

**ANALYTICAL AND EXPERIMENTAL STUDY ON THE  
FLEXURAL BEHAVIOR OF SELF COMPACTING CONCRETE  
USING STEEL FIBER AND RECYCLED CONCRETE  
AGGREGATES**

Submitted in partial fulfillment of the requirement for the  
award of degree of Master of Engineering in Structural engineering

Submitted by,

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**MAY - 2023**



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### BONAFIDE CERTIFICATE

This is to certify that this Project Report is the Bonafide work of **KAVIRAJ D (Reg No: 41380009)** who carried out the project entitled **“ANALYTICAL AND EXPERIMENTAL STUDY ON THE FLEXURAL BEHAVIOR OF SELF COMPACTING CONCRETE USING STEEL FIBER AND RECYCLED CONCRETE AGGREGATES”** under our supervision from December 2022 to May 2023.

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I **KAVIRAJ D (41380009)** here by declare that the Project Report entitled **“ANALYTICAL AND EXPERIMENTAL STUDY ON THE FLEXURAL BEHAVIOR OF SELF COMPACTING CONCRETE USING STEEL FIBER AND RECYCLED CONCRETE AGGREGATES”**, done under the guidance of Ms.P. Eshanthini is submitted in partial fulfillment of the requirements for the award of Master of Engineering degree in Structural Engineering.

**DATE** : 05-05-2023

**PLACE:** Chennai



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## **ABSTRACT**

Inappropriate vibration and compaction can cause unoccupied spaces and macro-pores inside of concrete, which can impact the Concrete's durability and mechanical strength as well as be one of the causes of concrete deterioration. Okamura first developed Self-Compacting Concrete (SCC) in 1986, and it is a well-considered answer to the issues mentioned above. Concrete that compacts itself under its own weight is known as self-compacting concrete and requires no further effort to do so.

Numerous studies have been conducted to examine the behaviour of plain SCC. Additionally, numerous studies from the past have shown that different fibres can be used to enhance the structural qualities of concrete. But here the combination of steel fiber and recycled concrete aggregates on the flexural behavior of SCC to be investigated.

Steel fibres are added to concrete at several rates (0%, 0.5%, 0.75%, and 1%) and recycled concrete aggregate is used to replace coarse aggregate to a certain extent 25%. Cubes, Cylinders, Prisms and RCC beams were casted. Also founded the properties of fresh and hardened concrete. It had been found that the RCASF 3 mix performed better than the RCASF 1 and RCASF 2 replacement mixes. Results from the experiments and analytical were examined. Results from analytical are slightly lower to those from experiments.

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## LIST OF SYMBOLS AND ABBREVIATIONS

|                   |                                                                                   |
|-------------------|-----------------------------------------------------------------------------------|
| SCC               | Self Compacting Concrete                                                          |
| RCA               | Recycled Concrete Aggregate                                                       |
| SFR- RCA SCC      | Steel fiber reinforced recycled concrete aggregate based self compacting concrete |
| SFVC              | Steel Fiber Vibrated Concrete                                                     |
| VC                | Vibrated Concrete                                                                 |
| RA                | Recycled Aggregate                                                                |
| CO <sub>2</sub>   | Carbon Dioxide                                                                    |
| SFSCC             | Steel Fiber Self Compacting Concrete                                              |
| NA                | Natural Aggregate                                                                 |
| FA                | Fine Aggregate                                                                    |
| CA                | Coarse Aggregate                                                                  |
| IST               | Initial Setting Time                                                              |
| Wt                | Weight                                                                            |
| IS                | Indian Standard                                                                   |
| ASTM              | American Society for Testing Materials                                            |
| RCASF 1           | Recycled Concrete Aggregate 25% & 0.5% Steel Fiber                                |
| RCASF 2           | Recycled Concrete Aggregate 25% & 0.75% Steel Fiber                               |
| RCASF 3           | Recycled Concrete Aggregate 25% & 1.0% Steel Fiber                                |
| RCC               | Reinforced Cement Concrete                                                        |
| Mpa/s             | Mega Pascal per Second                                                            |
| N/mm <sup>2</sup> | Newton per Square Millimetre                                                      |
| KN                | Kilo Newton                                                                       |

|     |                              |
|-----|------------------------------|
| FEA | Finite Element Analysis      |
| CAD | Computer Aided Design        |
| CAM | Computer Aided Manufacturing |
| RAM | Random Access Memory         |
| CPU | Central Processing Unit      |
| GPU | Graphics Processing Unit     |

# CHAPTER 1

## 1. INTRODUCTION

### 1.1 GENERAL

Self-compacting concrete (SCC), which has several advantages over normal concrete, has recently become more widely accepted. SCC is a very homogenous and flowable concrete mix that can fill and compact in every corner of the formwork with just its own weight, negating the requirement for outside vibration. The ability of SCC to create strong concrete structures is one of its main benefits. Strong concrete structures are necessary to ensure long-lasting and high-quality concrete constructions. SCC can produce great strength and durability by lowering the amount of voids in the concrete mix and removing the possibility of segregation. Additionally, SCC's improved fluidity makes it possible for it to be used in buildings with intricate and crowded reinforcements.

Additionally, the absence of external vibration lessens noise pollution, which is advantageous for nearby residents and workers. SCC's ability to self-compact also makes construction work safer and more efficient by lowering the requirement for manual labour and the chance of accidents. Overall, SCC utilisation provides several advantages for the construction industry, and its acceptance is likely to increase going forward.

#### ***1.1.1 Self Compacting Concrete***

Self-Compacting Concrete (SCC) is a kind of concrete that can flow and compact by itself without the aid of outside vibration. SCC is distinguished by its superb homogeneity and finish, high fluidity, and capacity to fill complex forms without segregation or bleeding. SCC is frequently employed in situations where conventional concrete placing methods are impractical or unfeasible, such as crowded reinforcing, complex geometries, or places where vibration equipment has limited access.

SCC can accelerate construction and lower labour costs because only minimum labour is needed to put and finish the concrete. Cement, aggregates,

water, and admixtures are the main ingredients of SCC in most cases, just as they are in conventional concrete.

However, SCC frequently contains higher levels of fine particles, which improve the mixture's fluidity and self-compactibility, like fly ash or silica fume. SCC may also contain superplasticizers and viscosity-modifying chemicals to enhance the mixture's rheology and workability.

SCC is frequently employed in situations, such as substantially reinforced structures, complicated architectural shapes, and regions with limited access, where typical concrete installation procedures are challenging or impracticable. Additionally, it offers a number of advantages, such as increased toughness, better surface quality, lower labour costs, and increased safety on construction sites

### ***1.1.2 Steel fiber***

In fiber-reinforced concrete, steel fibres are a typical type of fibre. They are short, broken steel filaments that typically have diameters between 0.25 mm and 0.75 mm and lengths between 25 mm and 50 mm. To enhance the mechanical qualities of concrete, such as flexural and tensile strength, toughness, and ductility, steel fibres are added to the concrete mixture. The fibres are equally dispersed throughout the concrete mixture, and when the concrete dries, they form a three-dimensional reinforcing network that helps to disperse stresses and stop cracks from forming.

In comparison to conventional concrete, the use of steel fibres in concrete can offer a number of benefits, including improved durability, increased resistance to impact and fatigue loading, and decreased susceptibility to cracking due to shrinkage or temperature changes. Additionally, steel fibres can improve structural performance, enabling the design of thinner and lighter concrete components.

It is crucial to remember that adding steel fibres to concrete may also bring some difficulties, such as making mixing and laying the concrete more challenging and wearing down mixing and placing equipment more quickly.

### ***1.1.3 Recycled Concrete Aggregate***

The recycled concrete aggregate (RCA) is made when concrete buildings are demolished and recycled. Concrete that has been crushed and graded and treated to remove impurities like rebar and other metal items as well as to generate pieces of a uniform size and shape make up RCA. When building roads, embankments or new concrete pavements, RCA can be used as an alternative to natural aggregates in a variety of construction applications. Utilising RCA in construction can lessen the need for new aggregates and the negative effects of aggregate extraction on the environment.

RCA is superior to conventional natural aggregates in a number of ways, including cost, environmental effect, and sustainability. Depending on the quality and grading of the RCA, it also possesses engineering attributes including strength, durability, and workability that are comparable to or better than natural aggregates.

However, the use of RCA does necessitate careful consideration of a number of factors, including the RCA's quality, potential for contamination, and the likelihood that the recycled material will exhibit alkali-silica reactivity. In order to make sure that the RCA satisfies the relevant performance requirements for the particular application, proper quality control and testing are essential. Overall, the use of RCA is a promising strategy for sustainable construction, as it helps to reduce waste and preserve natural resources, while providing comparable or better performance than traditional aggregates.

### ***1.1.4 Benefits of Recycled Concrete Aggregate***

Recycled concrete aggregate (RCA) has a number of advantages in construction, including:

Environmental sustainability: RCA lessens the requirement for virgin aggregates and the quantity of garbage that is delivered to landfills. With the use of RCA, less energy is used and less greenhouse gases are emitted during the manufacture and delivery of new aggregates.

Cost Savings: RCA is frequently less expensive than virgin aggregates, making it a desirable choice for building projects where conserving money is a top priority.

Reduced demand for natural resources: The usage of RCA helps to protect natural resources and lessens the negative environmental effects of aggregate exploitation.

Better Performance : According to the RCA's quality and grading, it can have technical attributes including strength, durability, and workability that are equivalent to or superior than those of natural aggregates.

Versatility: RCA can be used for a wide range of building projects, such as road bases, embankments, and as a base or sub-base material for fresh concrete pavements.

Local sourcing: The necessity for long-distance transportation of aggregates can be reduced because RCA can be obtained locally from structures made of recycled concrete.

Overall, the use of RCA is a sustainable and economical choice for building projects that prioritise cost effectiveness and environmental sustainability while still achieving comparable or better performance than conventional aggregates.

#### ***1.1.5 Steel fiber reinforced recycled concrete aggregate based self compacting concrete***

Concrete made with recycled aggregate and steel fibre is known as steel fibre reinforced recycled aggregate based self-compacting concrete (SFR-RCA SCC). It has self-compacting qualities and is made up of a mixture of recycled concrete aggregate, steel fibres, and other components.

Utilising recycled concrete aggregate in SFR-RCA SCC lessens the demand for new aggregates and lessens the negative environmental effects of the production of concrete. The mechanical qualities of the concrete, such as its tensile and flexural strength, toughness, and durability, are improved by the insertion of steel fibres.

SFR-RCA SCC has the ability to self-compact, so it may flow readily into intricate shapes and difficult-to-reach spaces without the need for human compaction, which can lower labour costs and enhance the quality of the finished product.

The kind and dose of steel fibres, the quality and grading of the recycled concrete aggregate, and the formulation of the mix to produce the appropriate self-compacting qualities must all be carefully taken into account while producing SFR-RCA SCC.

Compared to conventional concrete, SFR-RCA SCC offers a number of advantages, including increased sustainability, less environmental impact, and improved mechanical qualities. While still generating high-quality products, the usage of SFR-RAC SCC can also help to save building costs and enhance the efficiency of construction processes.

## **1.2 OBJECTIVES**

- To determine the properties of fresh and hardened concrete.
- To investigate the flexural properties of conventional SCC and steel fiber-reinforced SCC based on recycled aggregate.
- To create a model beam using the Abaqus software.
- To compare the results of the experiment with those from the finite element software

## **1.3 SCOPE**

The scope of the present investigation includes:

- Analyze the characteristics of steel fiber-reinforced SCC at different steel fibre dosages in order to maximise the dosage of steel fibres.
- Create an analytical model to forecast the flexural strength of steel fibre reinforced vibrated concrete (SFVC) using recycled and natural coarse particles.
- Numerical modeling of steel fiber reinforced using a finite element software doe both SCC, VC and validates based on experimental results.

#### **1.4 NEED FOR STUDY**

- To study the influence of Recycled Concrete Aggregate effect on flexural behaviour of self compacting concrete.
- To investigate how steel fibres affect SCC under flexural behaviour.
- To make concrete with a sustainable material.

## CHAPTER 2

### 2. LITERATURE REVIEW

#### 2.1 LITERATURES

In order to understand the role of steel fibers on strength and flexural behaviour of SCC and moreover to distinguish the effect of recycled concrete aggregates on strength properties of SCC and normal concrete, a thorough literature review is planned in the present chapter.

