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# EFFECT OF STEEL FIBRES ON SELF- COMPACTING CONCRETE WITH PARTIAL REPLACEMENT OF FLY ASH WITH OPC 53 COMPACTING CEMENT

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## ABSTRACT

This study investigates the mechanical properties of fiber-reinforced self-compacting concrete (SCC) with partial replacement of Ordinary Portland Cement (OPC) 53 with fly ash. Fly ash was substituted at levels of 0%, 15%, 20%, and 25% to examine strength variations. Hooked steel fibers, with a diameter of 0.4mm and length of 30mm (aspect ratio of 75), were added at 0.75% by weight to improve the concrete's performance in terms of bending, impact, and compressive strength. The fresh-state properties of SCC, including filling ability, passing ability, and segregation resistance, were evaluated using slump, V-funnel, and L-box tests. Hardened concrete properties, such as compressive strength, split tensile strength, and flexural strength, were also assessed. Findings highlight that fiber inclusion enhances crack control and durability, though it impacts flow ability in heavily reinforced areas.

## INTRODUCTION

Concrete plays a vital role in infrastructure development due to its strength, durability, cost-effectiveness, and adaptability. Traditionally, concrete—a mix of cement, fine and coarse aggregates, water, and admixtures—requires vibration for compact placement, which becomes challenging in densely reinforced structures. Here, self-compacting concrete (SCC) offers a solution, eliminating the need for external vibration, making placement easier in complex structures and enhancing finish quality.
Concrete is inherently strong in compression but weak in tension. Adding steel fibers to SCC improves ductility and crack resistance, enhancing its tensile properties.

### Workability of SCC

SCC is different from traditional concrete due to its unique workability characteristics, including:

- **Filling Ability**
- **Passing Ability**
- **Segregation Resistance**

These properties are tested through methods like:
1. Slump-Flow (Abrams Cone) for filling ability
2. V-Funnel for filling and segregation resistance
3. L-Box and J-Ring for passing ability

**Segregation**

Segregation occurs when materials separate within concrete, often due to improper mixing. Using high-quality materials, air-entraining agents, and proper water content reduces segregation risk.

**Cement**

Cement, the key binding component in concrete, is manufactured through either wet or dry processes, with dry processes being more efficient. It is classified by grade and properties:
1. **Ordinary Portland Cement (OPC)** – Grades 33, 43, 53
2. **Portland Pozzolana Cement (PPC)**
3. **Portland Slag Cement**
4. **Low Heat Cement**
5. **Rapid Hardening Cement**

Cement's quick setting and cohesive properties make it essential for durable construction.

**Chemical Composition:** The Chemical Composition of The OPC 53 Cement Which Are Typically Classified As

**Table 1:** Oxide and Chemical Compounds in Portland cement

| Chemical | Typical Oxide Percent (%) |
|---|---|
| Potassium oxide/Sodium Oxide ($K_2O/Na_2O$) | 1 |
| Sulfur Trioxide ($SO_3$) | 2 |
| Magnesium Oxide (MgO) | 10.5 |
| Ferro Oxide ($Fe_2O_3$) | 03 |
| Aluminum Oxide($Al_2O_3$) | 06 |
| Calcium (CaO) | 63 |
| Silicon dioxide($SiO_2$) | 20 |

**Aggregate**

Aggregates, sourced from quarries and rivers, are essential in concrete, enhancing strength and reducing shrinkage. Making up about 75% of the concrete volume, they contribute significantly to strength and economy. Aggregates are classified as **coarse** (retaining on a 4.75mm sieve) and **fine** (passing through a 4.75mm sieve), with both types graded according to IS standards to ensure durability and proper grading.

**Admixtures**

Admixtures are additives that modify concrete properties for improved performance. They include:

- **Mineral Admixtures**: Materials like fly ash, silica fume, and ground granulated blast-furnace slag, which replace part of the cement to enhance durability, reduce water demand, and control costs.
- **Chemical Admixtures**: Plasticizers, superplasticizers, and viscosity-modifying agents improve workability, setting times, and overall concrete strength.

**Fibers**

Fibers, such as steel, glass, and synthetic types, are added to concrete to improve its tensile strength, durability, and ductility. These fibers provide crack resistance, enhance tensile properties, and increase fatigue strength, making concrete more resilient even under stress.

**Requirements for SCC**

Self-compacting concrete (SCC) must have:

1. **Filling Ability**: Ability to flow and fill all spaces.
2. **Passing Ability**: Ability to pass through tight spaces and reinforcing bars without obstruction.
3. **Resistance to Segregation**: Ability to maintain ingredient uniformity during transport and placement.

**Advantages of SCC**

SCC offers multiple benefits, such as faster construction, improved durability, better surface finish, and reduced noise and labor needs, making it ideal for high-performance and complex structures.

**Fiber Reinforced Self-Compacting Concrete (FRSCC)**

FRSCC combines the self-compacting properties of SCC with fiber reinforcement, improving strength and toughness by resisting cracks and stress propagation. Steel fibers are commonly used, enhancing fire resistance, wear resistance, and durability. FRSCC reduces transportation and placement costs due to its improved workability and can replace steel reinforcement in certain applications, offering economic and environmental benefits.

