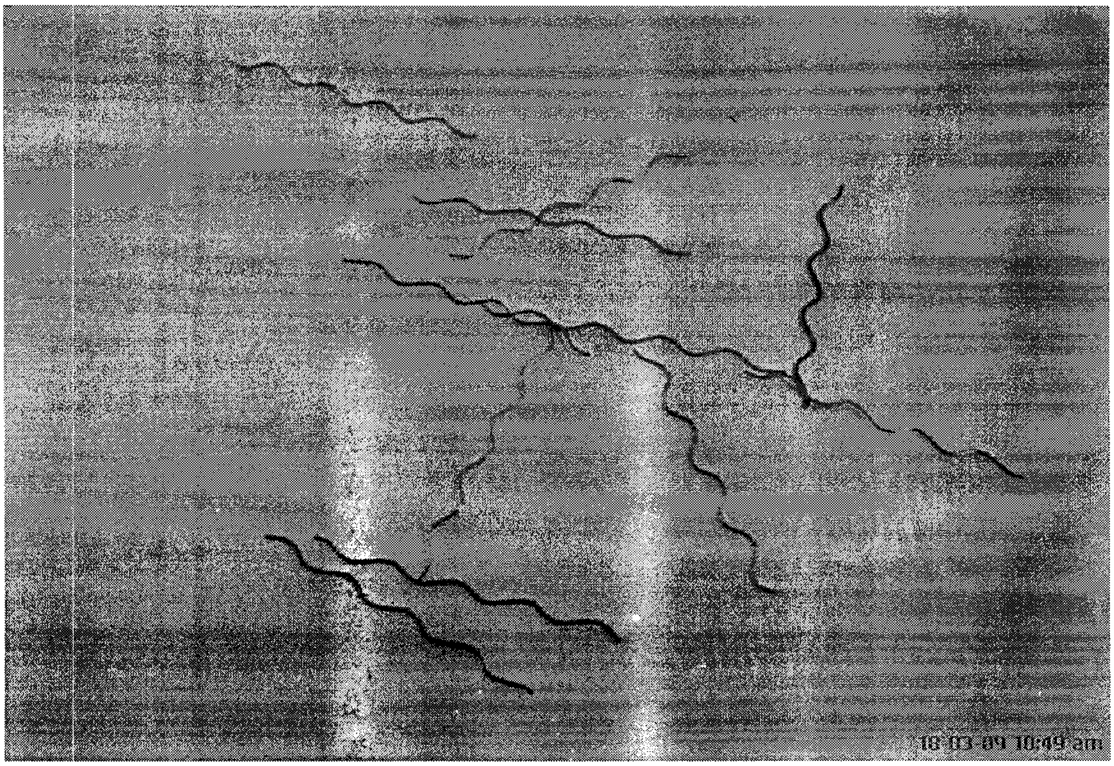

Fig.4.1 steel fibre.

4.2 MIX DESIGN BY ACI METHOD

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

Design stipulations:

Characteristic strength required at 28^{th} day	:	40MPa.
Standard deviation	:	4MPa.
Maximum size of aggregate	:	12.5mm

Test data of materials:

Specific gravity of fine aggregate	:	2.72
Specific gravity of coarse aggregate	:	3.05
Dry rodded bulk density of CA	:	1487.6 kg/m^3.
Fineness modulus of fine aggregate	:	2.85.

Design:

Target mean strength

Target mean strength = f_{ck} + 1.64S

= 40 + (1.64 x 4)

= 46.56 N/mm^2.

Water cement ratio

Estimated W/C ratio = 0.38 (from exposure condition Table 11.6)

Cement content

A Slump of 150 to 180 mm is necessary. For 12.5mm maximum size of aggregate and for non air entrained concrete. The mixing water content is 166.7 kg/m^3 of concrete. Approximate entrapped air content is 2%.

The required cement content = 166.7/0.38

= 436.6 kg/m^3.

Coarse aggregate

From the table 11.4, for 12.5mm CA, for Fineness Modulus of Fine aggregate 2.85, Bulk volume of dry rounded coarse aggregate per unit volume of concrete = 0.6

Weight of Coarse Aggregate = 0.6 * 1487.6

= 892.56 kg/m^3.

Fine aggregate:

From Table 11.9, the first estimate of density of fresh concrete for 12.5mm maximum size of aggregate and for non air entrained concrete =2315 kg/m^3.

Weight of Fine aggregate = 2196- (166.7+436.6+892.56)

= 819.14 kg/m^3.

Mix ratio obtained by ACI method is:

Water	Cement	Fine aggregate	Coarse aggregate
166.7l/m^3	436.6kg/m^3	819.14kg/m^3	892.56kg/m^3
0.38	1	1.87	2.04

4.3 METHODOLOGY ADOPTED IN THIS STUDY

The sequential procedure adopted in this experimental study is as follows:

- Initially, a nominal mix with 80 to 100mm is targeted without the use of super plasticizers.
- A vertical slump of 180 mm is then aimed by adding super plasticizer to the mix obtained in previous mix. If any segregation especially bleeding takes place at this stage, as judged visually, a part of coarse aggregate is replaced by fine aggregate. The percentage of replacement is chosen to be small.
- To proceed towards achieving SCC the coarse aggregate is then replaced with fly ash, by various percentages of 10, 15, 20%, until a horizontal slump for SCC is achieved. And also the other tests like U –box, V- funnel test also reached with the limits of SCC.
- Finally, after achieving the appropriate SCC mix, specimens are casted and tested for the hardened properties.

4.4 TRIAL MIX PROPORTIONS TO OBTAIN SCC

The various trial mix proportions of different ratios are conducted in the laboratory to achieve the Self Compacting Concrete. By the addition of the HRWR of various ratio of 1.0%, 1.5% and the VMA of various ratio of 0.25%,0.5% to achieve the Self Compacting Concrete. In this stage the segregation of aggregates are found. So the coarse aggregate is replaced by fine aggregate by 5% and then the bleeding was not seen. To achieve the SCC mix the coarse aggregate is replaced by the fly ash by various percentages of 10, 15 and 20%. The finally the SCC mix was achieved in 20% replacement of coarse aggregate by fly ash. The mix proportion of achieved SCC is shown in the below:

Mix Ratio for SCC obtained from various trials is

Water	Cement	FA	CA	Fly ash	HRWR	VMA
166.7	436.6	858	685	262	10.48	3.493
0.38	1	1.97	1.57	0.6	0.024	0.008

This mix ratio is taken as the Conventional SCC ratio. This ratio satisfies all the fresh properties tests for SCC such as the slump flow test for the filling ability of the SCC, U – box test for the flow ability and also the segregation property of the SCC, V – funnel test for the filling ability of the SCC. Thus it satisfying all the requirements of SCC this mix proportion is taken as control mix of SCC and the steel fibres of various contents such as 0.25%, 0.5%, 0.75%and 1.0% are added the achieved mix the various characteristic such as the fresh and hardened properties are studied by the addition of steel fibre.