**Farhad Aslani et al. (2012)** To examine the mechanical properties, such as moduli of elasticity, tensile strength, and finally compressive stress-strain, three models have been built in this study. The material properties of self-compacting concrete will be significantly impacted by changes in mix design. It has been noted that the differences between Self Compacting Concrete and normal concrete for the Tensile Strength and Modulus of Elasticity models frequently change with compressive strength.

**Antonios Kanellopoulos et al. (2012)** The microstructure of SCC is enhanced by the use of mineral admixtures, thus enhancing SCC durability. Concrete's durability is increased by adding cement substitutes. Three different percentages of silica fume have been employed here as a partial replacement for cement.

**M. Pająk et al. (2013)** Here, four different percentages of two distinct types of steel fibres were utilised in the SCC, and their flexural behaviour was examined. When compared to straight steel fibre, the deflection at maximum load was higher for hooked end steel fibre. The increase in fibre volume ratio has boosted the flexural strength of SCC. The fracture energy is also increased by an increase in fibre dose, and it is found that it is particularly high for hook-ended steel fibre.

**Carmin Lima et al. (2013)** The workability, compressive strength, and tensile strength of concrete decrease as the percentage of recycled aggregate increases. Fly ash has been added to concrete as a solution to this and to enhance its performance

in terms of durability. As a partial replacement for cement, fly ash has been incorporated. Chloride penetration is also resisted by the fly ash in concrete.

**K.C.Panda et al. (2013)** Self-compacting concrete (SCC) is mixed with recycled coarse aggregate (RCA) in varying amounts, and the results are compared to those of regular concrete. At four different percentages, RCA replaces the Natural Coarse Aggregate in some amounts. In the event that there are no replacements in the concrete, the SCC's hardened qualities are inferior to those of regular concrete. With an increase in recycled aggregate (RA) replacement ratios, SCC's strength declines.

**Alireza Khaloo et al. (2014)** Utilising four different fibre volume fractions and examining the mechanical properties of self-compacting concrete are the two main objectives of the study. It has been discovered that while the presence of steel fibre increases the self-compacting concrete's flexural toughness and splitting tensile strength as well as its ultimate load carrying capacity, the presence of fibres decreases its workability and compressive strength.

**Tayfun Uygunoğlu et al. (2014)** Investigation is conducted in the Self Compacting Concrete using recovered aggregate and marble debris from crushed concrete. A control series was created using various water-to-cement ratios and crushed lime stone aggregate. Then, recycled aggregate or marble waste are used to completely replace it. When using marble waste instead of limestone aggregate, the fresh and hardened properties revealed that the workability and segregation resistance had increased.

**Cristina Frazão et al (2015)** In this work, the mechanical characteristics and toughness of self-compacting concrete with steel fibre addition have been investigated. It was discovered that the steel fibre addition increases post peak resistance. Increased post-cracking flexural resistance and energy absorption are also benefits of steel fibre.

**GuangchengLong et al. (2015)** The mixing ratios have a significant impact on the self-compacting concrete's ecological impact index. The quantity of cement in concrete is replaced by the inclusion of mineral admixtures, which lowers the

ecological effect index. When compared to adding one or two mineral admixtures to the Self Compacting Concrete, the addition of three mineral admixtures significantly affects the ecological index.

**Rahmat Madandous et al. (2015)** The study uses two distinct coarse aggregates, four various proportions of steel fibre volume fraction, four different cement contents, and experimental work is done to determine the mechanical properties. It has been discovered that the properties are significantly influenced by the mixture's qualities and the amounts of steel fibre. Due to the addition of steel fibre, the workability of the self-compacting concrete is also decreased in this instance, but the compressive strength of self-compacting concrete with large aggregate size is slightly increased.

**Rui VascoSilva et al. (2016)** This essay provides a thorough literature assessment of the impact of recycled aggregate on the elastic modulus of concrete. It has been discovered that when the amount of recycled aggregate content increases, the modulus of elasticity decreases. For a typical concrete, a connection between the elastic modulus and compressive strength has been established.

**Yimmy FernandoSilva et al (2016)** The self-compacting concrete contained a mineral additive made from masonry waste and recycled concrete. After comparing the mechanical properties of the fresh and hardened materials, it was discovered that the inclusion of recycled coarse aggregate had reduced the mechanical properties because of the poor bond between the existing mortar and the aggregate.

**Małgorzata Pająk et al. (2017)** The compressive and flexural behaviour of the Self Compacting Concrete were determined using the combination of two distinct fibres of varying lengths. It has been found that hybrid steel fibres somewhat decrease passing ability but have no effect on workability. When hybrid steel fibre is utilised in low percentages, the flexural characteristics are raised.

**EhsanMohseni et al. (2017)** examined how the recycled coarse aggregate, steel fibres, and polypropylene fibres affected the self-compacting concrete's durability, mechanical characteristics, and microstructure. The mechanical qualities were

improved by the addition of both fibres. When compared to natural aggregate, recycled aggregate absorbs more water.

**StefaniaManzi et al. (2017)** A study of the creep and shrinkage of self-compacting concrete containing coarse and fine recycled concrete aggregate was conducted. It is possible to employ recycled concrete aggregates up to 40% by volume in self-compacting concrete, both coarse and fine. When recycled aggregate is used in self-compacting concrete, the mechanical properties also show promising outcomes. The inclusion of recycled aggregate has a greater impact on creep than shrinkage.

**GeorgeDimitriou et al. (2018)** This study examines the impact of recycled aggregate and a process for enhancing its qualities. It recommends a straightforward strategy: less mortar that is adhered, which will have less adverse effects and produce greater quality. Both durability and mechanical qualities have been greatly improved by the mineral admixtures.

**HuiGuo et al (2018)** Poor durability is a result of the declining recycling of aggregate. By employing pozzolanic materials either as a surface coating or combined with the concrete, the durability is increased. The characteristics of recycled aggregate and the resilience of concrete are improved by CO<sub>2</sub> treatment. The durability is inversely related to the amount of adhering mortar.

**Kho PinVerian et al. (2018)** The characteristics of the original aggregate and the state of the destroyed concrete affect the RCA's quality. Due to the presence of mortar on the surface of recycled aggregate, its properties differ from those of natural aggregate. This literature has discussed the many strategies to raise the calibre of concrete incorporating RCA.

**H. Mahir Mahmud et al. (2018)** SCC performance was assessed, and the impact of steel fibre addition on flexural behaviour and mechanical characteristics was looked at. When steel fibre is added to concrete, the workability and flowability are reduced, but the results are improved once the concrete has solidified. Compared to regular

concrete beams, Steel Fibre Self Compacting Concrete (SFSCC) beams are more ductile. Additionally, the crack's width has been considerably narrowed. Therefore, the SCC's flexural behaviour and capacity were enhanced by the addition of SF.

**GuoliangBalet al. (2020)** On a material level, a quantifiable relationship was shown between the amount of old attached mortar and RA performance. Because recycled aggregate (RA) contains old mortar, its properties differ from those of natural aggregate. Not only is it possible to increase the performance of RA by eliminating the current mortar from it, but it is also possible to do so by regulating the water-to-cement ratio and modifying the moisture content of the aggregate. The main cause of the RA's worse quality than the NA is the presence of adhering mortars.

**VíctorRevilla-Cuesta et al. (2020)** In this work, SCC with RCA and combination with other wastes are designed. On the basis of thorough designs that ultimately result in greater performance when compared to NA, the usage of RCA in SCC produces better results. Due to the high water absorption of RCA, the flowability of SCC is decreased; this problem can be resolved by adjusting the water content.

**ChangSun et al. (2020)** Determines whether it is feasible to prepare SCC using recycled waste concrete. Self-compacting concrete with recycled concrete was studied for both its fresh and hardened qualities. The mechanical characteristics and workability of SCC are declining, and the replacement % is likewise constrained. With an increase in recycled waste concrete, the high water absorption rate reduces the workability. With an increase in the rates of recycled materials from waste concrete, the mechanical qualities also drop.

**KazimTurk et al. (2021)** investigated how SCC's workability, mechanical characteristics, and flexural behaviour were affected by volume fraction and the mix of macro and micro fibres. Although the flexural toughness increases as the volume of the fibre fraction increases, the workability decreases. Superior dilatancy was also

noted. In every way, micro fibres performed better than macro fibre. Microfiber is preferred over macrofiber with a low aspect ratio for greater workability.

**BoWang et al. (2021)** gave a thorough analysis of the RA and RCA's history, manufacturing method, and material qualities, among other things. Additionally, a summary of the techniques for enhancing RAC mechanical properties and long-term performance is provided. This paper reviews both the difficulties in applying RAC and those difficulties as well. The RAC compressive properties are predicted using artificial intelligence techniques. .

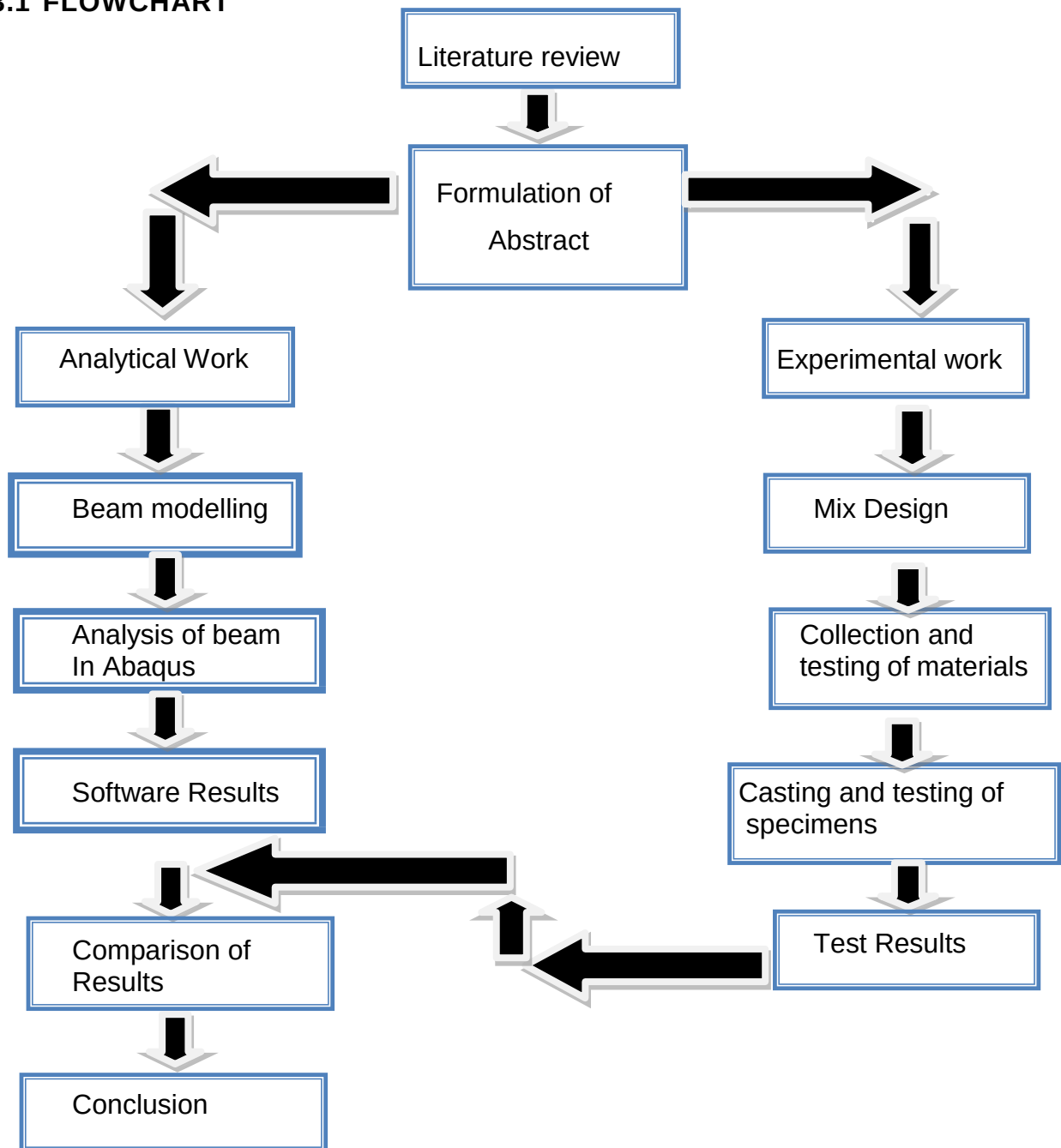
## **2.2 SUMMARY OF LITERATURE REVIEW**

- It was clear from a thorough reading of the SCC literature that SCC is a type of concrete that can compact with its own weight into every crevice of formwork. On SCC, there is a wealth of literature available.
- The use of recycled aggregates in concrete, particularly in SCC, is currently becoming more significant as a replacement for natural aggregates. The analysis of the literature revealed that, when utilised in the right replacement proportions, recycled aggregates can be used to dispose of waste concrete more effectively than natural aggregates. The effect of steel fibres on SCC was also researched. The Increase in RCA proportion affects various properties of Concrete hence the replacement percentage is limited and addition of Steel fibers enhances the Flexural strength in Concrete.
- By adding steel fibres to concrete, the tensile strength can be significantly increased, and the rapid brittle failure mode can be changed to a ductile mode.
- Steel fibres with hooked ends have a much greater impact on concrete's mechanical qualities than steel fibres with straight or crimped ends.