**LITERATURE REVIEW**

- Parathiba Aggarwal, Rafal Siddiquie, Yogesh Aggarwal, and Surinder M. Gupta (Department of Civil Engineering, Haryana and Patiala, Punjab) conducted an experimental study on the mix design of self-compacting concrete (SCC) aimed at enhancing performance, deformability, and stability. They developed a mix design through extensive trials in Kurukshetra, evaluating SCC properties using tests such as the Slump Cone, V-Funnel, and L-Box. Workability and compressive strength were tested at 7, 14, 28, and 90 days.
- Krishna Murthy N., Narasimha Rao A.V., Ramana Reddy I.V., and Vijay Shekar (Department of Civil Engineering, S.V. University, Tirupati) discussed material selection for SCC mix design. They explored

using pozzolanic materials like fly ash and metakaolin, adopting a water/binder ratio of 0.39 with 5%–20% metakaolin and 10%–30% fly ash as partial cement replacements. Testing adhered to Bureau of Indian Standards and ASTM provisions.

 Selina Ruby G., Geethanjali C., Jaison Varghese, and P. Muthu Priaya (Department of Civil Engineering) studied hybrid fiber-reinforced concrete using a combination of steel and polypropylene fibers. Testing M40 concrete with a fiber volume fraction of 0.5%, they found the optimal mix (75% steel, 25% polypropylene) achieved the highest compressive and tensile strength due to the complementary elastic properties of the fibers.

 Abbas AL-Ameeri in *American Journal of Civil Engineering* examined steel fiber effects on SCC's mechanical properties, finding that adding 0.75% steel fibers significantly improved compressive strength.

 V.V. Kamalakar and Venkat Swaroop in the *International Journal of Computational Engineering Research* identified 0.9% as the optimal dosage of superplasticizers for compatibility with OPC 53 cement.

 Prof. Kishor S. Sable and Prof. Madhuri K. Rathi, in the *International Journal of Computer Technology and Electronics Engineering*, examined fiber-reinforced SCC. They found that adding 2.5% steel fibers improves concrete performance, although higher aspect ratios reduce workability.

 Nan Su, Kung-Chung Hsu, and colleagues (2001) proposed a new SCC mix design method, which was found to produce high-quality SCC more efficiently than the Japan Ready-Mixed Concrete Association (JRMCA) method.

 Krishna Rao and R. Vavindra explored F-grade fly ash for fiber-reinforced SCC, concluding that high fly ash content and steel fiber usage together improved concrete strength.

 Haddadou N., Chaid R., and team (2014) analyzed the effect of mixed steel fibers on SCC, using fibers of varying lengths (50 mm and 30 mm). Their results showed significant improvement in tensile and flexural strength for fiber-reinforced SCC with mineral additives.

 Mustafa Sahmaran, Alperen Yurtseven, and colleagues (2005) examined the workability of hybrid fiber-reinforced SCC, finding that combining two types of steel fibers enhanced workability and performance.

## MATERIALS AND PROPERTIES

### Materials

This project evaluated the impact of steel fibers on SCC's strength and durability. Key materials included cement, fly ash, river sand, coarse aggregate (CA), superplasticizer (SP), water, and steel fiber, tested per IS code standards.

### Cement

53-grade Portland cement (OPC) from KCP Corporation (IS: 12269) was used. The cement's specific gravity was 3.15, with a normal consistency of 33%. The initial and final setting times were 105 and 360 minutes, respectively.

**Table 3.1 : Physical Properties of OPC 53 grade Cement**

| Properties | Values for OPC 53 |
|---|---|
| Fineness | 8.3% |
| Normal Consistency | 34% |
| Specific Gravity | 3.2 |
| Initial Setting | 42 minutes |
| Final Setting | 338 minutes |
| Soundness | 2.1 mm |

**Fly Ash**

Fly ash from Vijayawada, India, was used with specific gravity and fineness of 1.975 and 1.195, respectively. It's a by-product of industrial combustion, commonly used in Portland cement construction to improve workability, long-term strength, and durability of concrete. Fly ash, often replacing 15-40% of cement by mass, reduces hydration heat, permeability, and cracking while enhancing sulfate resistance and controlling alkali-silica reactions. Though beneficial for long-term strength and durability, fly ash may initially reduce early strength due to residual carbon.

**Table 3.2** Constituents of Fly Ash

| S.No | Property | Formula | % content |
|---|---|---|---|
| 1. | Silicon Dioxide | $SiO_2$ | 59.04 |
| 2. | Aluminium Oxide | $Al_2O_3$ | 34.08 |
| 3. | Iron Oxide | $Fe_2O_3$ | 2.0 |
| 4. | Lime | CaO | 0.22 |
| 5. | Sulphur Trioxide | $SO_3$ | 0.05 |
| 6. | Magnesium Oxide | MgO | 0.43 |
| 7. | Alakalies | $Na_2O$ | 0.5 |
| 8. | Alakalies | $K_2O$ | 0.76 |
| 9. | Loss of ignition | LOI | 0.63 |

**Fig 1** cement in a tray

**Fig 2** Fly ash in a tray

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**Table 3.3 : Properties of Fly Ash**

| Properties | Test Values |
|---|---|
| Specific Gravity | 2.2 |
| Fineness | 7.9 |

## Fine Aggregate

Natural river sand (Zone II) with a specific gravity of 2.62 and a fineness modulus of 2.72 was used, following IS: 383-1970 standards. The maximum size of fine aggregate (FA) is 4.75 mm. Testing was conducted as per IS: 2386-1963.