4.4.1 MIX PROPORTION OF SCC WITH 0.25% STEEL FIBRE

The steel fibre of 0.25% is added to the achieved SCC. By the addition of steel fibre to the same mix proportion with the same amount of HRWR and VMA the mix achieved the results of all tests of slump flow test, U – box test V- funnel test within the required limits of SCC. The mix proportion of SCC with 0.25% steel fibre is shown as below:

Mix Ratio for SCC with 0.25% steel fibre

Water	Cement	FA	CA	Fly ash	HRWR	VMA	SF
166.7	436.6	858	685	262	10.48	3.493	1.75
0.38	1	1.97	1.57	0.6	0.024	0.008	0.004

4.4.2 MIX PROPORTION OF SCC WITH 0.5% STEEL FIBRE

The steel fibre of 0.5% is added to the achieved SCC. By the addition of steel fibre to the same mix proportion with the same amount of HRWR and VMA the mix achieved the results of all tests of slump flow test, U – box test V- funnel test within the required limits of SCC. The mix proportion of SCC with 0.5% steel fibre is shown as below:

Mix Ratio for SCC with 0.5% steel fibre

Water	Cement	FA	CA	Fly ash	HRWR	VMA	SF
166.7	436.6	858	685	262	10.48	3.493	3.49
0.38	1	1.97	1.57	0.6	0.024	0.008	0.008

4.4.3 MIX PROPORTION OF SCC WITH 0.75% STEEL FIBRE

The steel fibre of 0.75% is added to the achieved SCC. By the addition of steel fibre to the same mix proportion with the same amount of HRWR and VMA the mix achieved the results of all tests of slump flow test, U – box test V- funnel test within the required limits of SCC. The mix proportion of SCC with 0.75% steel fibre is shown as below:

Mix Ratio for SCC with 0.75% steel fibre

Water	Cement	FA	CA	Fly ash	HRWR	VMA	SF
166.7	436.6	858	685	262	10.48	3.493	5.24
0.38	1	1.97	1.57	0.6	0.024	0.008	0.012

4.4.4 MIX PROPORTION OF SCC WITH 1% STEEL FIBRE

The steel fibre of 1% is added to the achieved SCC. By the addition of steel fibre to the same mix proportion with the same amount of HRWR and VMA the mix achieved the results of all tests of slump flow test, U – box test V- funnel test within the required limits of SCC. The mix proportion of SCC with 1% steel fibre is shown as below:

Mix Ratio for SCC with 1% steel fibre

Water	Cement	FA	CA	Fly ash	HRWR	VMA	SF
166.7	436.6	858	685	262	10.48	3.493	6.98
0.38	1	1.97	1.57	0.6	0.024	0.008	0.016

The comparison of these five mixes such as the SCC without steel fibre, SCC with 0.25%, 0.5%, 0.75% and 1% of steel fibre is shown in the below table 9.

Table No: 4.3 Mix proportion of SCC. SCC with 0.25% .0.5%.0.75%and 1% of steel fibre

Materials	Control Mix SCC	With 0.25% SF	With 0.50% SF	With 0.75% SF	With 1% SF
Cement Kg/m^3	436.6	436.6	436.6	436.6	436.6
Fly ash Kg/m^3	262	262	262	262	262
Water	166.7	166.7	166.7	166.7	166.7
FA Kg/m^3	858	858	858	858	858
CA (12.5mm) Kg/m^3	685	685	685	685	685
HRWR	10.48	10.48	10.48	10.48	10.48
VMA	3.493	3.493	3.493	3.493	3.493
Steel fibre	0	1.75	3.49	5.24	6.98

4.5 CONCRETE PRODUCTION AND PLACING

The concrete production and placing of SCC is described below:

4.5.1 Aggregates

Aggregate should come from same source. There should not be many variations in size, shape and moisture content.

4.5.2 Mixing

Any suitable mixer could be used – Generally, mixing time need to be longer than for conventional concrete. Time of addition of admixture is important. A system should be established for optimum benefit during trial itself.

In the beginning there may be fluctuations in the quality of freshly mixed concrete. It is recommended that every batch must be tested until consistent and compliant results are obtained. Subsequently, checking could be done "by the eye" and routine testing is sufficient.

4.5.3 Placing

Formwork must be in good conditions to prevent leakage. Though it is easier to place SCC than ordinary concrete, the following rules are to be followed fo minimize the risk of segregation.

- Limit of vertical free fall distance to 5 meter.
- Limit the height of pour lifts (layer) to 500 mm.
- Limit of permissible distance of horizontal flow from point of discharge to 10 mm.

4.5.4 Curing

On account of no bleeding or very little bleeding, SCC tends to dry faster and may cause more plastic shrinkage cracking. Therefore, initial curing should be commenced as soon as practicable. Alternatively the SCC must be effectively covered by polyethylene sheet. Due to the high content of powder, SCC can show more plastic shrinkage or creep than ordinary concrete mixes. There are disagreements on the above statement. These aspects should be considered during designing and specifying SCC. It should also be noted that early curing is necessary for SCC.

4.6 TESTS ON HARDENED CONCRETE

Testing of hardened concrete plays an important role in controlling and confirming the quality of cement concrete work. Systematic testing of raw materials, fresh concrete and hardened concrete are inseparable part of any quality control programme for concrete, which helps to achieve higher efficiency of the material used and greater assurance of the performance of the concrete with regard to both strength and durability.

4.6.1 Compression Test

One of the important properties of concrete is its strength in compression. The strength in compression has definite relationship with all other properties of concrete i.e. these properties are improved with the improvement in compression strength. The aim of this experimental test is to determine the maximum load carrying capacity of test specimens.

Cubes of size 100 x 100 x 100 mm were cast. Six numbers of specimens were rested for 7, 28 days. A total of 30 cubes for M-40 grade controlled concrete of SCC, SCC with 0.25%, 0.5%, 0.75% and 1% of steel fibre were tested.

The compression test specimens were tested on a compression testing machine (CTM) of capacity 2000 KN. The specimen was placed on machine in such a way that its position is at right angles to its own position which it had at the time of casting. Load is applied gradually as the rate of 14 N/mm^2/min or 320 KN/min. All the specimens were loaded to failure and the corresponding failure loads were recorded. The mean value of the three specimens of each type is taken as final compressive strength.

4.6.2 Split Tensile Test

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. The main of this experimental test is to determine the maximum load carrying capacity of test specimens.

Cylinders of size 100 mm in diameter and 200 mm height were cast for split tensile test. Two numbers of specimens were tested for each 7, 28days. A total of 10 cylinders for M-40 grade controlled concrete of SCC, SCC with 0.25% , 0.5%, 0.75% and 1% of steel fibre were tested.

The splitting tests are well known as indirect tests used for determining the tensile strength of concrete. They are some times referred as split tensile strength of concrete. The test consists of applying a compressive line load along the opposite generator of a concrete cylinder placed with its axis horizontal between the compressive plates of CTM. The load was increased until the specimen fails, and the maximum load applied to the specimen during the test was recorded. The mean value of the three specimen of each type is taken as final split tensile strength value.

4.6.3 Flexure Test

The main of this experimental test is to determine the maximum load carrying capacity of beam specimens. This was carried for M-40 grade controlled concrete of SCC, SCC with 0.25%, 0.5%, 0.75% and 1% of steel fibre were tested. The specimen is subjected to two point loading and the load at the failure of the specimen is noted down.