## CHAPTER 3

### 3.METHODOLOGY

#### 3.1 FLOWCHART



*Fig 3.1 Methodology Flowchart*

## CHAPTER 4

### MATERIAL AND EXPERIMENTAL INVESTIGATION

#### 4.1 MATERIALS

##### 4.1.1 Cement

In the current experiment, ordinary Portland cement of grade 43 that complies with IS: 8112 has been used. This is the cement that is used the most frequently for making general concrete.

##### 4.1.1.1 Physical Properties of Cement

1. **Fineness:** The cement's fineness test serves as a gauge for cement's particle size. By passing the cement through a regular sieve, the fineness of the cement is ascertained. The test uses a sieve with a typical mesh size of 90 microns. Cement is poured in a container with a known volume in the Blaine air permeability method. After that, the container is attached to a tool that gauges how quickly air moves through the sample. Based on how much air goes through the sample, the fineness of the cement is determined.
2. **Initial Setting Time:** The Initial Setting Time (IST) test is a common test procedure used to figure out how long it takes a cement paste to reach the initial set, or stiffness, level. The purpose of the test is to make sure that the cement being used in a building project has the right setting characteristics for the intended use. To carry out the IST test, a sample of cement is combined with water to create a paste, which is then put into a Vicat apparatus as per standard procedure. The Vicat device consists of a 300g, 1mm-diameter needle that is authorised to pierce the paste to a depth of 25mm. The initial setting time is defined as the moment the needle stops piercing the paste and the cement paste reaches a predetermined rigidity.

3. **Final Setting Time:** Another common test procedure used to gauge how long it takes a cement paste to attain its final set is the Final Setting Time test. The term "final set" describes the stage at which the cement paste has fully dried and is incapable of being moulded or shaped. The FST test is carried out by combining a sample of cement with water to create a paste, which is then put into a typical Vicat apparatus. A 1.13kg, 1.13mm-diameter needle that is comparable to the one used in the IST test is permitted to pierce the paste until it leaves no trace on the cement's surface. The final setting time is the moment when the needle stops leaving an impression.
  
4. **Specific gravity of cement:** Weigh the empty Le Chatelier flask and record its weight. Fill the flask with kerosene up to the 0 ml mark. Immerse the flask in water and allow it to reach a temperature of  $27 \pm 2^{\circ}\text{C}$ . Weigh the flask with the kerosene and record its weight. Add 64 g of cement to the flask using a funnel. Allow the flask to stand for 24 hours. Weigh the flask with the cement and kerosene and record its weight. Calculate the specific gravity of the cement using the formula:

Specific gravity =  $(\text{Weight of flask with cement and kerosene} - \text{Weight of flask with kerosene}) / (\text{Weight of flask with kerosene} - \text{Weight of empty flask})$

**Table 4.1 Physical Properties of Cement**

| S.NO | PHYSICAL PROPERTY                          | RESULT                    |
|------|--------------------------------------------|---------------------------|
| 1    | Initial Setting Time<br>Final Setting Time | 45 Minutes<br>255 Minutes |
| 2    | Standard Consistency                       | 32 %                      |
| 3    | Specific Gravity                           | 2.7                       |

#### **4.1.2 Fly ash**

Fly ash is quite similar to the volcanic ashes that were used to make hydraulic cement about 2300 years ago. Fly Ash, a mineral byproduct of burrowing wells, is collected for usage from the powder factories' exhaust faces. A clear architectural advantage provided by fly ash concrete is its better textural uniformity and finer detail.

Less water is required when fly ash is added to concrete. Utilising fly ash reduces the price of concrete because it is less expensive than cement.

**Table 4.2 Physical Properties of Fly Ash**

| S.NO | PHYSICAL PROPERTY | RESULT                 |
|------|-------------------|------------------------|
| 1    | Specific Gravity  | 2.2                    |
| 2    | Bulk Density      | 1047 Kg/m <sup>3</sup> |
| 3    | Moisture Content  | <0.3%                  |

#### **4.1.3 Fine Aggregate**

Good quality easily locally available M sand will be used. Generally fines are classified based on size, that is below 4.75mm is regarded as fine aggregate

##### **4.1.3.1. Physical Properties of Fine Aggregate**

1. Grain size distribution test: Take a sample of the fine aggregate weighs about 500 g. The sample should be placed on the top sieve, and the sieve shaker should be turned on for long enough to separate and collect all of the particles on their appropriate sieves. Weigh each sieve, then note the results. Calculate each sieve's passing and retention rates as follows:

Percentage passing = (Weight of sample retained on the sieve / Initial weight of the sample) x 100.

Percentage retained = 100 - Percentage passing

Plot the grain size distribution curve using the y-axis for the percentage passing and the x-axis for the sieve size.

2. Specific gravity test: The weight of a certain volume of material divided by the weight of a corresponding volume of water is known as specific gravity. The fine aggregate has a specific gravity of 2.46.
3. Water Absorption test: The water absorption test is used to determine the percentage of water absorption capacity of fine aggregate. In this test take a weight of 200 gm of fine aggregate. The Sample was tested for 24 hrs in full of water. After 24hrs the sample was taken from water and weighs it. Now find out the percentage of water content of Fine aggregate.

**Table 4.3 Physical Properties of Fine Aggregate**

| S.NO | PHYSICAL PROPERTY                  | RESULT                                           |
|------|------------------------------------|--------------------------------------------------|
| 1    | Specific Gravity                   | 2.46                                             |
| 2    | Bulk Density<br>Loose<br>Compacted | 1620 Kg/m <sup>3</sup><br>1820 Kg/m <sup>3</sup> |
| 3    | Water Absorption                   | 1.20                                             |

**Table 4.4 Sieve Analysis of M-Sand**

| S.No | Sieve size | Weight retained<br>Kg | Percentage of weight retained | Cumulative % of retained | Percentage Passing | PERMISSIBLE PERCENT AG E PASSING AS PER IS 383 |
|------|------------|-----------------------|-------------------------------|--------------------------|--------------------|------------------------------------------------|
| 1    | 4.75 mm    | 0.034                 | 0.0034                        | 0.034                    | 3.40               | 96.60                                          |
| 2    | 2.36 mm    | 0.028                 | 0.0028                        | 0.062                    | 6.20               | 93.80                                          |
| 3    | 1.18 mm    | 0.100                 | 0.0100                        | 0.162                    | 16.20              | 83.80                                          |
| 4    | 600 μ      | 0.400                 | 0.0400                        | 0.562                    | 56.20              | 43.80                                          |
| 5    | 300μ       | 0.310                 | 0.0310                        | 0.872                    | 87.20              | 12.80                                          |
| 6    | 150μ       | 0.088                 | 0.0088                        | 0.960                    | 96.00              | 4.00                                           |
| 7    | Pan        | 0.020                 | 0.0020                        | 0.980                    | 98.00              | 2.00                                           |

**4.1.4 Coarse Aggregate**

Crushed angular metal of 20mm size from local source will be used as Coarse aggregate. In General Coarse Aggregate used for concrete is blast out of quarries and crushed or broken to a size of less than 20mm. This we make use in Conventional concrete preparation. These aggregates are made use in SCC.

**4.1.4.1 Physical Properties of Coarse Aggregate**

1. Impact test: The coarse aggregate's impact value ranges from 15 to 30%. It gauges the degree to which the aggregate will withstand an abrupt shock or collision. By dividing the weight of the crushed material by the initial weight of the sample and multiplying by 100, the Impact Value, which is given as a

percentage, is computed. A stronger aggregate with more impact resistance has a lower Impact value.

2. Specific gravity test: The weight of a certain volume of material divided by the weight of a corresponding volume of water is known as specific gravity. The range of coarse aggregate's specific gravity is 2.5 to 3.0. It measures how dense a substance is in comparison to a standard reference material.
3. Sieve Analysis test: Take a sample of the coarse aggregate weighs about 500 g. The sample should be placed on the top sieve, and the sieve shaker should be turned on for long enough to separate and collect all of the particles on their appropriate sieves. Weigh each sieve, then note the results. Calculate each sieve's passing and retention rates as follows:

The percentage of material passing through each sieve is also calculated by subtracting the percentage of material retained on each sieve from 100. A graph is then plotted with the sieve size on the X-axis and the percentage passing through each sieve on the Y-axis. The particle size distribution of the coarse aggregate is determined by analyzing the graph.

4. Water Absorption test: The water absorption test is used to determine the percentage of water absorption capacity of coarse aggregate. In this test take a weight of 200 gm of coarse aggregate. The Sample was tested for 24 hrs in full of water. After 24hrs the sample was taken from water and weighs it. Now find out the percentage of water content of coarse aggregate

**Table 4.5 Sieve Analysis of Coarse Aggregate**

| Sieve size in (mm) | Wt. retained ( kgs) | Cumulative Wt retained ( kgs) | Wt. passing ( kgs) | Wt. passing (%) |
|--------------------|---------------------|-------------------------------|--------------------|-----------------|
| 25                 | 0                   | 0                             | 5                  | 100             |
| 20                 | 0.320               | 0.320                         | 4.68               | 93.6            |
| 16                 | 3.086               | 3.406                         | 1.594              | 31.88           |
| 12.5               | 1.342               | 4.748                         | 0.252              | 5.04            |
| 10                 | 0.162               | 4.91                          | 0.09               | 1.8             |
| 4.75               | 0.022               | 4.932                         | 0.068              | 1.36            |

**Table 4.6 Physical Properties of Coarse Aggregate**

| S.NO | PROPERTY         | RESULTS                |
|------|------------------|------------------------|
| 1    | Specific Gravity | 2.66                   |
| 2    | Bulk Density     | 1654 Kg/m <sup>3</sup> |
| 3    | Water Absorption | 1.0 %                  |

**4.1.5 Recycled Concrete Aggregate (RCA)**

The concrete laboratory's test specimens of concrete cubes and beams will be crushed to produce the RCA used in this investigation. The aggregates must be cleaned with water to eliminate any impurities, pre-soaked for 30 minutes, and then let to air dry before use.

**Table 4.7 Sieve Analysis of Recycled Concrete Aggregate**

| Sieve size (mm) | Wt. retained (kgs) | Cumulative Wt retained (kgs) | Wt. passing (kgs) | Wt. passing (%) |
|-----------------|--------------------|------------------------------|-------------------|-----------------|
| 25              | 0                  | 0                            | 5                 | 100             |
| 20              | 0.182              | 0.182                        | 4.818             | 96.36           |
| 16              | 1.142              | 1.324                        | 3.676             | 73.52           |
| 12.5            | 2.910              | 4.234                        | 0.766             | 15.32           |
| 10              | 0.624              | 4.858                        | 0.142             | 2.84            |
| 4.75            | 0.012              | 4.87                         | 0.13              | 2.60            |

**Table 4.8 Physical Properties of Recycled Concrete Aggregate**

| S.NO | PROPERTY         | RESULTS                |
|------|------------------|------------------------|
| 1    | Specific Gravity | 2.14                   |
| 2    | Bulk Density     | 1543 Kg/m <sup>3</sup> |
| 3    | Impact           | 13.82%                 |
| 4    | Water Absorption | 5.27 %                 |

**4.1.6 Steel Fibers**

Steel fibres with hooked ends were used in this investigation. These fibres have hooked ends and are constructed from cold-drawn wire with exceptional tensile strength. They are well suited for ground-supported slabs, jointless floors, and exterior road pavements since they are known to increase the ductility, toughness, and crack resistance of concrete.