**Fig 3 locally available river sand in a tray**

**Table 3.4 Fineness modulus of fine aggregate**

| I.S. sieve size | Weight of aggregate retained in gms | Cumulative weight retained in gms | Cumulative % of weight retained | % of passing | remarks |
|---|---|---|---|---|---|
| 10 mm | 0 | 0 | 0 | 100 | |
| 4.75 mm | 0 | 0 | 0 | 100 | |
| 2.36 mm | 3 | 3 | 0.03 | 99.97 | Zone-III |
| 1.18 mm | 57 | 60 | 0.6 | 99.40 | |
| 600 μ | 162 | 222 | 2.22 | 97.78 | |
| 300 μ | 536 | 758 | 75.8 | 24.2 | |
| 150 μ | 203.5 | 961.5 | 96.51 | 3.49 | |
| <150 μ | 15 | 1000 | 100 | 0 | |

Weight of aggregate sample taken =1000g

Fineness modulus of fine aggregate= 298.75/100 = 2.98

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**Table 3.5: Physical Properties of Fine Aggregate**

| Properties | Test Values |
|---|---|
| Fineness | 3 |
| Specific Gravity | 2.56 |

**Coarse Aggregate (CA)**

Coarse aggregate (CA), per EN 12620, is suitable for SCC production. While lightweight aggregates can be used, low paste viscosity can cause them to migrate to the surface. Optimal reinforcement spacing is essential to avoid clogging as SCC flows through, which the L-box test evaluates. Typically, the maximum aggregate size is limited to 10-12 mm to improve flow and minimize clogging. The particle size distribution and shape impact SCC flow, with smaller, more spherical particles reducing internal friction and enhancing flow.

**Fig 4 Coarse Aggregate of size 10mm**

**Table 3.6: Physical Properties of Coarse Aggregate**

| Properties | Test Value |
|---|---|
| Fineness | 2.9 |
| Water-absorption | 1% |
| Specific Gravity | 2.9 |

**Steel Fibers**

Steel fibers enhance SCC by improving durability, strength, and resistance to cracking. Optimal reinforcement spacing and aggregate size—typically limited to 10-12 mm—are crucial to prevent clogging, especially as SCC flows through reinforcements. Shape and size distribution of fibers affect SCC flow, with smaller, spherical particles reducing internal friction and enhancing flow.

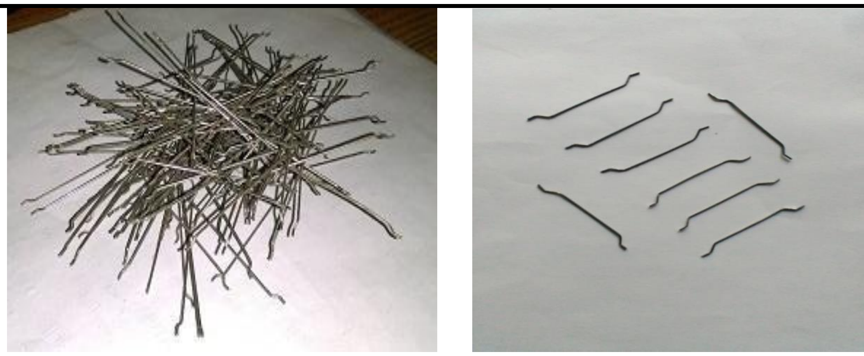

**Fig 5- hooked end steel fibers**

In this study, hooked end steel fibers were used, Steel fiber is made of cold drawn steel. Galvanized, stainless steel. The properties of the steel fibers used in this study are shown in Table 3.2 below.

**Table 3.7: Properties of Hooked Steel Fibers**

| Specifications | Values |
|---|---|
| Length (l) | 30 mm |
| Diameter (d) | 0.4 mm |
| Aspect ratio (l/d) | 75 |
| Specific Gravity | 7.24 |
| Appearance | Bright and clean wire |

### Advantages of Steel Fibers

- Enhances toughness and durability, reducing brittleness and increasing load capacity.
- Improves three-dimensional impact resistance.
- Blocks space behind the grid and reduces crack propagation.
- Increases impact resistance by 20-200% with 0.5-2% volume.
- Reduces concrete usage.
- Cost-effective and efficient solution.

### Superplasticizer

The superplasticizer used is Master Glenium 8650, a polycarboxylate-based additive. It enhances concrete performance, offering high durability and strength without chlorides or low bases. Compatible with all cement types.