Prisms of size 100 x 100 x 500 mm were cast. Two numbers of specimens for each set were tested for 7, 28days. A total of 10 beams were casted. These specimens were tested in universal Testing Machine (UTM) of capacity 1000 KN. The main value of the specimen of each type is taken as final flexure value. Flexing strength of the specimen is expressed as the modules of rupture.

4.6.3 Stress-Strain Relationship

One of the important properties of concrete is its stress-strain relationship. The aim of this experimental test is to determine the maximum Young's Modulus of test specimens.

Cylinders of size 150mm x 300mm were cast. Four numbers of specimens were rested for 7, 28 days. A total of 20 cylinders for M-40 grade controlled concrete of SCC, SCC with 0.25%, 0.5%, 0.75% and 1% of steel fibre were tested.

4.7 PREPARATION OF SPECIMENS

Total specimens casted in this experimental study are shown in the table no. 10 as shown in below:

Table No: 4.4 Total specimens casted in the study

Sl.No.	Particulars	Cubes of size 100*100*100mm	Cylinders of size 150mm dia and 300mm height	Prisms of size 500*100*100mm	Cylinders of size 100mm dia and 200mm height
1	Controlled SCC	6	4	2	2
2	SCC with 0.25% steel fibre	6	4	2	2
3	SCC with 0.5% steel fibre	6	4	2	2
4	SCC with 0.75% steel fibre	6	4	2	2
5	SCC with 1.0% steel fibre	6	4	2	2
Total		30	20	10	10
Grand total		60			

The casting of these specimen are done and after 24 hours of casting the concrete test specimens were demoulded and immersed in water until the start of tests. The tests were conducted at the age of 7and 28 days.

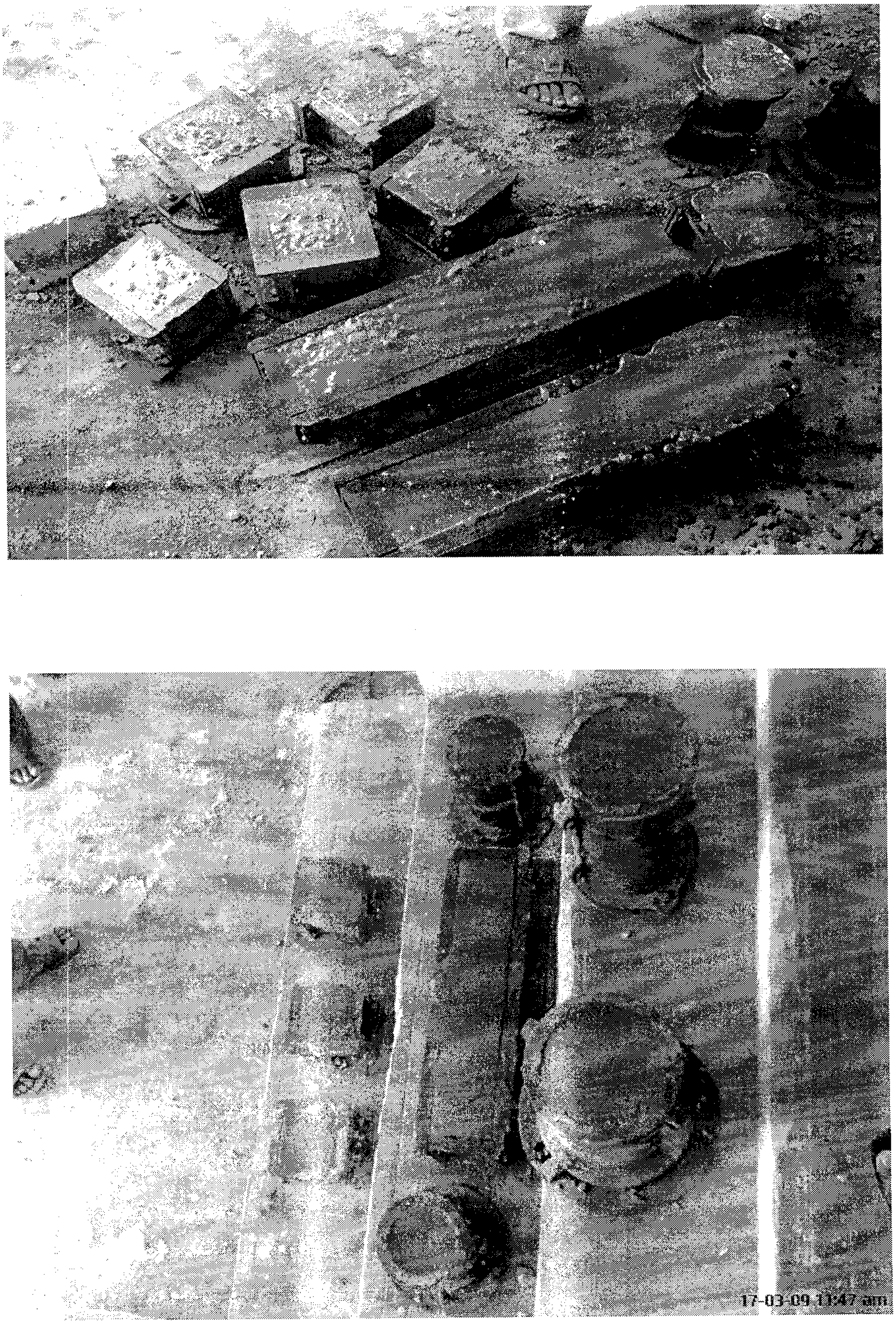

Fig.No: 4.2 casting work

CHAPTER 5

RESULTS AND DISCUSSIONS

Based on the SCC mix obtained through the sequential mix proportion and through various tests, the characteristics of fresh concrete properties and the hardened concrete properties are discussed in this chapter.

5.1 FRESH PROPERTIES

The fresh properties tests such as slump flow test, T_{50} slump flow in sec, U – box test and V- funnel test are conducted. All the mixes such as controlled concrete of SCC, SCC with 0.25%, 0.5%, 0.75% and 1% of steel fibre satisfied the requirements of the limiting values for Self Compacting Concrete. The values of the test results are explained below:

5.1.1 SCC without Steel Fibre

The SCC without glass fibre shows the slump flow highest of 660mm (Acceptable range 600 to 800mm) compared to the slump flow of the SCC with 0.25% , 0.5%, 0.75% and 1% of steel fibre. The time for the concrete to reach 50 cm diameter flow is noted as 3 sec (Acceptable range 2 to 5sec). The U – box test result shows the height difference between the 2 compartments as 20 mm (Acceptable range <30mm). The V – funnel test shows for the emptying the funnel is 6 sec (Acceptable range 6 to 12sec). The V – funnel T_5min test shows after setting of concrete for 5 minutes is 10 sec (Acceptable range 9 to 15sec).

The test results of the SCC without steel fibre and also the comparison with other mixes is shown in the Table.No5.1.