**Fig 4.1 Steel Fibers**

**Table 4.9 Properties of hooked end steel fiber**

| S. No. | Properties   | Value   |
|--------|--------------|---------|
| 1      | 1. Diameter  | 0.60 mm |
| 2      | Length       | 30 mm   |
| 3      | Aspect ratio | 50      |

#### **4.1.7 Admixture**

Concrete admixtures are substances other than cement, water, and aggregates that are added to the concrete mixture. Concrete's working characteristics, strength, durability, setting time, and resistance to chemical and environmental attack are all improved by the use of additives. Concrete can use a variety of admixtures, including water-reducing, accelerating, retarding, air-entraining, and superplasticizing admixtures.

Superplasticizer based on polycarboxylate ether will be utilised. High range water reducers, commonly referred to as super plasticizers, are used to lower the water content of concrete. Master Glenium is the company's trade name. This admixture was a unique kind of modern generation created for the unique applications employed for high performance and high workability concrete. The characteristics of super plasticizer as attested by IS 9103:1999 (R2004) and ASTM C494- 2017 Type F standards

**Table 4.10 Properties of super plasticizer**

| Sl. No. | Properties       | Super plasticizer contents |
|---------|------------------|----------------------------|
| 1       | Colour           | Reddish brown liquid       |
| 2       | Specific gravity | 1.14                       |
| 3       | Solid contents   | 40%                        |
| 4       | pH               | 8.6                        |
| 5       | Relative density | 1.08 $\pm$ 0.02 at 25°C    |

#### **4.1.8 Water**

The water utilised for the experiment was determined to be of acceptable quality and to comply with all evaluated criteria, including pH value, hardness, sulphate, and chlorides, within the upper allowable limits. According to IS 456-2000, potable water is utilised for concrete mixing and curing.

## **4.2 MIX PROPORTIONS**

Mix Proportions for M30 have been developed based on IS 10262: 2019 and the quantities of materials required for the study have been tabulated below. The water cement ratio of 0.43 has been set constant throughout the work.

**Table 4.11 Combination of Steel Fiber And Recycled Aggregate**

| MIX          | STEEL FIBER (%) | RECYCLED AGGREGATE (%) |
|--------------|-----------------|------------------------|
| Conventional | -               | -                      |
| RCASF 1      | 0.50            | 25                     |
| RCASF 2      | 0.75            | 25                     |
| RCASF 3      | 1               | 25                     |

The different mixes mentioned in the table are:

1. Conventional - This is the mix without any steel fibers and Recycled Concrete Aggregate.
2. RCASF1 - This mix includes 0.50% of steel fibers by volume of concrete and the quantity of natural aggregate is partially Replaced by 25 %.
3. RCASF2 - This mix includes 0.75% of steel fibers by volume of concrete and the quantity of natural aggregate is partially Replaced by 25 %.
4. RCASF3 - This mix includes 1% of steel fibers by volume of concrete and the quantity of natural aggregate is partially Replaced by 25 %.

**Table 4.12 Mix Proportion of M30 Grade of Self Compacting Concrete**

| MIX          | CEMENT<br>(Kg/m3) | FLY<br>ASH<br>(Kg/m3 ) | WATER<br>(L/m3) | FA<br>(Kg/m3 ) | CA<br>(Kg/m3 ) | RCA<br>(Kg/m3 ) | SP   | SF    |
|--------------|-------------------|------------------------|-----------------|----------------|----------------|-----------------|------|-------|
| Conventional | 287               | 155                    | 190             | 975            | 737            | -               | 2.65 | -     |
| RCASF 1      | 287               | 155                    | 190             | 975            | 552.75         | 184.25          | 2.65 | 11.73 |
| RCASF 2      | 287               | 155                    | 190             | 975            | 552.75         | 184.25          | 2.65 | 17.6  |
| RCASF 3      | 287               | 155                    | 190             | 975            | 552.75         | 184.25          | 2.65 | 23.47 |

### 4.3 SAMPLES DETAILS AND CASTING PROCESS

The No. of Cubes, Cylinder, Prisms and RCC Beams to be casted are listed below for each combinations.

➤ SCC WITOUT SF AND RCA

Cubes 9 nos

Cylinder 6 nos

Prisms 3 nos

RCC BEAMS 1 nos

➤ SCC WITH 0.50% SF AND 25% RCA

Cubes 9 nos

Cylinder 6 nos

Prisms 3 nos

RC BEAM 1 nos

➤ SCC WITH 0.75% SF AND 25% RCA

Cubes 9 nos

Cylinder 6 nos

Prisms 3 nos

RCC BEAM 1 nos

➤ SCC WITH 1.0% SF AND 25% RCA

Cubes 9 nos

Cylinder 6 nos

Prisms 3 nos

RCC BEAM 1 nos



***Fig 4.2 Cube, cylinder and beam mould with oil applied and casting process***

## **4.4 EXPERIMENTAL INVESTIGATION**

### ***4.4.1 Test on Fresh Concrete (SCC)***

#### ***4.4.1.1 Slump flow test for SCC***

A common test procedure to assess the flowability of Self-Compacting Concrete (SCC) is the slump flow test. SCC is a self-leveling, extremely flowable concrete that can be poured into intricate designs without the use of vibration. The slump flow test evaluates SCC's workability and its capacity to flow freely and fill moulds without segregation or obstruction.

The test mould is set up on a flat surface, and its exterior has been lightly greased. The components are properly blended to achieve a homogeneous consistency before being processed into the SCC mix in accordance with the necessary design proportions.

The mix is poured into the mold in one continuous flow, without any consolidation or vibration. The SCC mix flows outwards and spreads horizontally due to its high fluidity. After the SCC has stopped flowing, the diameter of the spread

is measured in two perpendicular directions. The average of the two measurements is taken as the slump flow value of the SCC.

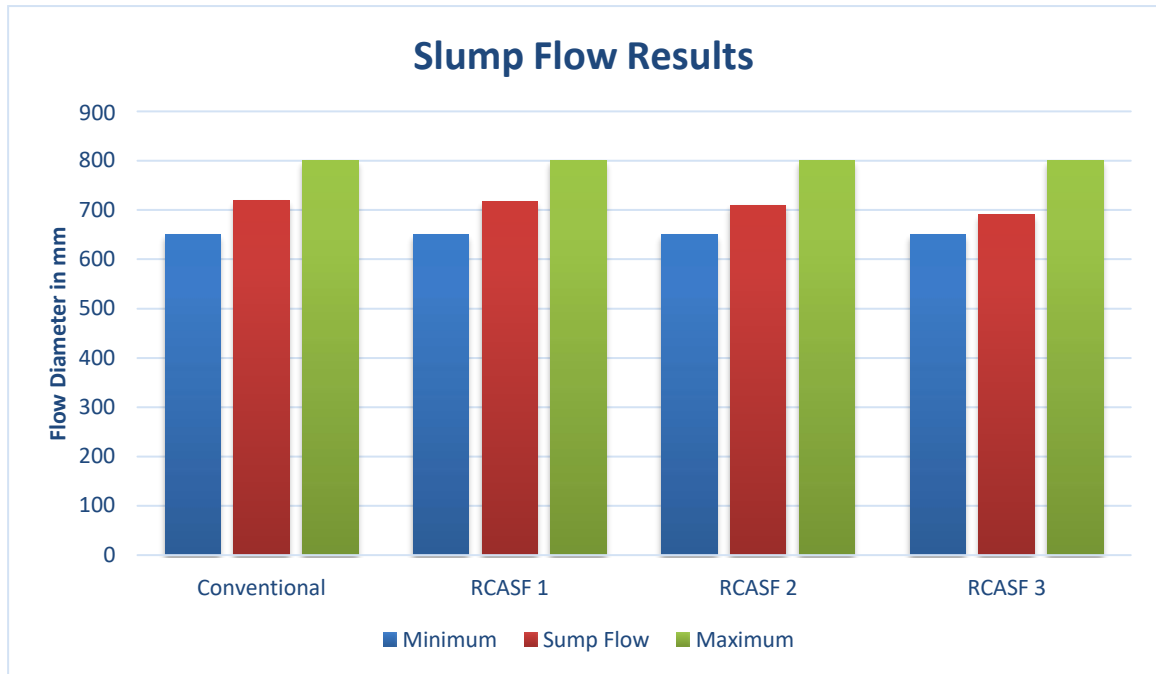


**Fig 4.3 Slump Flow**

The slump flow value indicates the workability and flowability of the SCC. A higher value indicates a more fluid SCC that is easier to place and compact, while a lower value indicates a stiffer SCC that may require vibration to ensure adequate compaction. The test can be used to optimize the mix design of SCC by adjusting the proportions of the ingredients to achieve the desired flowability and workability.

**Table 4.13 Slump Flow Results**

| S.NO | DESCRIPTION                     | CONVENTIONAL | RCASF<br>1 | RCASF2 | RCASF 3 |
|------|---------------------------------|--------------|------------|--------|---------|
| 1    | Slump Flow<br>(650 – 800<br>mm) | 720          | 718        | 710    | 690     |



***Fig 4.4 Slump Flow Results***

#### ***4.4.1.2 L – Box test***

The L Box test is a standard test method used to measure the passing ability and flowability of Self-Compacting Concrete (SCC). This test measures the ability of SCC to flow and fill a narrow section of the mold without segregation or blockage. It is also used to assess the filling ability of SCC in a two-layered structure.



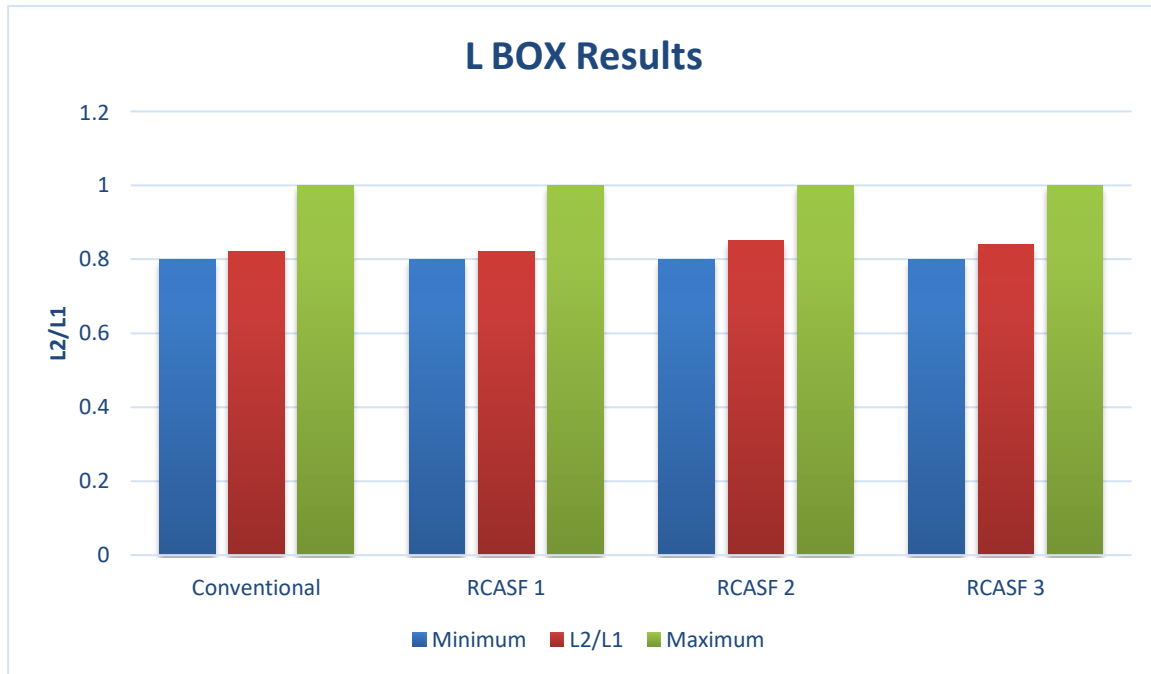
***Fig 4.5 L – Box Apparatus***

The L Box apparatus is prepared, which consists of two horizontal sections connected by a vertical section. The mold is first filled with a layer of concrete of a certain height. The concrete is allowed to settle and then the second layer of concrete is added. The concrete is allowed to settle for a period of time.

The mold is then lifted and tilted to a 90-degree angle, and the time taken for the concrete to flow and fill the second compartment of the L Box apparatus is measured. The height of the concrete is also measured in each compartment of the L Box apparatus to determine any segregation. The L Box test provides information on the filling ability of SCC in a narrow section and can be used to optimize the mix design of SCC. A good SCC mix should flow freely and fill the narrow section of the L Box apparatus without any blockage or segregation. The test can be used to determine the suitability of SCC for use in structures with narrow sections and to ensure the uniformity of SCC in multi-layered structures.