### Features and Benefits

- Eliminates vibration, reducing labor costs.
- Significantly enhances early and ultimate strength.

- Increases modulus of elasticity (E-modulus).
- Improves bonding with reinforcement and stress resistance.
- Reduces permeability, enhancing durability.

**Uses**

- Production of self-compacting concrete.
- High-performance concrete with improved durability.
- Early and ultimate strength development.
- Good processing with no segregation or bleeding.
- Ideal for prefabricated and prestressed concrete, including volcanic ash concrete and fly ash-based mixes.

**PERFORMANCE DATA**

**Table 3.8 :** properties of super plasticizer poly carboxylic ether (Master Glenium 8632)

| | |
|---|---|
| **Colour** | Light brown liquid |
| **Specific gravity** | 1.08 |
| **Ph** | > 6 at 25°C |
| **Chloride ion content** | < 0.2% |
| **Relative density** | 1.04±0.01 |

**Workability**

The mixture remains workable for over 45 minutes at +25°C, with workability loss influenced by temperature, cement type, aggregate, transport, and consistency. It uses a multi-component carboxylate-based plasticizer (ratio 1.08, solid content ≥29%) compliant with ASTM C494 Type G, and free from harmful additives.

**Corrosive Properties**

The mixture does not promote corrosion in concrete or galvanized steel, and is free from chloride and calcium chloride-based ingredients, meeting industry standards for minimal chloride ion content.

**Self-Compacting Concrete Mix Design**

**Development of Rational Mix Design Procedure**

The South Sue method for SCC design focuses on factors like filler, fine aggregate ratio, and powder content, instead of packaging factors. These parameters, along with fly ash, cement, and water content, are crucial for mix design. A rational procedure is developed based on experimental data.

**Mix Design for M40 Grade**

- **Grade Designation**: M40
- **Cement**: OPC 53 grade
- **Nominal Maximum Aggregate Size**: 20 mm
- **SCC Characteristics**:
  - Slump Flow: 650-800 mm
  - Passing Ability (L-box test, h2/h1 ratio): 0.9
  - V-funnel Flow Time: ≤8s
- **Cement Content**: 450 kg/$m^3$
- **Admixtures**:
  - Superplasticizer: PCE type
  - Mineral Admixture: Fly ash (IS 3812)

**Test Data**

- **Cement**: OPC 53 Grade (Specific Gravity: 3.14)
- **Chemical Admixture**: Master Glenium SKY8632
- **Coarse Aggregate**: Specific Gravity: 2.74, Absorption: 0.5%
- **Fine Aggregate**: Specific Gravity: 2.65, Absorption: 1.0%

**Mix Design Steps (IS: 10262-2009)**

**Step 1: Target Mean Strength**

- fck′=fck+1.65Sf'_{ck} = f_{ck} + 1.65Sfck′=fck+1.65S
- fck′=40+1.65×5=48.25 MPaf'_{ck} = 40 + 1.65 \times 5 = 48.25 \, MPafck′=40+1.65×5=48.25MPa

**Step 2: Water Content**

- Maximum water content for 10mm aggregate: 208 L
- Reduced by 29% with superplasticizer: 208×0.71=147.68 L208 \times 0.71 = 147.68 \, L208×0.71=147.68L

**Step 3: Cement and Fly Ash Content**

- Water-cement ratio: 0.40
- Cementitious material content: 147.68/0.40=520 kg/m3147.68 / 0.40 = 520 \, kg/m^3147.68/0.40=520kg/m3

**Step 4: Coarse Aggregate Content**

- Coarse aggregate: 1190.57 kg/$m^3$

**Step 5: Fine Aggregate Content**

- Fine aggregate: 611.7 kg/$m^3$

**Table 4.1 The grade of M40 is**

| Aggregate type | Cement | Fine aggregate | Coarse aggregate | W/C ratio |
|---|---|---|---|---|
| **Weigth / m3** | 520 | 611.7 | 1190.6 | 208 |
| **Ratio** | 1 | 1.17 | 2.28 | 0.4 |

### Test Procedures

The required Self-Compacting Concrete (SCC) mix ratio is obtained from the design. Steel fibers (0.75% by volume) are added to each mix, using hooked steel fibers with a diameter of 0.4 mm and a length of 30 mm (aspect ratio of 75). Fly ash is added in varying percentages (0%, 15%, 20%, and 25%).
After preparing each SCC mixture, a flow test is conducted to assess the flow properties of the concrete.