5.1.2 SCC with 0.25% Steel Fibre

The SCC with 0.25% steel fibre shows the slump flow of 630mm (Acceptable range 600 to 800mm) which is lesser compared to the slump flow of the SCC without steel fibre and higher than SCC with 0.5% steel fibre. The time for the concrete to reach 50 cm diameter flow is noted as 3 sec (Acceptable range 2 to 5sec).

The U – box test result shows the height difference between the 2 compartments as 20mm (Acceptable range <30mm). The V – funnel test shows for the emptying the funnel is 8 sec (Acceptable range 6 to 12sec). The V – funnel T_5min test shows after setting of concrete for 5 minutes is 13 sec (Acceptable range 9 to 15sec).

The test results of the SCC with 0.25% steel fibre and also the comparison with other mixes is shown in the Table.No5.1.

5.1.3 SCC with 0.5% Steel Fibre

The SCC with 0.5% steel fibre shows the slump flow lowest of 610mm (Acceptable range 600 to 800mm) compared to the slump flow of the SCC without steel fibre and SCC with 0.25% steel fibre. The time for the concrete to reach 50 cm diameter flow is noted as 4sec (Acceptable range 2 to 5sec). The U – box test result shows the height difference between the 2 compartments as 30 mm (Acceptable range <30mm). The V – funnel test shows for the emptying the funnel is 7 sec (Acceptable range 6 to 12sec). The V – funnel T_5min test shows after setting of concrete for 5 minutes is 12 sec (Acceptable range 9 to 15sec).

The test results of the SCC with 0.5% steel fibre and also the comparison with other mixes is shown in the Table.No5.1.

5.1.4 SCC with 0.75% Steel Fibre

The SCC with 0.75% steel fibre shows the slump flow of 640mm (Acceptable range 600 to 800mm) which is lesser compared to the slump flow of the SCC without steel fibre and which is more compared to the slump flow of the SCC with 0.25% steel fibre. The time for the concrete to reach 50 cm diameter flow is noted as 5 sec (Acceptable range 2 to 5sec). The U – box test result shows the height difference between the 2 compartments as 20 mm (Acceptable range <30mm). The V – funnel test shows for the emptying the funnel is 8 sec (Acceptable range 6 to 12sec). The V – funnel T_5min test shows after setting of concrete for 5 minutes is 14 sec (Acceptable range 9 to 15sec).

The test results of the SCC with 0.75% steel fibre and also the comparison with other mixes is shown in the Table.No5.1.

5.1.4 SCC with 1% Steel Fibre

The SCC with 1% steel fibre shows the slump flow of 600 mm (Acceptable range 600 to 800mm) which is lesser compared to the slump flow of the SCC without steel fibre and SCC with 0.25%, 0.5%, and 0.75% steel fibre. The time for the concrete to reach 50 cm diameter flow is noted as 5 sec (Acceptable range 2 to 5sec). The U – box test result shows the height difference between the 2 compartments as 30 mm (Acceptable range <30mm). The V – funnel test shows for the emptying the funnel is 9 sec (Acceptable range 6 to 12sec). The V – funnel T_5min test shows after setting of concrete for 5 minutes is 12 sec (Acceptable range 9 to 15sec).

The test results of the SCC with 1% steel fibre and also the comparison with other mixes is shown in the Table.No5.1.

Table No: 5.1 Fresh property results of various mix

Test Methods	SCC – Normal	SCC with 0.25% steel Fibre	SCC with 0.5% steel Fibre	SCC with 0.75% steel Fibre	SCC with 1.0% steel Fibre
Slump flow mm	660	630	610	640	600
T_{50} cm Slump flow Sec	3	3	5	4	6
V – funnel test Sec	6	8	7	8	9
V – funnel test at T_5 min Sec	10	13	12	14	12
U – box test mm	20	20	30	20	30