**Table 4.14 L Box Results**

| <b>S.NO</b> | <b>DESCRIPTION</b> | <b>CONVENTIONAL</b> | <b>RCASF<br/>1</b> | <b>RCASF2</b> | <b>RCASF 3</b> |
|-------------|--------------------|---------------------|--------------------|---------------|----------------|
| 1           | L Box (0.80 – 1.0) | 0.85                | 0.82               | 0.85          | 0.84           |



**Fig 4.6 L Box Results**

#### 4.4.1.3 V – Funnel Test

The V Funnel test is a standard test method used to measure the flowability and passing ability of Self-Compacting Concrete (SCC). This test measures the ability of SCC to flow and fill a conical mold without segregation or blockage.

The V Funnel apparatus is prepared, which consists of a funnel with a 60-degree angle and a cylindrical mold with a 100 mm diameter and 200 mm height. The mold is placed on a level surface, and a piece of paper is placed at the bottom of the mold to prevent any loss of material during the test. The SCC mix is prepared according to the required design proportions and is poured into the funnel in one continuous flow, without any consolidation or vibration. The SCC mix flows through the funnel and into the mold, and the time taken for the SCC to pass through the funnel is measured. The height of the SCC in the mold is measured, and any segregation or bleeding is noted.

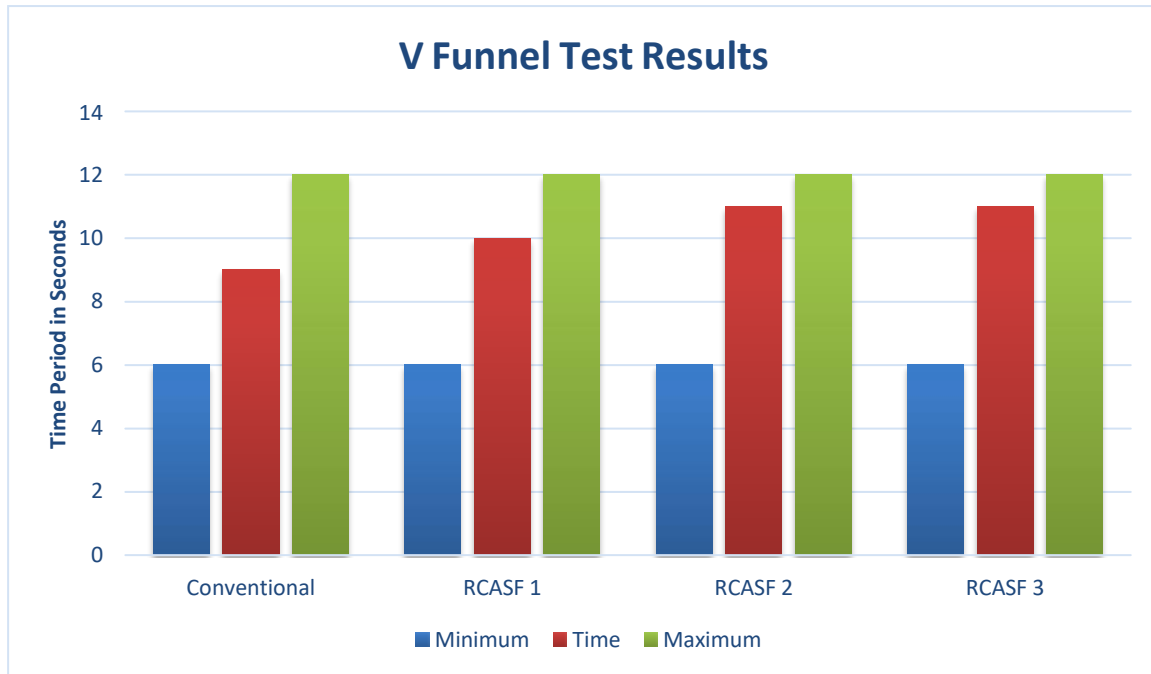


**Fig 4.7 V – Funnel Apparatus**

The V Funnel test provides information on the flowability and passing ability of SCC, and it can be used to optimize the mix design of SCC by adjusting the proportions of the ingredients to achieve the desired flowability and workability. A good SCC mix should flow freely through the funnel and fill the mold without any blockage or segregation. The test can also be used to determine the suitability of SCC for use in structures with tight reinforcement or narrow sections

**Table 4.15 V Funnel Results**

| S.NO | DESCRIPTION                | CONVENTIONAL | RCASF<br>1 | RCASF2 | RCASF 3 |
|------|----------------------------|--------------|------------|--------|---------|
| 1    | V Funnel ( 6 – 12 seconds) | 9            | 10         | 11     | 11      |



**Fig 4.8 V Funnel Results**

#### **4.4.2 Tests on the Hardened Concrete (SCC)**

##### **4.4.2.1 Compression Strength for cubes**

To ascertain the compressive strength of concrete, compression testing on concrete cubes is a typical and popular technique. Typically, 150 mm x 150 mm x 150 mm concrete cubes are cast.

To prevent voids, the concrete is poured into the mould and tamped with. The test specimens are placed in water for cure once the mould has been removed after 24 hours. For a predetermined amount of time, usually 28 days, it is cured in a lab under carefully monitored conditions. After being taken out of the curing tank, the cubes are left to air dry. The cubes are set up in a compression testing device, which exerts a compressive load on it until it breaks. Up until the cube fails or achieves its maximum load capacity, the load is delivered at a consistent rate, typically 0.7 MPa/s.

By dividing the maximum load by the cube's cross-sectional area, the concrete's compressive strength is computed. The maximum load capacity is noted.



**Fig 4.9 Compression Testing Machine**

A dependable and standardised approach to assess the compressive strength of concrete is compression testing using concrete cubes. The test findings are used to determine whether concrete is strong enough to meet the criteria and to assess its quality and durability in various applications. We may find any problems with the concrete and take corrective action to make sure the construction is secure and long-lasting by doing compression tests on concrete cubes.

**Table 4.16 Average compressive strength of cube at 7, 14 and 28 days**

| S.NO | MIX          | AVERAGE COMPRESSIVE STRENGTH IN<br>N/mm <sup>2</sup> |         |         |
|------|--------------|------------------------------------------------------|---------|---------|
|      |              | 7 days                                               | 14 days | 28 days |
| 1    | Conventional | 20.97                                                | 28.84   | 37.45   |
| 2    | RCASF 1      | 17.77                                                | 24.43   | 31.73   |
| 3    | RCASF 2      | 17.61                                                | 24.22   | 31.45   |
| 4    | RCASF 3      | 18.00                                                | 24.75   | 32.15   |

#### 4.4.2.2 Split Tensile strength for Cylinder

SCC cylinder specimens are cast using the proper techniques, then they must cure for the required amount of time in order to pass the test. The testing device's lower platen receives the cured cylinder specimen. The specimen is fastened to the upper platen while being centeredly aligned with the loading assembly's axis. The cylinder specimen is subjected to an axial compressive load at a constant rate of loading until the specimen ruptures. During the test, a load cell linked to the testing apparatus measures the load placed on the cylinder specimen. Prior to the rupture, the cylinder specimen was subjected to a maximum load of using the following formula, the split tensile strength of the SCC cylinder specimen is determined:

$$\text{Split Tensile Strength (N/mm}^2\text{)} = (2P)/(\pi DL)$$

Where, P = Maximum load applied on the cylinder specimen just before the rupture (in Newtons)

D = Diameter of the cylinder specimen (in mm)

L = Length of the cylinder specimen (in mm)



**Fig 4.10 Split tensile test Apparatus**

**Table 4.17 Average Split Tensile strength of Cylinder at 7, 14 and 28 days**

| S.NO | MIX          | AVERAGE SPLIT TENSILE STRENGTH IN<br>N/mm <sup>2</sup> |         |         |
|------|--------------|--------------------------------------------------------|---------|---------|
|      |              | 7 days                                                 | 14 days | 28 days |
| 1    | Conventional | 1.66                                                   | 2.28    | 2.96    |
| 2    | RCASF 1      | 1.59                                                   | 2.19    | 2.85    |
| 3    | RCASF 2      | 1.63                                                   | 2.24    | 2.92    |
| 4    | RCASF 3      | 1.56                                                   | 2.14    | 2.79    |

#### *4.4.2.3 Flexural strength for prisms*

Flexural testing, also known as the three-point bend test, is a method used to determine the flexural strength of concrete prisms. This test is important in evaluating the strength and quality of concrete, especially in construction projects where the concrete will be subjected to bending forces.

Concrete prisms should be cast in molds of specific dimensions and cured under controlled conditions until they reach the required age for testing. The standard size of the prism used in the test is 100mm x 100mm x 500mm. The prism should be placed horizontally on two supports, with a third support placed on top of the prism in the center.

The distance between the two lower supports should be such that the span length between the two supports is 400mm. The prism should be properly aligned with the loading device so that the center of the prism is directly under the center of the loading device. Apply a load to the center of the prism at a rate specified in the testing standard. The load should be applied until the prism breaks or until the specified maximum load is reached. Record the maximum load that the prism can withstand before it breaks, as well as the dimensions of the prism. Calculate the flexural strength of the prism using the recorded data.



**Fig 4.11 Flexural test apparatus**

**Table 4.18 Average Flexural strength of prisms at 28 days**

| S.NO | MIX          | AVERAGE FLEXURAL STRENGTH FOR 28 DAYS N/mm <sup>2</sup> |
|------|--------------|---------------------------------------------------------|
| 1    | Conventional | 4.93                                                    |
| 2    | RCASF 1      | 4.41                                                    |
| 3    | RCASF 2      | 5.12                                                    |
| 4    | RCASF 3      | 5.46                                                    |

#### 4.4.2.4 Flexural Behaviour of RCC Beam

The capacity of a beam to withstand bending and tensile pressures is what determines the beam's flexural strength. Using a device known as a loading frame, a flexural strength test can be used to analyse the behaviour of RC beams.

The loading frame is made up of two supports that are spaced apart in a fixed way to support the beam and a loading mechanism that puts pressure on the beam's centre. Once the beam is mounted on the supports, the loading system gradually applies a load to the centre of the beam until it breaks.

Under the applied load during the test, the beam deflects or bends downward. The beam deforms more and more as the load is increased until it achieves its maximum load-carrying capacity. The beam now begins to crack, and the deflection quickly rises until the beam breaks.

At several points during the test, the deflection and load are recorded. These numbers are then utilised to determine the beam's flexural strength. By examining

the tension and strain in the beam at the point of failure, the flexural strength is identified. Equations that are derived from the geometry of the beam and the applied load can be used to determine the stress and strain.

A RCC beam's flexural behaviour can be influenced by a number of variables, including as the beam's dimensions, the kind and quantity of reinforcement employed, the standard of the concrete, and the curing circumstances. Designing and building reliable structures requires an understanding of the flexural behaviour of RC beams. In order to design and build reliable buildings, it is imperative to comprehend the flexural behaviour of RC beams.



***Fig 4.12 Casted Beam***



***Fig 4.13 Beam Curing Process***



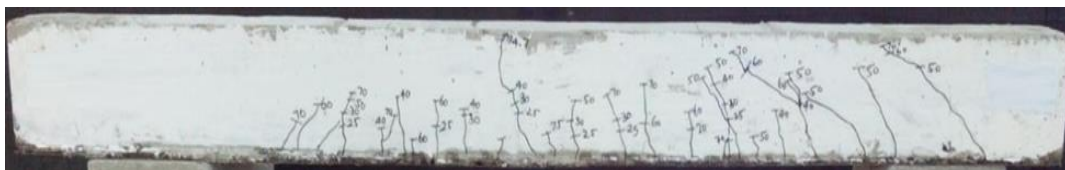
***Fig 4.14 Loading Frame Setup with Conventional Beam***



***Fig 4.15 RCASF 1 Beam***



***Fig 4.16 RCASF 2 Beam***



***Fig 4.17 RCASF 3 Beam***

**Table 4.19 Experimental Deflection Results for RCC beam specimens**

| Sl.No | Load (KN) | Displacement in 'mm' |         |         |         |
|-------|-----------|----------------------|---------|---------|---------|
|       |           | Conventional         | RCASF 1 | RCASF 2 | RCASF 3 |
| 1     | 10        | 0.25                 | 0.25    | 0.20    | 0.15    |
| 2     | 20        | 0.33                 | 0.27    | 0.30    | 0.27    |
| 3     | 30        | 0.52                 | 0.51    | 0.44    | 0.45    |
| 4     | 40        | 0.77                 | 0.68    | 0.71    | 0.69    |
| 5     | 50        | 1.02                 | 0.95    | 0.96    | 0.9     |
| 6     | 60        | 1.34                 | 1.24    | 1.27    | 1.2     |
| 7     | 70        | 1.76                 | 1.63    | 1.55    | 1.62    |
| 8     | 80        | 2.12                 | 2.15    | 2.00    | 1.96    |
| 9     | 90        | 2.51                 | 2.25    | 2.25    | 2.17    |
| 10    | 100       | 2.75                 | 2.60    | 2.59    | 2.38    |

## CHAPTER 5 ANALYTICAL INVESTIGATION

### 5.1 ABAQUS

Abaqus is a commercial finite element analysis (FEA) software package developed by Dassault Systèmes. It is widely used in the engineering and research communities to simulate the behavior of structures and materials under various loading conditions.