### Tests on Self-Compacting Concrete

Tests are primarily carried out on fresh concrete to evaluate performance and workability, including:

- Slump flow test
- V-funnel test
- L-box test

**Table 5.1: List of tests method for Workable Properties on SCC**

| Characteristic | Method of test |
|---|---|
| Filling Ability | Slump Flow by Abrams cone (mm) |
| | $T_{50cm}$ Slump Flow (sec) |
| | “V” funnel (sec) |
| | Orimet (mm) |
| Passing Ability | “L” Box Test (sec) |
| | “J” Ring Test (mm) |
| | “U” Box test (mm) |
| Segregation | “V” funnel $T_{5minutes}$ Test (sec) |

**Table 5.2: Basic test on concrete with Standard and Typical Value**

| Test Method | Standard Test value |
|---|---|
| Slump Flow by Abrams cone | 650 to 800 mm |
| $T_{50cm}$ Slump Flow | 2 to 5 sec |
| “V” funnel | 8 to 12 sec |
| “V” funnel $T_{5minutes}$ Test | +3 sec |
| “L” Box Test | $H_2/H_1$= 0.8 to 1.0 |
| “J” Ring Test | 0-1 mm |
| “U” Box test | $H_2$-$H_1$ = 30 mm (max) |

**Slump Flow Test**

The slump flow test measures the filling ability and segregation resistance of Self-Compacting Concrete (SCC). It assesses how easily concrete flows horizontally without segregation and identifies any mortar separation. The test is essential for evaluating the flowability and stability of SCC.

**Principle**

The test measures two parameters:

1. **Slump Flow** - the distance the concrete flows horizontally.
2. **Flow Time (T50)** - optional, measures the time taken for the concrete to flow a set distance.

**Equipment**

- Slump cone (base diameter 200 mm, top diameter 100 mm, height 300 mm)
- Smooth, flat surface (900x900 mm)
- Trowel, scoop, measuring tape, stopwatch, moist sponge

**Procedure**

1. Place the clean floor on a stable, horizontal surface.
2. Position the slump cone on the marked area and fill it with concrete in layers, striking off the excess.
3. After lifting the cone, measure the final spread of the concrete in two perpendicular directions. The average diameter is the slump flow in mm. Ensure there is no slurry or segregation at the edges of the sample.


**Fig 7** Flow Table, Abraham's Cone **Fig 8** Spirit Instrument

**T50 Slump Flow Test**

The T50 slump flow test measures the time it takes for SCC to flow 500 mm after the slump cone is lifted.

**Procedure**

1. Lift the slump cone and start the stopwatch.
2. Measure the time for the concrete to flow 500 mm.

**Interpretation**

- A shorter T50 time indicates faster flow.
- Ideal T50 time: 2 to 5 seconds.

**Fig 9** Working method with slump cone

**Fig 10** Measurement of slump flow

**V-Funnel Test**

The V-funnel test evaluates the viscosity and filling capacity of self-compacting concrete (SCC) with a maximum aggregate size of 20 mm. The funnel is filled with about 12 liters of concrete.

**Principle**

The flow time through the narrow opening indicates the filling capacity and plastic viscosity of SCC, with no obstruction or segregation.

**Equipment**

- V-shaped funnel (metal, smooth surface, ±1mm tolerance).
- Containers larger than the funnel, holding at least 12 liters.
- Stopwatch (0.1 second precision).
- Straight edge for leveling concrete.
- Wet sponge or towel to moisten the funnel interior.

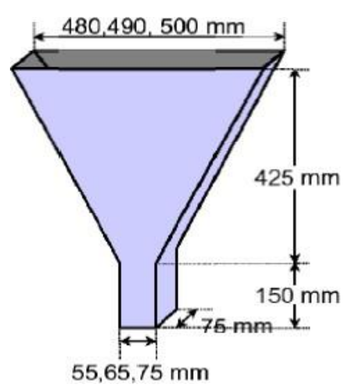


**Fig 11** “v” funnel Equipment as per Guidelines

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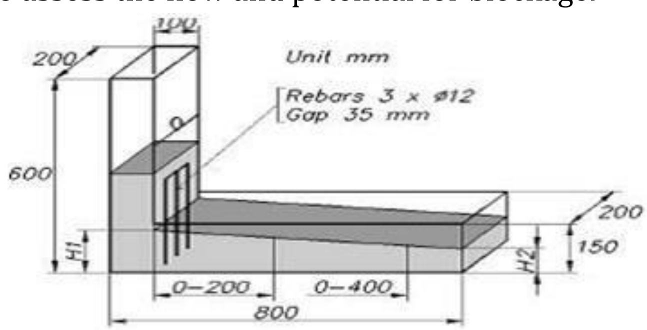
Place the clean V-shaped funnel on a stable, level floor. Wet the funnel and its inner surfaces, including the door. Fill the funnel with 10 liters of concrete, leveling it with a straight edge. Position a container beneath the funnel to catch the concrete. Open the door and start the stopwatch. Measure the time it takes for the concrete to flow through the funnel and into the container. Record the flow time (TV). According to EFNARC guidelines, the flow time should be between 8-12 seconds.

**Fig 12** "v" funnel as per the EFNARC guide lines **Fig 13** Practical test with "v" Funnel

**The L-box test**

developed in Japan, evaluates the passing ability of self-compacting concrete (SCC) through tight spaces, such as between rebar, without obstruction. It includes two variants: the double-click test and the three-bar test, which simulates denser reinforcement. The test measures the height of the SCC as it passes through the rebar, helping to assess the flow and potential for blockage.




F

ig 14 "L" box equipment

- L-box (with two types of doors: one with three smooth strips, the other with two smooth bars) with gap sizes of 41 mm and 59 mm.
- Leveling tools and suitable collection containers.
- L-box dimensions (tolerance ±1 mm) with a rigid structure, smooth and flat surface, and corrosion-resistant material.