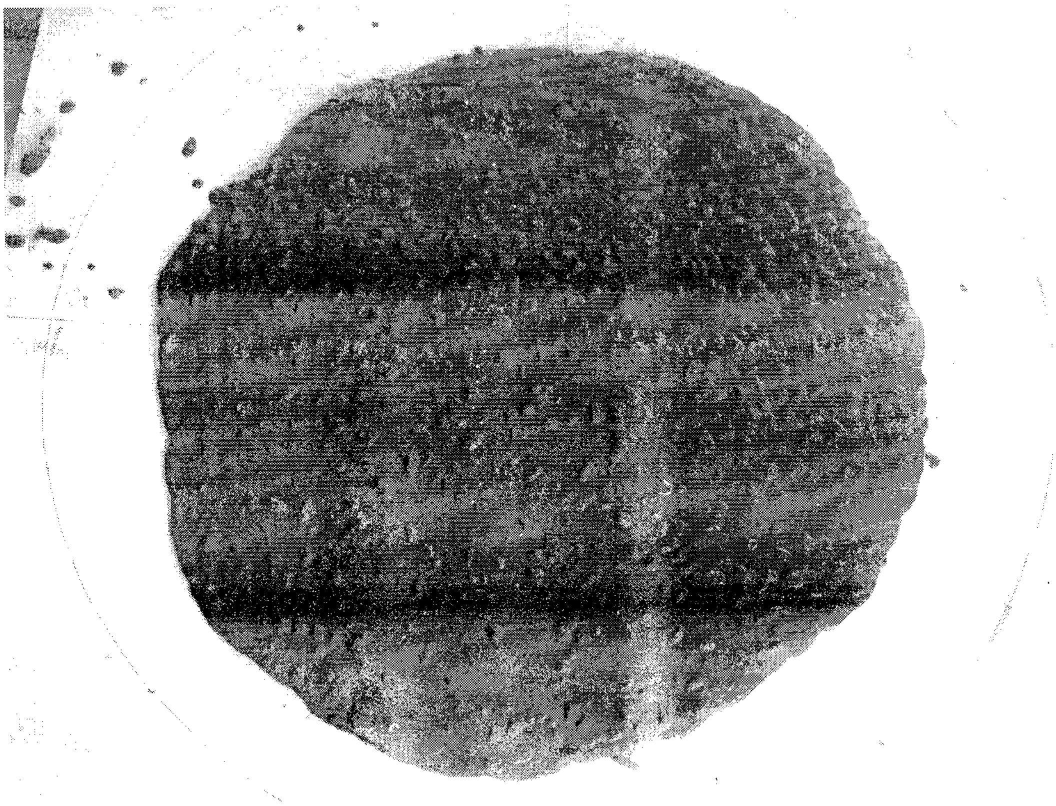

Fig..No: 5.1 Horizontal flow of SCC

Fig..No:5.2 V-Funnel test of SCC

Fig..No:5.3 L- box test

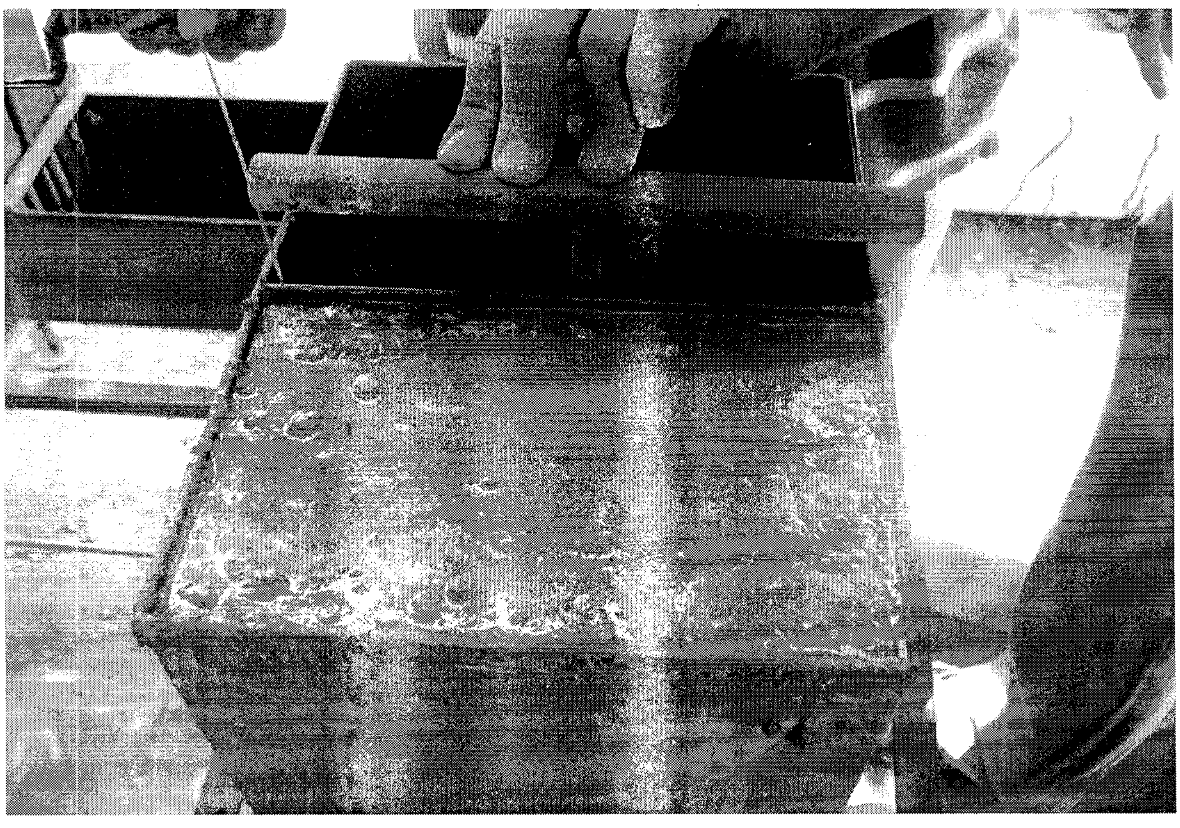

Fig..No:5.4 U- Box test

5.2 HARDENED PROPERTIES

The hardened property test such as compression test by using compression testing machine, split tensile test by using compression testing machine and flexural test by using ultimate testing machine are conducted. The results obtained for the various mixes of SCC, SCC with 0.25% Steel Fibre and SCC with 0.5% Steel Fibre are shown in the Table.No5.2, 5.3 and 5.4, 5.5 and also the comparison of the results are discussed below:

5.2.1 Compressive Strength

The 7 day compressive strength of the SCC without steel Fibre shows a value of 30.30N/mm^2, SCC with 0.25% steel Fibre shows the value of 33.3N/mm^2, SCC with 0.5% steel Fibre shows the value of 35.6 N/mm^2, SCC with 0.75% steel Fibre shows the value of 37.6 N/mm^2 and the SCC with 1% steel Fibre shows the value of 39.3 N/mm^2.

The comparison of the 7 day strength results shows that SCC with 0.25%, 0.5%, 0.75% and 1% of SF shows an increases of 9%, 14.8%, 19.4% and 22.9% with respect to control mix of SCC.

The 28 day compressive strength of the SCC without steel Fibre shows a value of 43.30N/mm^2, SCC with 0.25% steel Fibre shows the value of 47.6N/mm^2, SCC with 0.5% steel Fibre shows the value of 49.6 N/mm^2, SCC with 0.75% steel Fibre shows the value of 53.3 N/mm^2 and the SCC with 1% steel Fibre shows the value of 58.6 N/mm^2.

The comparison of the 28 day strength results shows that SCC with 0.25%, 0.5%, 0.75% and 1% of SF shows an increases of 9%, 12.7%, 18.8% and 26.1% with respect to control mix of SCC.

Fig.No: 5.5 compressive strength test

Table No: 5.2 compressive strength results of various mix

% of fibre added	Compressive Strength of cubes at 7th day (N/mm²)	Compressive Strength of cubes at 28th day (N/mm²)
0%	30.3	43.3
0.25%	33.3	47.6
0.5%	35.6	49.6
0.75%	37.6	53.3
1.0%	39.3	58.6

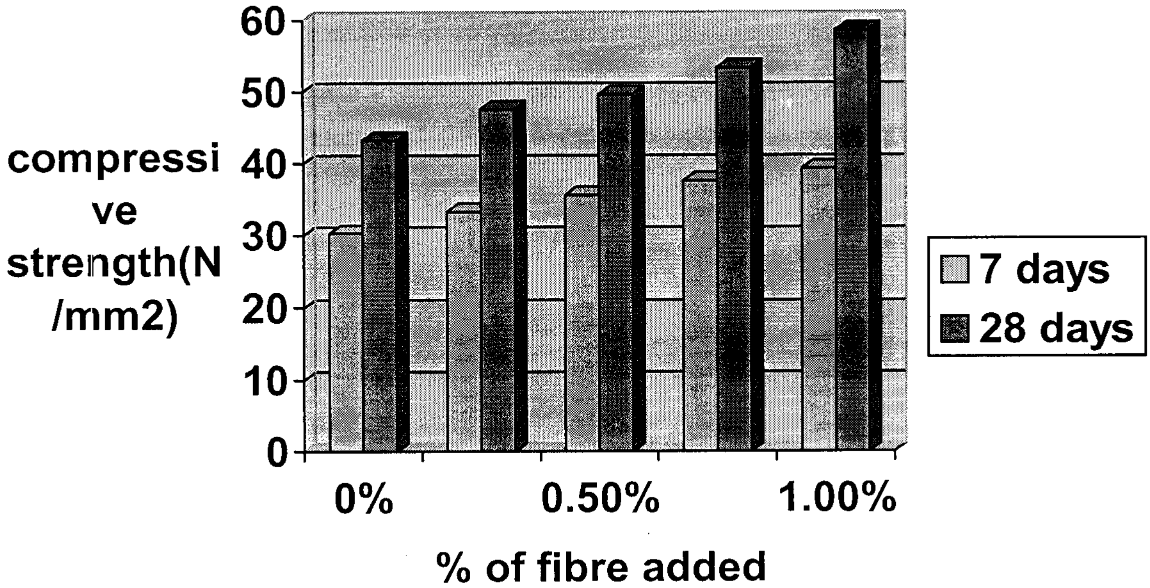

Fig .No.5.6 Comparison of Compresive strength of various mixes

5.2.2 Split Tensile Strength

The 7 day split tensile strength of the SCC without steel Fibre shows a value of 2.91 N/mm^2, SCC with 0.25% steel Fibre shows the value of 3.36N/mm^2, SCC with 0.5% steel Fibre shows the value of 3.42 N/mm^2, SCC with 0.75% steel Fibre shows the value of 3.86 N/mm^2 and the SCC with 1% steel Fibre shows the value of 4.66 N/mm^2.