Abaqus offers a comprehensive set of features and capabilities for modeling, analyzing, and visualizing complex simulations, including static and dynamic structural analysis, heat transfer analysis, fluid-structure interaction, and electromagnetic analysis. It also includes a powerful scripting language for automating repetitive tasks and customizing the software to specific needs.

The software is commonly used in industries such as aerospace, automotive, civil engineering, and biomechanics, among others. Abaqus is known for its robustness and accuracy in simulating real-world problems, and it has a large user community and extensive documentation and support resources.

#### ***5.1.1 Advantages of Abaqus***

Abaqus is a powerful finite element analysis software package that has several advantages, including:

- **Versatility:** Abaqus can handle a wide range of analysis types, including linear and nonlinear static and dynamic analyses, thermal analyses, and fluid-structure interaction analyses.
- **Robustness:** Abaqus has been extensively validated and tested, and is known for its accuracy and robustness in solving complex engineering problems.
- **User-friendly interface:** Abaqus has a user-friendly interface that makes it easy to set up and run complex simulations.

- Customizability: Abaqus is highly customizable, allowing users to create their own material models, user subroutines, and other custom features.
- Large community and support: Abaqus has a large community of users and developers who provide support and share knowledge through forums, webinars, and other resources.
- Integration with other software: Abaqus can be easily integrated with other software packages, such as CAD and CAM software, to streamline the design and analysis process.
- Scalability: Abaqus can handle problems of varying size and complexity, from small-scale laboratory tests to large-scale industrial applications.

Overall, Abaqus is a powerful and versatile software package that can help engineers and researchers solve a wide range of complex engineering problems.

### ***5.1.2 Disadvantages of Abaqus***

Abaqus is a popular finite element analysis (FEA) software used for simulating the behavior of structures and components under various loading conditions. While Abaqus has many advantages, there are also some potential disadvantages to using it, including:

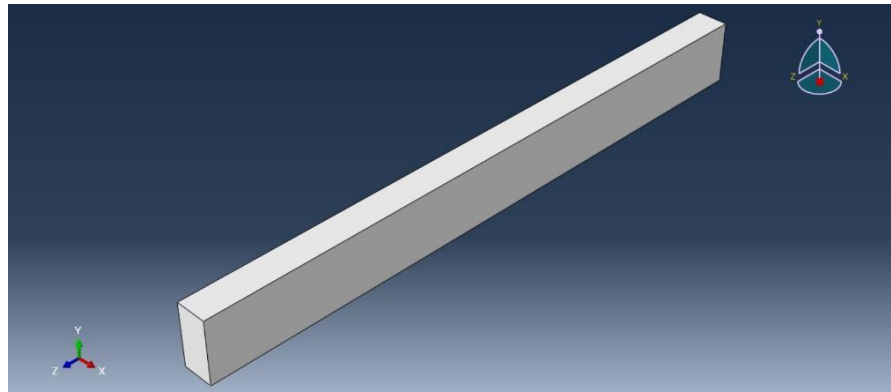
- Hardware requirements: Abaqus requires a powerful computer system with significant computational resources, including RAM, CPU, and GPU, which can be expensive to obtain and maintain.
- Steep learning curve: Abaqus is a powerful and complex software suite that requires extensive training and expertise to use effectively. Users must be familiar with both the software and the underlying engineering principles to use Abaqus to its full potential.
- Expensive licensing: Abaqus is a commercial software package that requires a license to use, and the cost can be high, especially for smaller businesses or individual users.

- Limited technical support: While Abaqus offers technical support to its users, it can be limited and may not be able to address all user concerns.
- Limited customization: Abaqus offers limited customization options, which may be problematic for users who require specialized functionality or features that are not available in the standard package.
- Time-consuming: The simulation process in Abaqus can be time-consuming, especially for large and complex models, which can limit the efficiency and productivity of users.

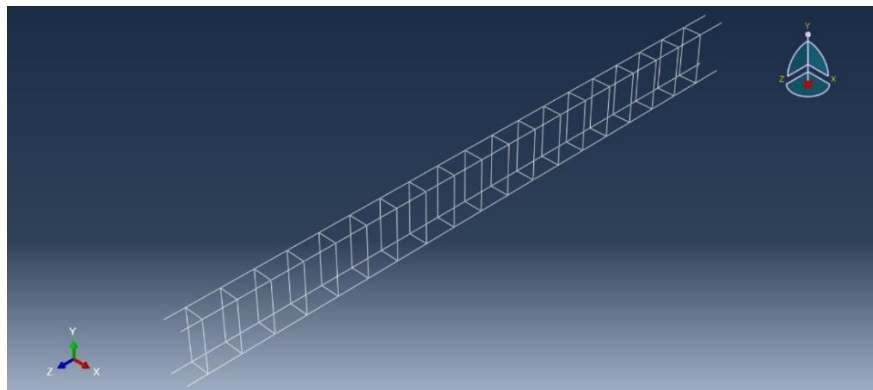
### **5.1.3 Application of Abaqus**

- Structural Analysis: Abaqus can be used to simulate and analyze the behavior of structures such as bridges, buildings, and aircraft under various loading conditions. It can also be used for structural optimization and design.
- Geotechnical Analysis: Abaqus can be used for simulating geotechnical problems such as soil-structure interaction, slope stability, and foundation design.
- Fluid-Structure Interaction: Abaqus can be used to simulate the interaction between fluids and structures, such as fluid flow through pipes and channels.
- Material Science: Abaqus can be used for simulating and analyzing the behavior of materials under various loading conditions, such as stress and strain analysis, fatigue analysis, and fracture mechanics.
- Manufacturing and Assembly: Abaqus can be used to simulate and optimize manufacturing and assembly processes, such as welding, casting, and forming.
- Life Sciences: Abaqus can be used for biomedical applications such as simulating the behavior of prosthetic implants and analyzing the mechanics of bones and other biological tissues.