- The vertical hopper should have a 14-liter capacity when filled to the top, and be removable for easy cleaning.

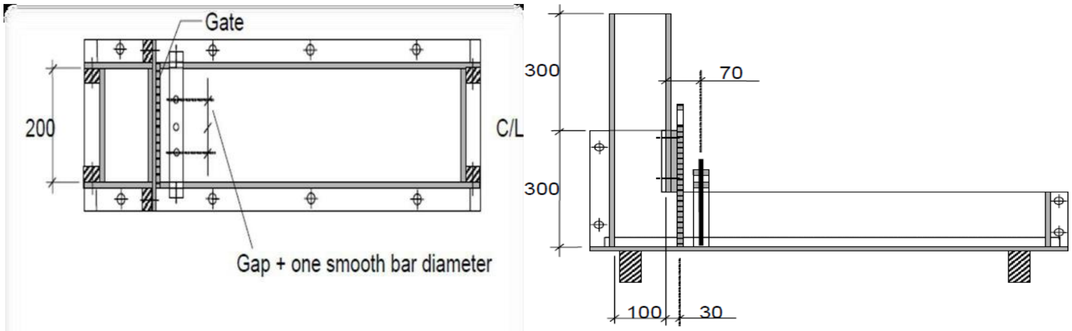



**Fig 15** Dimensions of typical design of L-box

**Fig 16** "L" Box set up

**Test Procedure of L-Box:**

1. Place the L-box on a stable, horizontal surface.
2. Fill the vertical section with about 14 liters of concrete, ensuring the sliding door is free to open and close.
3. Wet the inner surfaces and remove excess water.
4. Hold the concrete for 1 minute, then lift the sliding door to allow the concrete to flow into the horizontal section.
5. Start the stopwatch and record the time for the concrete to reach the 200 mm and 400 mm marks.
6. Measure the height (H1) in the vertical section and (H2) in the horizontal section when the flow stops.
7. Calculate the blocking ratio (H2/H1). A value closer to 1 indicates better fluidity and no blockage. The EU recommends a minimum value of 0.8.

**Fig 17** Conducting L-BOX test as per EFNARC guidelines

**Acceptance criteria for SCC**

**Table 5.3 Acceptance criteria for tests of SCC**

| S.No | Method | Units | Typical range of values | |
|---|---|---|---|---|
| | | | Minimum | Maximum |
| 1. | Slump flow test | mm | 650 | 800 |
| 2. | T50 slump flow | sec | 2 | 5 |
| 3. | V-Funnel test | sec | 6 | 12 |
| 4. | L-Box test ( H2/H1) | | 0.8 | 1.0 |

**Tests on Hardened Concrete**

**Preparation of Test Specimens:**

- Apply oil to molds and prepare concrete per the design mix.
- Pour concrete into molds without compaction.
- After 24 hours, remove the specimens and immerse them in clean water for curing.
- Cure for 28 days before testing.

**Specimens:**

- Cube: 150mm x 150mm x 150mm
- Cylindrical: 300mm diameter x 150mm height
- Beam: 150mm x 150mm x 700mm

**Test on Cubes for Compressive Strength:**

- According to IS 516: 1969, cubes of 150mm size are tested for compressive strength at 7 and 28 days.
- After curing, the cubes are tested under a 2000 kN capacity compression machine.
- Compressive strength is an essential test, as it correlates with the concrete's ideal properties.

**Fig 19** Compressive strength of different SCC mixes using CTM

**Formula** :

$$\textbf{Compressive Strength Of Cubes (N/mm}^2\textbf{)} = \frac{P}{A}$$

Where,

P = Applied load (KN)

A= Surface area ($mm^2$)

**Test on Cylinder for Split Tensile Strength:**

As per IS 5816: 1969, the split tensile test is a simple, reliable method for determining concrete's indirect tensile strength. This method is considered more uniform than other tensile tests and closely approximates the true strength, with split tensile strength being about 5-12% higher than direct tensile strength.

**Test Procedure:**

- The test is conducted using a compression testing machine (capacity of 1000 kN), with a control valve to adjust the loading rate.
- The cylinder (150mm diameter x 300mm height) is placed in the machine, and load is applied along the vertical diameter, causing compressive and horizontal stresses.
- The cylinder splits into two halves when the applied load exceeds the material's tensile strength.

4o mini

**Formula:**

$$\text{Split tensile strength (N/mm}^2\text{)} = \frac{2P}{\pi DL}$$

Where, P is the maximum compressive load on the cylinder (KN).

L is the length of the cylinder (mm).

D is the diameter of the cylinder (mm).