The comparison of the 7 day strength results shows that SCC with 0.25%, 0.5%, 0.75% and 1% of SF shows an increases of 13.3%, 14.9%, 24.6% and 37.5% with respect to control mix of SCC.

The 28 day split tensile strength of the SCC without steel Fibre shows a value of 4.16N/mm^2, SCC with 0.25% steel Fibre shows the value of 4.68N/mm^2, SCC with 0.5% steel Fibre shows the value of 4.88 N/mm^2, SCC with 0.75% steel Fibre shows the value of 5.46 N/mm^2 and the SCC with 1% steel Fibre shows the value of 6.47 N/mm^2.

The comparison of the 28 day strength results shows that SCC with 0.25%, 0.5%, 0.75% and 1% of SF shows an increase of 11.1%, 14.7%, 23.8% and 35.7% with respect to control mix of SCC.

Fig.No: 5.7 split tensile strength test

Table No: 5.3 split tensile strength results of various mix

% of fibre added	Split Tensile Strength of Cylinders at 7th day (N/mm^2)	Split Tensile Strength of Cylinders at 28th day (N/mm^2)
0%	2.91	4.16
0.25%	3.36	4.68
0.5%	3.42	4.88
0.75%	3.86	5.46
1.0%	4.66	6.47

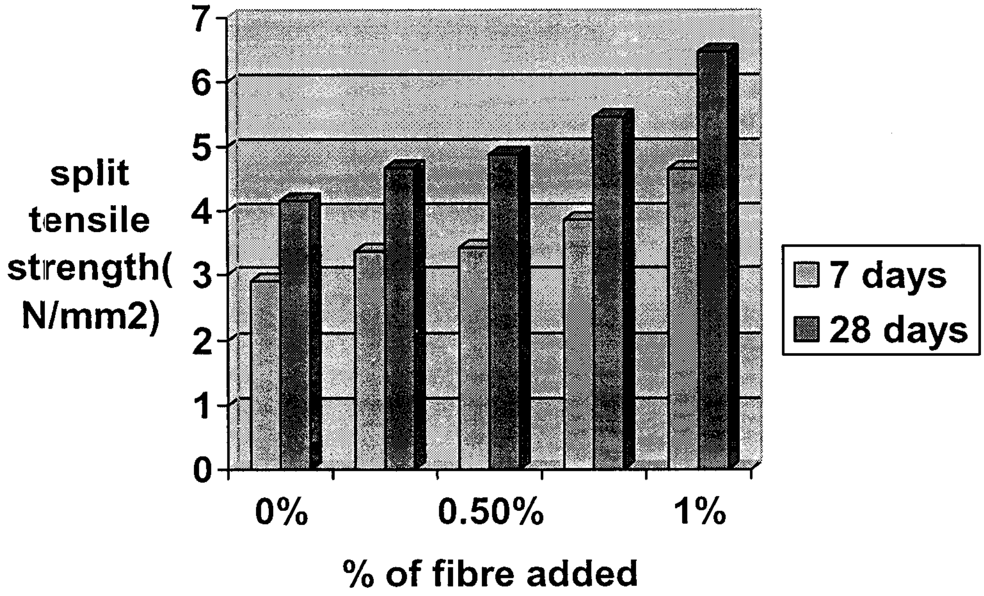

Fig .No.5.8 Comparison of split tensile strength of various mixes

5.2.3 Flexural Strength

The 7 day flexural strength of the SCC without steel Fibre shows a value of 3.85 N/mm^2, SCC with 0.25% steel Fibre shows the value of 3.99N/mm^2, SCC with 0.5% steel Fibre shows the value of 4.22 N/mm^2, SCC with 0.75% steel Fibre shows the value of 4.50 N/mm^2 and the SCC with 1% steel Fibre shows the value of 4.71 N/mm^2.

The comparison of the 7 day strength results shows that SCC with 0.25%, 0.5%, 0.75% and 1% of SF shows an increase of 3.5%, 8.7%, 14.4% and 18.2% with respect to control mix of SCC.

The 28 day flexural strength of the SCC without steel Fibre shows a value of 4.92N/mm^2, SCC with 0.25% steel Fibre shows the value of 5.11N/mm^2, SCC with 0.5% steel Fibre shows the value of 5.35 N/mm^2, SCC with 0.75% steel Fibre shows the value of 5.77 N/mm^2 and the SCC with 1% steel Fibre shows the value of 6.12 N/mm^2.

The comparison of the 28 day strength results shows that SCC with 0.25%, 0.5%, 0.75% and 1% of SF shows an increase of 3.7%, 8.03%, 14.7% and 19.6% with respect to control mix of SCC.

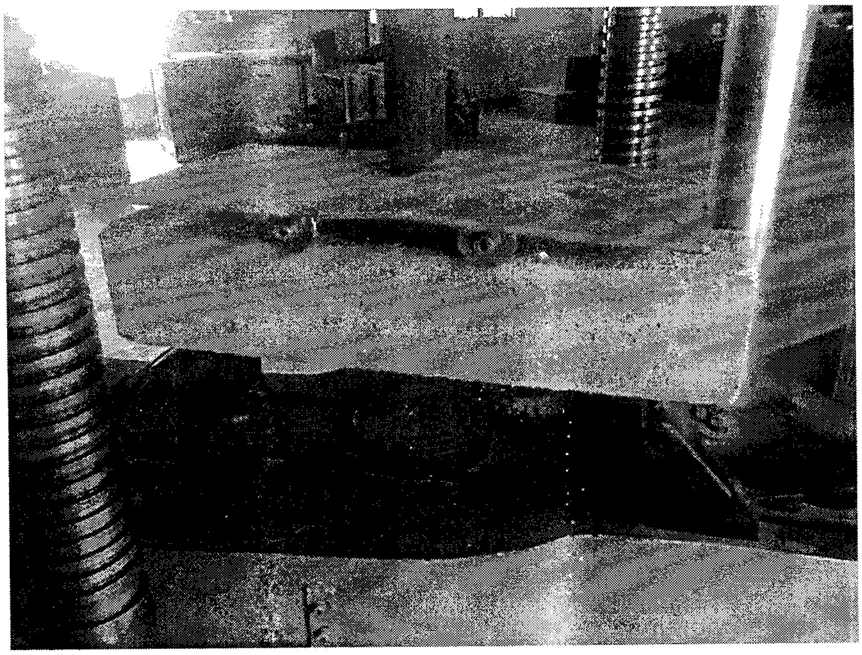

Fig.No: 5.9 flexural tensile strength test

Table No: 5.4 flexural strength results of various mix

% of fibre added	Flexural Strength of prism at 7th day (N/mm^2)	Flexural Strength of prism at 28th day (N/mm^2)
0%	3.85	4.92
0.25%	3.99	5.11
0.5%	4.22	5.35
0.75%	4.50	5.77
1.0%	4.71	6.12