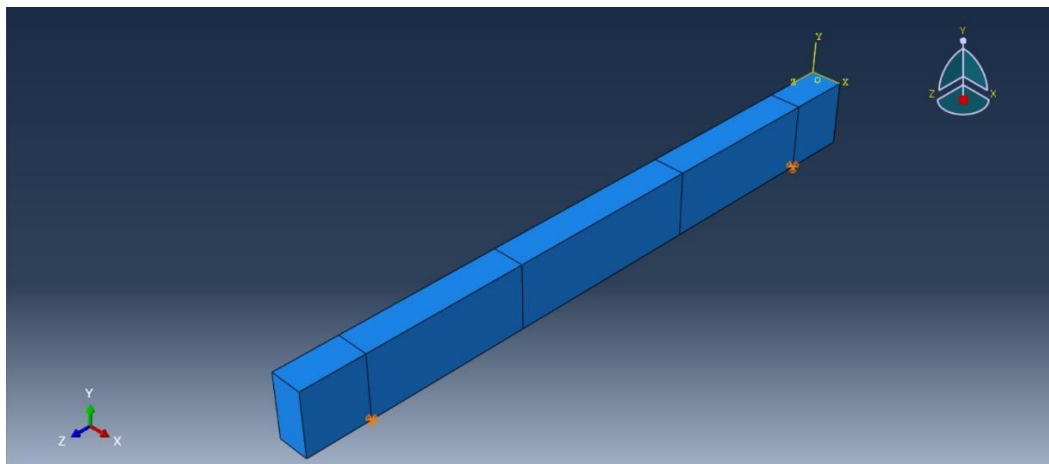
## 5.2 ANALYSIS USING ABAQUS



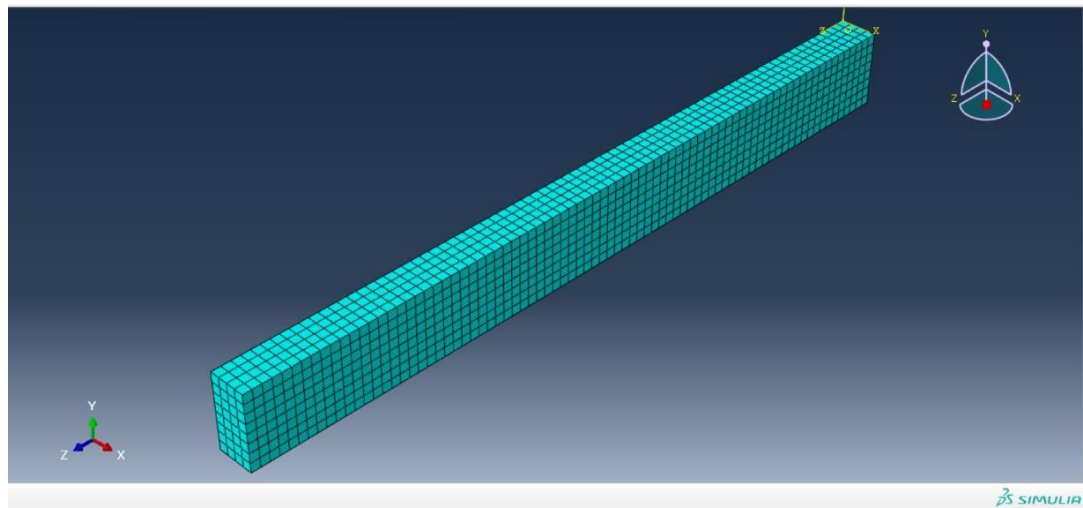
***Fig 5.1 Beam Model***



***Fig 5.2 Steel Reinforcement***

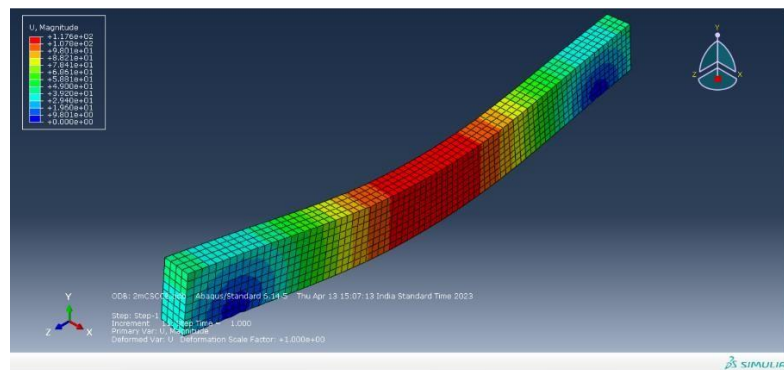


***Fig 5.3 Beam Boundary Condition***

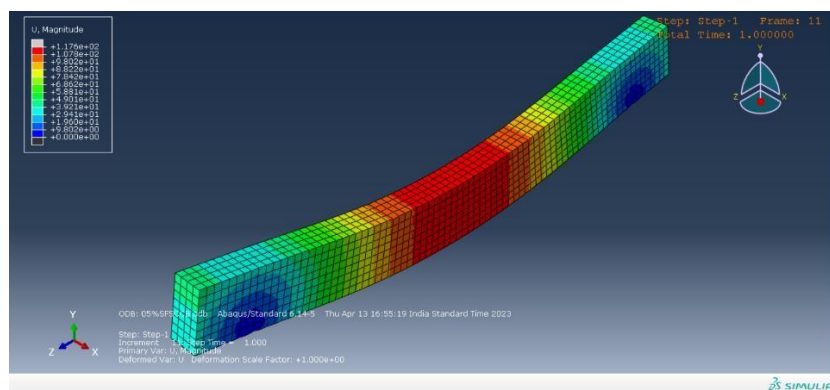


**Fig 5.4 Meshing of Beam**

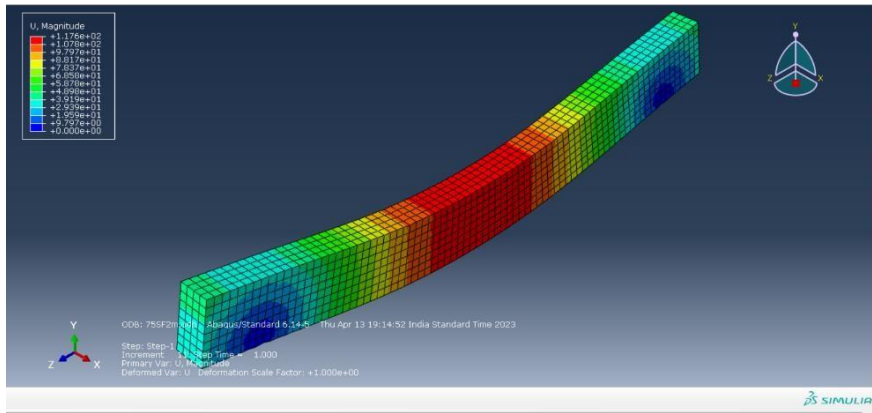
### 5.3 RESULTS FROM ABAQUS



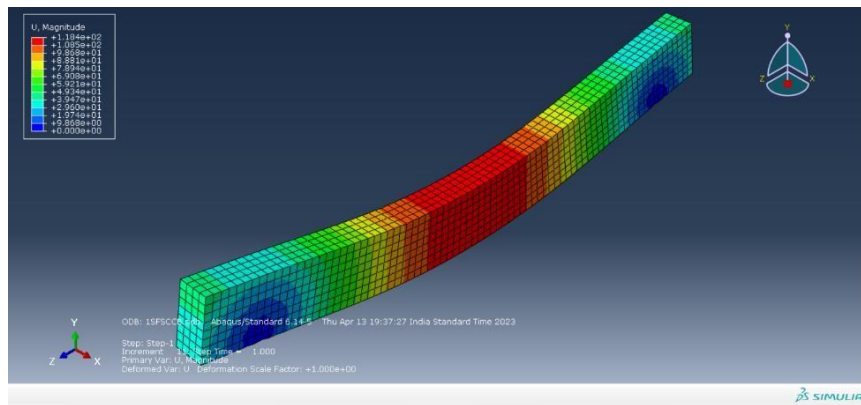
**Fig 5.5 Conventional Beam**



**Fig 5.6 RCASF 1 Beam**



**Fig 5.7 RCASF 2 Beam**



**Fig 5.8 RCASF 3 Beam**

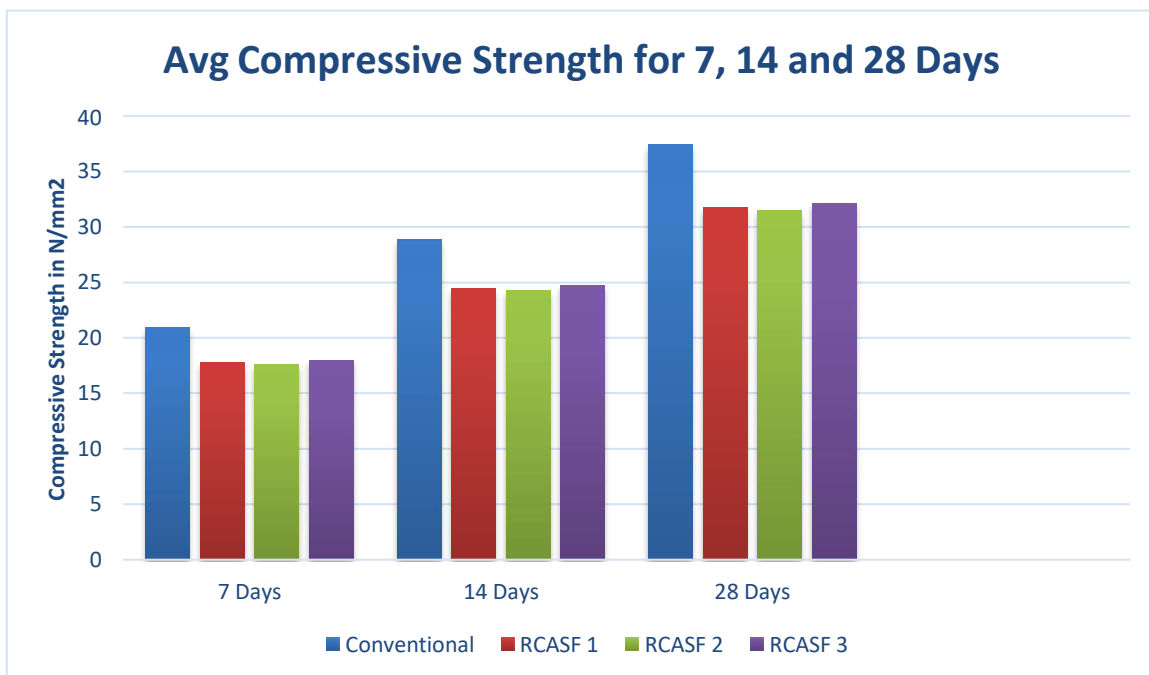
**Table 5.1 Analytical Deflection Results for RCC beam specimens**

| Sl.No | Load (KN) | Displacement in 'mm' |         |         |         |
|-------|-----------|----------------------|---------|---------|---------|
|       |           | Conventional         | RCASF 1 | RCASF 2 | RCASF 3 |
| 1     | 10        | 0.23                 | 0.25    | 0.23    | 0.20    |
| 2     | 20        | 0.52                 | 0.5     | 0.44    | 0.46    |
| 3     | 30        | 0.8                  | 0.75    | 0.70    | 0.66    |
| 4     | 40        | 1.02                 | 1.03    | 0.91    | 0.87    |
| 5     | 50        | 1.28                 | 1.22    | 1.13    | 1.06    |
| 6     | 60        | 1.61                 | 1.54    | 1.35    | 1.30    |
| 7     | 70        | 1.82                 | 1.72    | 1.60    | 1.56    |
| 8     | 80        | 2.09                 | 2.03    | 1.86    | 1.76    |
| 9     | 90        | 2.37                 | 2.25    | 2.05    | 2.04    |
| 10    | 100       | 2.67                 | 2.52    | 2.34    | 2.28    |

## CHAPTER 6 RESULTS AND DISCUSSION

The chapter looks into the effects of adding various amounts of steel fibres (0.5%, 0.75%, and 1.0%) and replacing 25% of conventional coarse aggregate with Recycled Concrete aggregate in concrete. The characteristics of the concrete specimens and beams being studied include their compressive strength, split-tensile strength, and deflection behaviour.

### 6.1 COMPRESSION TEST RESULTS

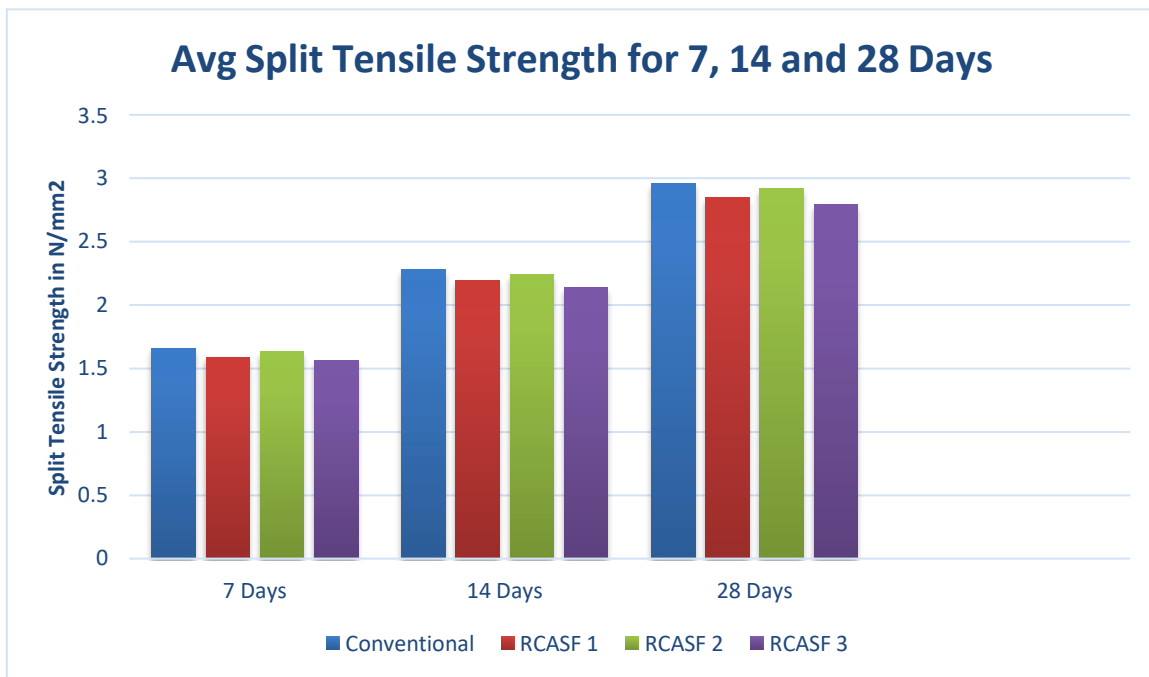


***Fig 6.1 Average compressive strength 7, 14 and 28 days***

According to the graph, RCASF 2 consistently had the lowest average compressive strength at 7 days, 14 days, and 28 days, whereas Conventional mix consistently had the strongest.

Compressive strength for RCASF1, RCASF2, and RCASF3 increases marginally from all ages as the percentage of steel fibres rises from 0.5% to 1%. Among the Replacement mixes RCASF 3 shows better results.

## 6.2 SPLIT TENSILE TEST RESULTS



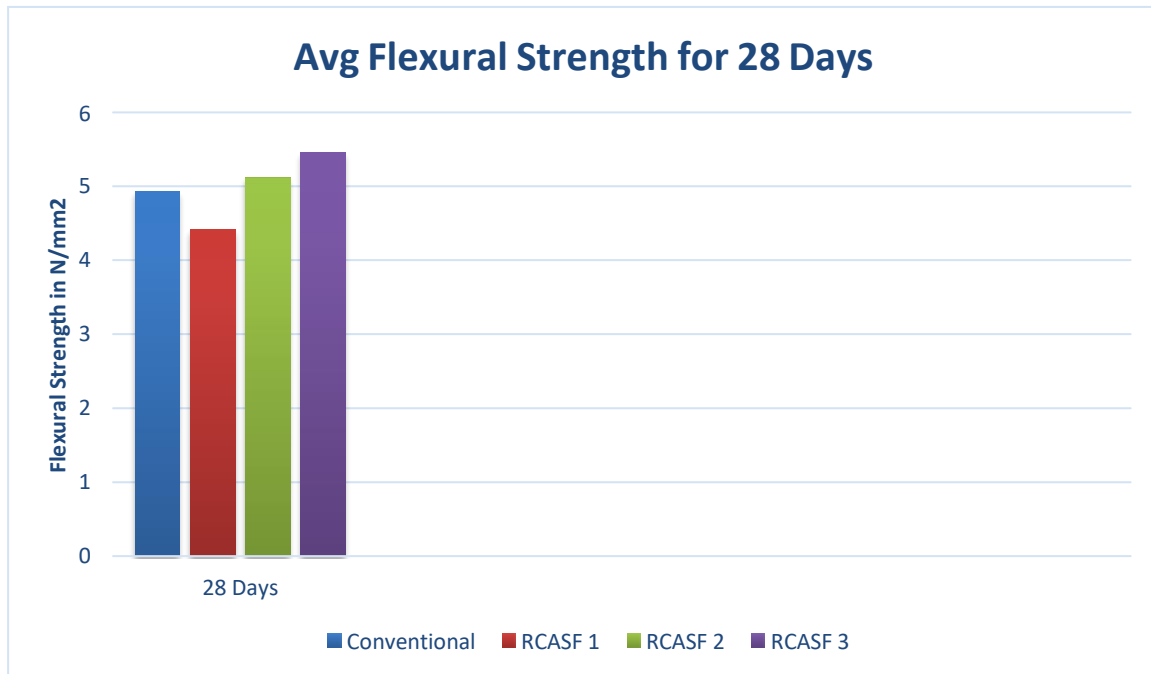
***Fig 6.2 Average Split Tensile strength 7, 14 and 28 days***

The graph demonstrates that for all three time periods, the average split tensile strength was highest for the conventional mix and lowest for RCASF 3.