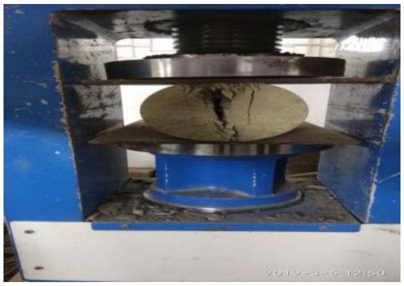


**Fig 20** split tensile strength test for different SCC mixes using UTM

**EXPERIMENTAL RESULTS & DISCUSSION**

In this study, after the completion of casting and curing of cubes, cylinders, a variety of mechanical properties namely compressive strength and splitting tensile strength were studied in detail. This chapter focuses on the findings.

**Fresh Properties of SCC**

The details of the fresh properties are shown in Table 5.1, M40 grade of concrete.

**Table: 6.1 Fresh properties of M40 grade SCC**

| Method | Slump abram cone test | | "v" funnel cone test | "L" box test |
|---|---|---|---|---|
| Type of test | Slump flow (mm) | T50 (sec) | Flow time (sec) | $H_2/H_1$ |
| With out steel fibers | 700 | 3 | 9 | 0.89 |
| With steel fibers | 670 | 4.5 | 10.5 | 0.95 |

**Mechanical Properties of SCC**

**Compressive Strength**

The results of the mechanical properties obtained from samples tested according to the Indian standard test procedure (according to IS: 516-1959) were discussed. M40 grade concrete, 10mm maximum size aggregate and two different curing times are research variables.

Details of the compressive strength of concrete at the M40 grade are shown in Table 6.2 & 6.3.

**Table: 6.2 Compressive Strength of Cubes for 7 days M 40 grade SCC**

| Days | Percentage Of steel fibers | Percentage of Fly ash | No | Load (Kn) | Strength (Mpa) | Avg. Strength (Mpa) |
|---|---|---|---|---|---|---|
| 7 | 0.75% | 0% | 1 | 910 | 40.44 | 41.77 |
| | | | 2 | 940 | 41.77 | |
| | | | 3 | 950 | 42.22 | |
| 7 | 0.75% | 15% | 1 | 1195 | 53.11 | 48.66 |
| | | | 2 | 1000 | 44.44 | |
| | | | 3 | 1105 | 49.11 | |
| 7 | 0.75% | 20% | 1 | 1029 | 45.73 | 45.74 |
| | | | 2 | 1028 | 45.68 | |
| | | | 3 | 1031 | 45.82 | |
| 7 | 0.75% | 25% | 1 | 910 | 40.44 | 41.10 |
| | | | 2 | 930 | 41.33 | |
| | | | 3 | 935 | 41.55 | |

**Fig 21 Test specimens**

**Table: 6.3 Compressive Strength of Cubes for 28 days M40 grade SCC**

| Days | Percentage Of steel fibers | Percentage of Fly ash | No | Load (Kn) | Strength (Mpa) | Avg. Strength (Mpa) |
|---|---|---|---|---|---|---|
| 28 | 0.75% | 0% | 1 | 1405 | 62.44 | 61.61 |
| | | | 2 | 1375 | 61.11 | |
| | | | 3 | 1380 | 61.33 | |
| 28 | 0.75% | 15% | 1 | 1477.98 | 65.68 | 65.09 |
| | | | 2 | 1456.87 | 64.75 | |
| | | | 3 | 1459.12 | 64.85 | |
| 28 | 0.75% | 20% | 1 | 1420.5 | 63.13 | 63.02 |
| | | | 2 | 1425.6 | 63.36 | |
| | | | 3 | 1408.4 | 62.59 | |
| 28 | 0.75% | 25% | 1 | 1080 | 48 | 48.63 |
| | | | 2 | 1125 | 50 | |
| | | | 3 | 1078 | 47.91 | |

## Split Tensile Strength

Table 6.4 shows the details of the split tensile strength of M40 grade of concrete for different percentages of FLY ASH.

**Table: 6.4 Split tensile strength test of Cylinders for 7 days M 40 grade SCC**

| Days | Percentage Of steel fibers | Percentage of Fly ash | No | Load (Kn) | Strength (Mpa) | Avg. Strength (Mpa) |
|---|---|---|---|---|---|---|
| 7 | 0.75% | 0% | 1 | 200 | 2.9 | 2.82 |
| | | | 2 | 195 | 2.8 | |
| | | | 3 | 196 | 2.77 | |
| 7 | 0.75% | 15% | 1 | 230 | 3.25 | 3.21 |
| | | | 2 | 225 | 2.18 | |
| | | | 3 | 227 | 3.21 | |
| 7 | 0.75% | 20% | 1 | 220 | 3.11 | 3.09 |
| | | | 2 | 218 | 3.08 | |
| | | | 3 | 218.6 | 3.09 | |
| 7 | 0.75% | 25% | 1 | 210.4 | 2.97 | 2.92 |
| | | | 2 | 209.8 | 2.96 | |
| | | | 3 | 200.3 | 2.83 | |