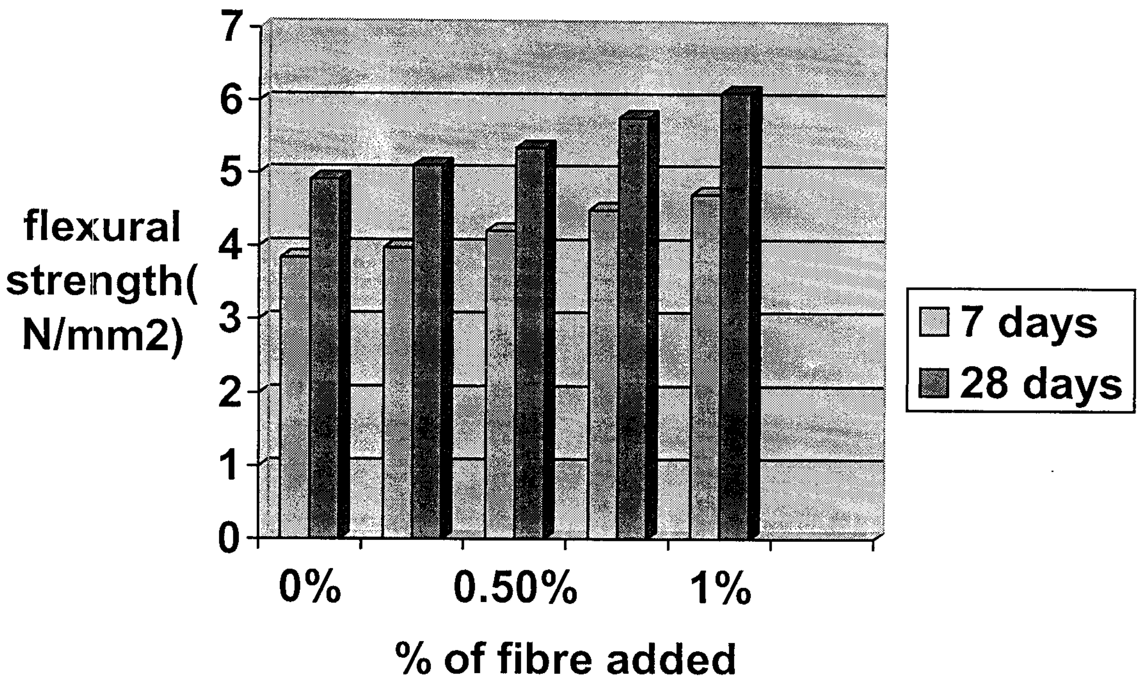

Fig .No.5.10 Comparison of flexural strength of various mixes

5.2.4 Stress-Strain Relationship

The 7 day youngs modulus of the SCC without steel Fibre shows a value of 26621.79 N/mm^2, SCC with 0.25% steel Fibre shows the value of 28619.72 N/mm^2, SCC with 0.5% steel Fibre shows the value of 29723.49 N/mm^2, SCC with 0.75% steel Fibre shows the value of 29594.3 N/mm^2 and the SCC with 1% steel Fibre shows the value of 28754.88 N/mm^2.

The 28 day flexural strength of the SCC without steel Fibre shows a value of 31390.93 N/mm^2, SCC with 0.25% steel Fibre shows the value of 31390.93 N/mm^2, SCC with 0.5% steel Fibre shows the value of 34452.5 N/mm^2, SCC with 0.75% steel Fibre shows the value of 35954.6 N/mm^2 and the SCC with 1% steel Fibre shows the value of 39617.08 N/mm^2.

Table No: 5.5 stress-strain results of various mixes

% of fibre added	Youngs modulus of cylinders at 7th day (N/mm^2)	Youngs modulus of cylinders at 28th day (N/mm^2)
0%	26621.79	31390.93
0.25%	28619.72	34294.3
0.5%	29723.49	34452.5
0.75%	29594.3	35954.6
1.0%	28754.88	39617.08