At 7 days, the RCASF 3 had an average split tensile strength of 1.56 N/mm<sup>2</sup>, compared to 1.66 N/mm<sup>2</sup> for the conventional mix. At 14 days, the RCASF 3 had an average of 2.14 N/mm<sup>2</sup>, compared to 2.28 N/mm<sup>2</sup> for the conventional mix. At 28 days, the RCASF 3 had an average of 2.79 N/mm<sup>2</sup>, compared to 2.96 N/mm<sup>2</sup> for the conventional mix.

According to the graph, the conventional mix may be able to withstand cracking under tensile stress better than the RCASF mixtures.

### 6.3 FLEXURAL TEST RESULTS



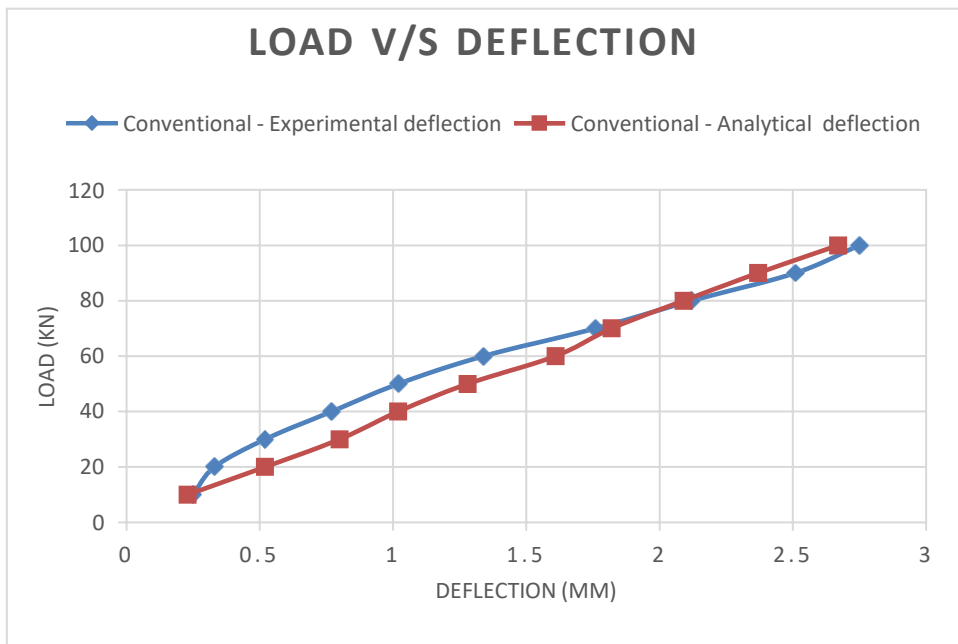
***Fig 6.3 Average Flexural strength at 28 days***

According to the graph, RCASF 3 has the highest average flexural strength, measuring 5.46 N/mm<sup>2</sup>. This indicates that compared to the other mixtures, this blend is more resistant to bending when subjected to a weight.

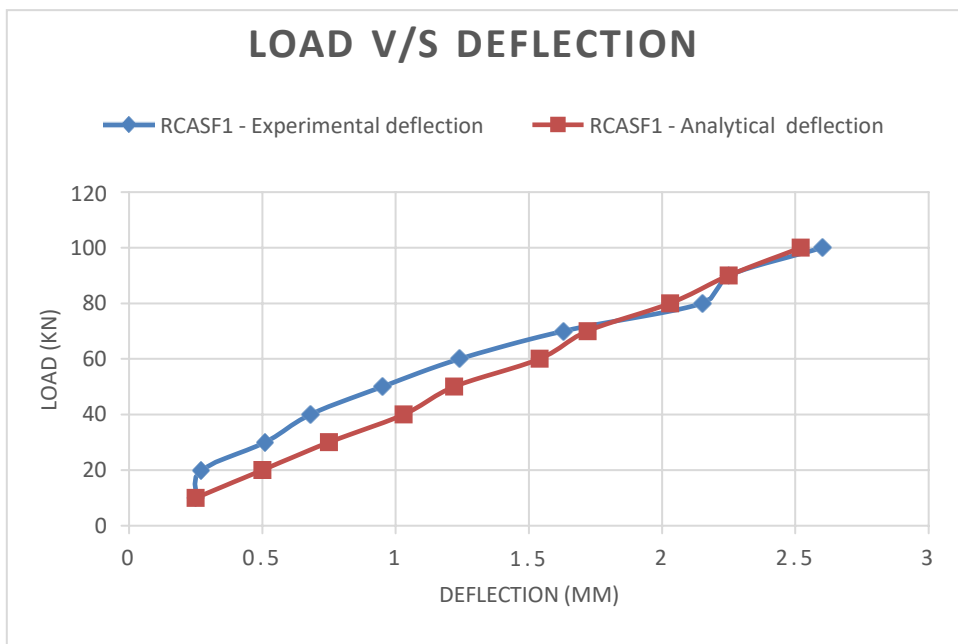
While RCASF 2 had an average flexural strength of 5.12 N/mm<sup>2</sup>, the conventional mix had a flexural strength of 4.93 N/mm<sup>2</sup>, which is marginally less. With an average flexural strength of 4.41 N/mm<sup>2</sup>, RCASF 1 had the lowest flexural strength of the four mixtures.

According to the graph, RCASF 3 might be the best option for applications where flexural strength is crucial. However, it is important to consider other factors as well when choosing a concrete mix, such as the specific requirements of the project and the availability and cost of the materials.

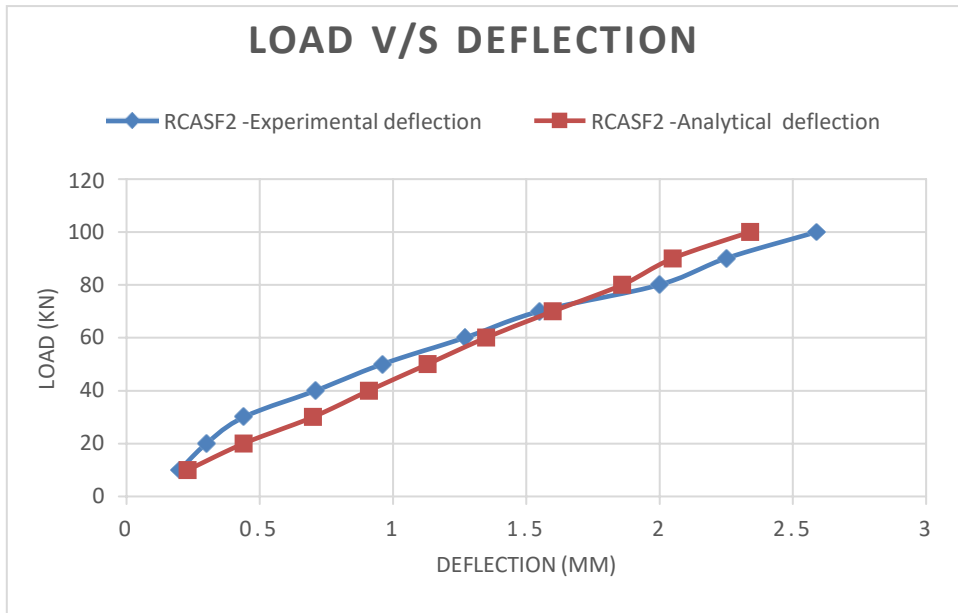
## 6.4 DISPLACEMENT FOR FOUR MODELS



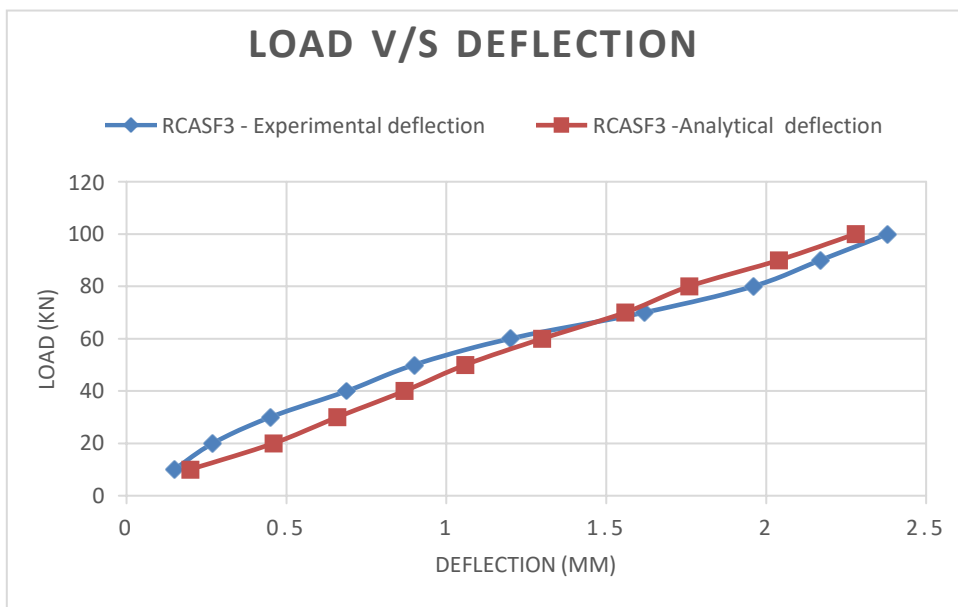
**Fig 6.4 The comparison between load vs deflection for experimental and Analytical results of Conventional Beam**



**Fig 6.5 The comparison between load vs deflection for experimental and Analytical results of RCASF1 Beam**



***Fig 6.6 The comparison between load vs deflection for experimental and Analytical results of RCASF2 Beam***



***Fig 6.7 The comparison between load vs deflection for experimental and Analytical results of RCASF3 Beam***

Both experimental and analytical findings were used to compare the deflection values of four different beam types with variable percentages. Beam models were generated in the Abaqus Software, the necessary properties, boundary conditions, loading, meshing, etc. were provided, and results were obtained. With Deflection (mm) in the X axis and Load (KN) in the Y axis, these results have been compared in the graph. In both experimental and analytical comparisons to other beams, the conventional beam exhibits greater deflection. Similar to other beams, the RCASF 3 mix beam exhibits less deflection in both experimental and analytical scenarios. Comparing the software's analytical results to experimental deflection, all of the beams' values are lower.

## **CHAPTER 7**

### **SUMMARY AND CONCLUSION**

#### **7.1 SUMMARY**

From various literature reviewed related to the replacement of recycled Concrete aggregate as an alternate for natural coarse is an efficient way to get rid of surplus concrete waste when used in the appropriate replacement amounts and also the influence of steel fibers on SCC was studied.

The Physical Properties of all the materials used in the concrete has been tested. The properties of Fresh and Hardened SCC were also investigated. In Abaqus Software models beams were developed. The experimental results were compared with the Finite Element software results.

#### **7.2 CONCLUSION**

In this study, the flexural behaviour of self-compacting concrete was tested using steel fibres at four different percentages (0.5%, 0.5%, 0.75%, and 10%). Along with the steel fibres, recycled concrete aggregates at a 25% addition were also used as a partial replacement for coarse aggregate.

Steel fibres with hooked ends have a much greater impact on concrete's mechanical qualities than steel fibres with straight or crimped ends.

The addition of steel fibres improves the concrete's flexural strength, and the increase in RCA content has an impact on several properties of concrete, limiting the replacement percentage.

According to the material analysis, recycled concrete aggregate has a significantly higher water absorption rate than natural coarse aggregate. The properties of fresh concrete in terms of workability are impacted by the addition of steel fibres.

Of the four mixes, the conventional mix has the highest compressive strength. RCASF 3 mix is one of the Replacement mixes with superior outcomes. Comparing the RCASF 3 Mix to conventional M30 grade concrete, the compressive strength is decreased 14%.

The Conventional mix and RCASF 2 mix gives more or less same results. There is only slight difference in the split tensile results.

Of the four mixes, RCASF 3 mix has the highest flexural strength. When compared to the conventional mix, the load carrying capacity is high. In Prisms, compared to conventional M30 grade concrete, it results in an 11% increase in flexural strength. The deflection in RCC beam was also lower than in conventional mix and various replacement mixes. Better outcomes are obtained with a higher percentage of steel fibre.

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