**Fig 22: Cylinder specimens**

**Table: 6.5 Split tensile strength test of Cylinders for 28 days M 40 grade SCC**

| Days | Percentage Of steel fibers | Percentage of Fly ash | No | Load (Kn) | Strength (Mpa) | Avg. Strength (Mpa) |
|---|---|---|---|---|---|---|
| 28 | 0.75% | 0% | 1 | 220 | 3.11 | 3.13 |
| | | | 2 | 221.8 | 3.13 | |
| | | | 3 | 222.9 | 3.15 | |
| 28 | 0.75% | 15% | 1 | 250.2 | 3.53 | 3.51 |
| | | | 2 | 248.6 | 3.51 | |
| | | | 3 | 246.8 | 3.49 | |
| 28 | 0.75% | 20% | 1 | 230.6 | 3.26 | 3.32 |
| | | | 2 | 238.4 | 3.37 | |
| | | | 3 | 236.5 | 3.34 | |
| 28 | 0.75% | 25% | 1 | 220.8 | 3.12 | 3.11 |
| | | | 2 | 222.6 | 3.14 | |
| | | | 3 | 218.8 | 3.09 | |

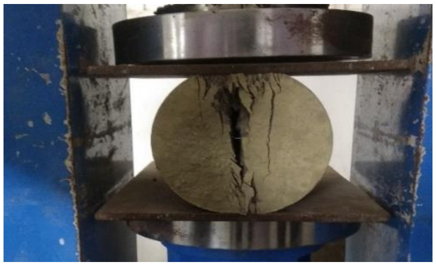
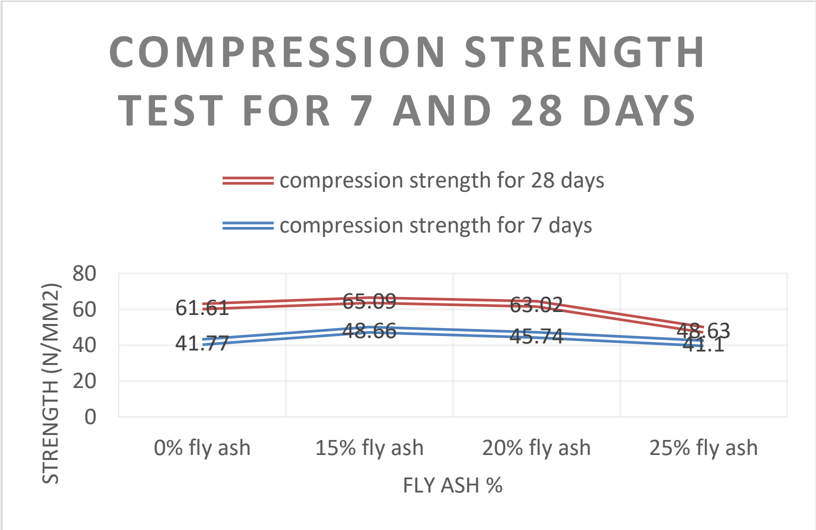
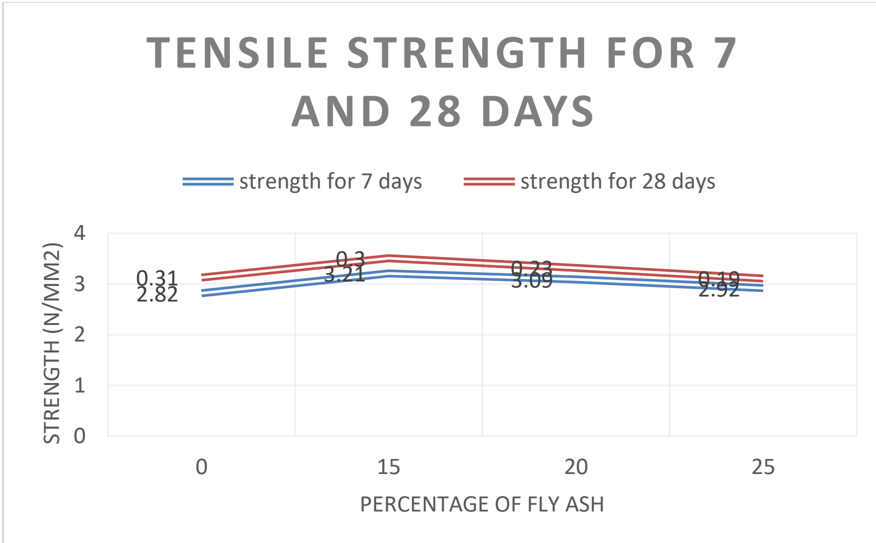


**FIG 22** Failure of Cylinder

**GRAPHICAL REPRASENTATIONS:**




**Graph for compressive strength of cubes for 7 and 28 days**




**Graph for split tensile strength of cylinders for 7 and 28 days**

**CONCLUSION:**

1. Adding steel fibers to self-compacting concrete marginally improves compressive and split tensile strength.
2. Mineral admixtures enhance high-strength SCC performance, increasing strength.
3. Replacing cement with fly ash improves SCC, with the best results observed when fly ash was included.
4. Compressive strength increased with 15% fly ash compared to 0%.
5. Split tensile strength also increased with 15% fly ash.
6. The PCE-based superplasticizer (Master Glenium SKY 8632) improved both flow ability and strength.
7. Flowability remained optimal up to 15% fly ash; further increases in fly ash reduced Flowability.

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