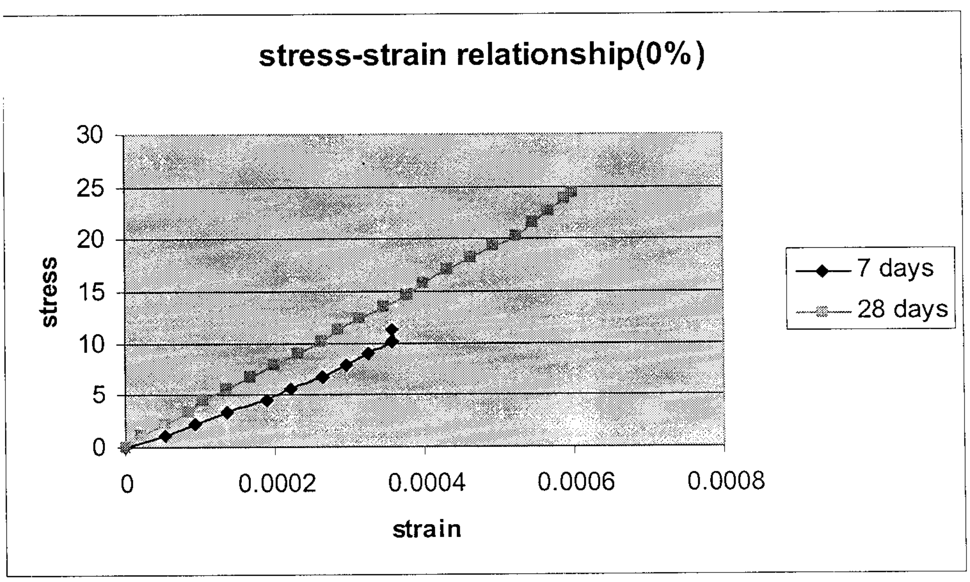

Fig .No.5.11 Comparison of stress-strain curve for without fbre SCC mix

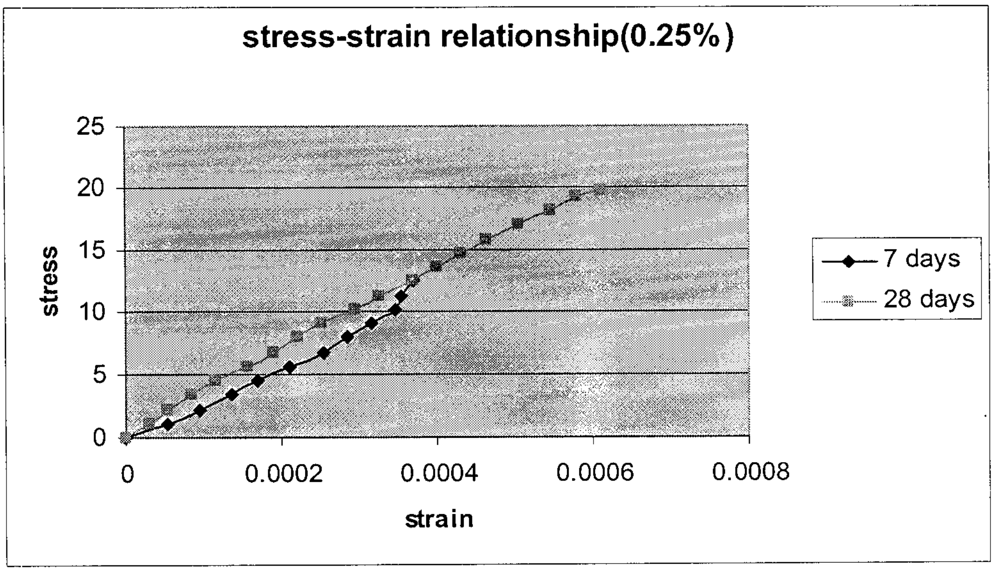

Fig .No.5.12 Comparison of stress-strain curve for 0.25% of fibre added SCC mix

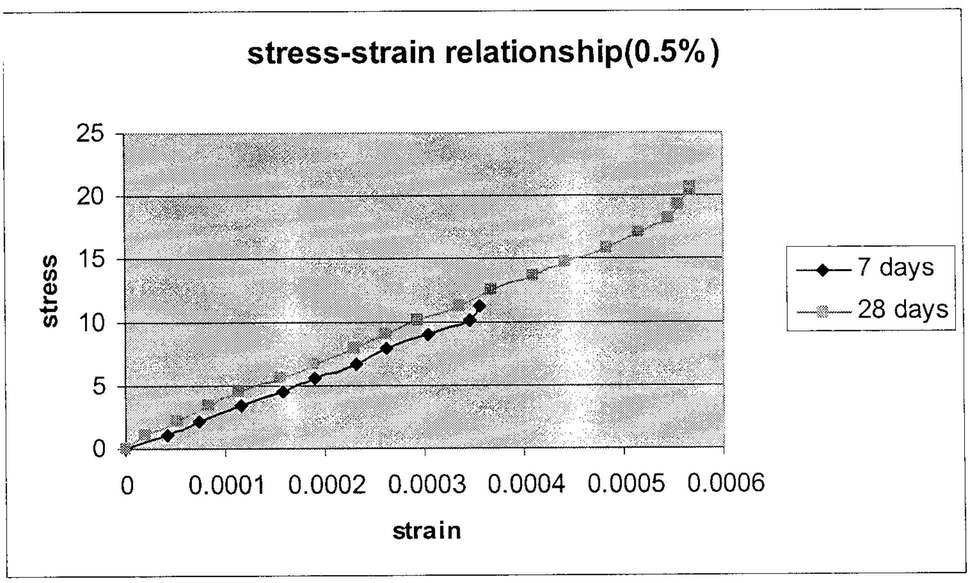

Fig .No.5.13 Comparison of stress-strain curve for 0.5% of fibre added SCC mix

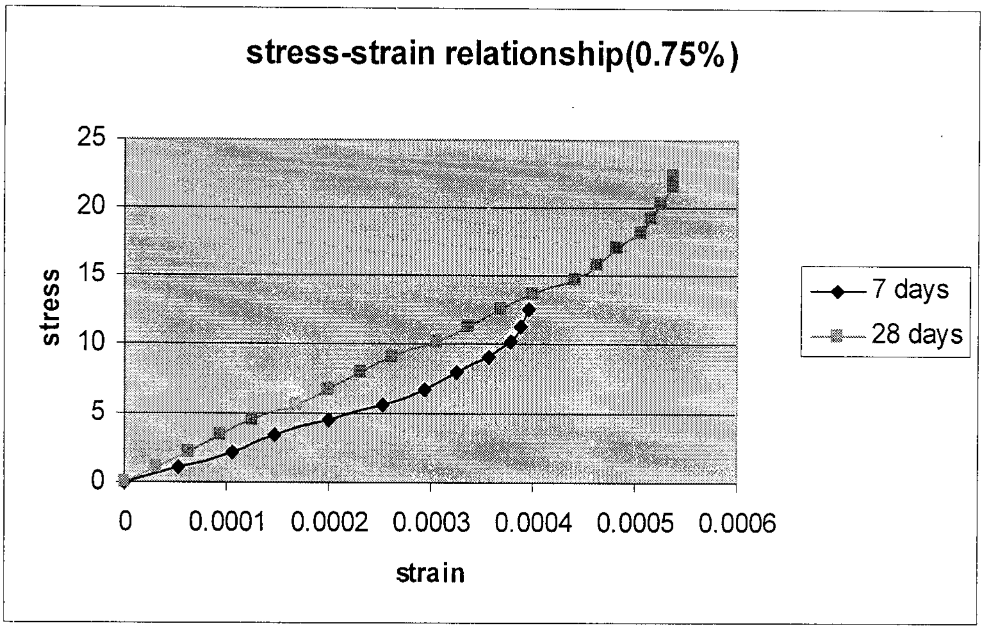

Fig .No.5.14 Comparison of stress-strain curve for 0.75% of fibre added SCC mix

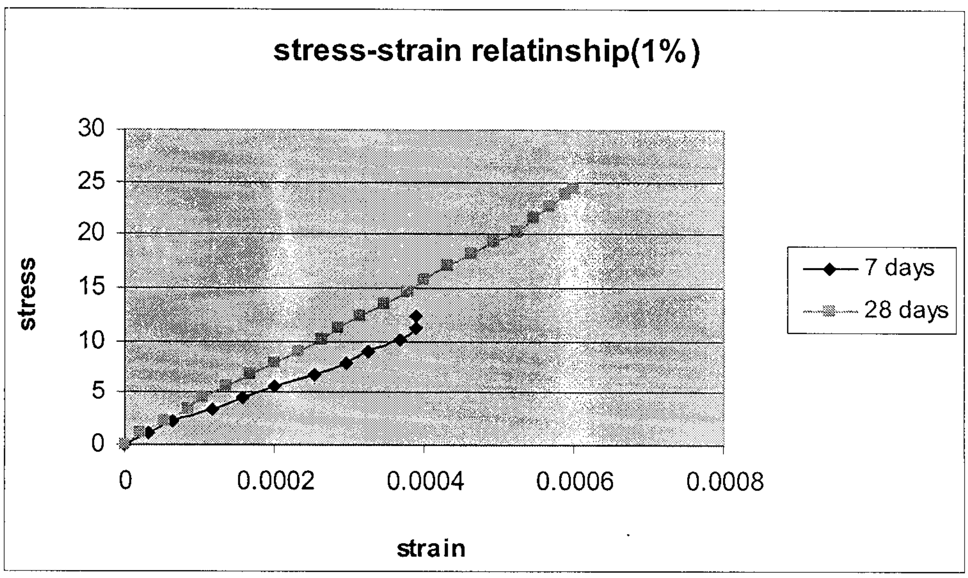

Fig .No.5.15 Comparison of stress-strain curve for 1% of fibre added SCC mix

CHAPTER 6

CONCLUSION

The following conclusions have been made from the above experimental study:

- From the test results of hardened concrete, it is been found that the all the mixes achieved the designed characteristic strength of M40 grade.
- Use of fly ash improve the setting characteristics of the SCC mix, but do not achieve the required flow properties of SCC. A VMA is required to achieve the flow.
- The compressive strength was conducted for all the different ratio of fibre mixes, it was found from the results that mix 5 (1% of fibre added) gives better strength.

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