EXPERIMENTAL PROGRAMME
CHAPTER 3
EXPERIMENTAL PROGRAMME

3.1 GENERAL

The objectives of present study have been mentioned in Chapter 1. To achieve these objectives an extensive investigations were carried out. Trial mixes of SCC were tested for development of self compacting concrete using blend of flyash and rice husk ash. It includes experimental investigation of rheological properties as well as hardened properties trial mixes. This chapter outlines the experimental programme carried out for investigation in detail. The procedure for carrying out mortar test, fresh properties of fresh and hardened test have been presented in this chapter.

The chapter also deals with experimental investigation on determination of properties of ingredients of self compacting concrete mixes, mortar test, mix design of self compacting concrete mixes, mixing order and determination of fresh and hardened properties of self compacting concrete trial mixes.

The following programme has been planned to carry out research work:

- Determining the physical and chemical properties of the ingredients of concrete as per relevant Indian Standard codes and specifications.
- Testing mortar trial mixes to determine the approximate dose of superplasticizer and water-powder ratio required to develop self compacting concrete.
- Testing of trial mixes for developing self compacting concrete
- Developing self compacting concrete mixes using different proportions of ingredients
- Formulating experimental set up required for studying fresh properties of SCC.
- Performing laboratory tests for studying and analyzing the various properties of fresh SCC using EFNARC standard.
- Conducting various tests on the hardened concrete for analyzing the properties and study various durability aspects of SCC.
- Analysing the effect of flyash and RHA on rheological properties of concrete
- Determination of the effect of temperature on the hardened SCC impregnated with flyash and RHA
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- Finding out relation between the crushing strength of SCC and various NDT values.
- Carrying out Cost-Benefit analysis of development of SCC from practical considerations
- Developing a model for predicting compressive strength of Self compacting concrete using data obtained from experimental investigation.

The procedure for testing of rheological properties is presented here under.

3.2 FRESH PROPERTIES OF SCC

Self-compacting concrete have a higher degree of workability than normal concrete. A concrete can be characterized as SCC only if it has tilling ability, passing ability and stability. The flowability is characterized by concrete’s fluidity and cohesion. Passing ability is the ability of the concrete to flow through restricted spaces without blocking. Stability is the ability of concrete to remain uniform and cohesive throughout the entire construction process.

Self-compacting mortars (SCMs) serve as a basis for the design of Self compacting concrete mixes. Hence, first Mortar flow test was carried out to determine the approximate dose of superplasticizer required to develop self compacting concrete.

3.2.1 Mortar Flow Test Procedure

Cement, flyash and Rice husk ash were used as the base powder material for use in the mortar flow test cone which is shown in figure 3.1 hereunder.

![Mortar Flow Cone and flow of mortar](image)

The mortar consisting of cement, flyash, sand and water was prepared and poured into slump cone. The surplus mortar was removed and the cone was raised vertically allowing it to flow freely. The final diameter of the mortar was measured in two perpendicular directions.
$$T_p = \left( \frac{d}{d_0} \right)^2 - 1$$ where $d = \frac{d_1 + d_2}{2}$ and $d_0 = 100$ mm i.e. bottom dia of flow cone. The tests were carried out with mortar mixes with increased water/powder ratio from 1 to 1.3. The relative flow obtained was plotted against water/powder ratio. The graph was extended to obtain $T_p$ i.e. Water/powder ratio for zero flow. (Fig 3.2)

![Figure 3.2: Determination of Water/powder Ratio for Zero Slump Flow](image)

### 3.2.2 Testing Procedures for Fresh Self Compacting Concrete

It is pertinent to mention that so far none of the test methods for SCC have been standardised and included in Indian Standard Code. The following are some of the features of self compacting concrete as mentioned in Indian Standard code IS 456-2000 (Amendment No. 3, 2007)

1. Slump flow: Minimum 600 mm.
2. Sufficient amount of fines (<0.125 mm) preferably in the range of 400 kg/m$^3$ to 600 kg/m$^3$. This can be achieved by having sand content more than 38% and using mineral admixture to the order of 25 to 50% by mass of cementitious materials.
3. Use of high range water reducing (HRWR) admixture and viscosity modifying agent (VMA) in appropriate dosages is permitted.

European guidelines (EFNARC) guidelines are used worldwide for testing rheological properties of Self compacting concrete with slight modifications as per local conditions. EFNARC guidelines for testing, covers number of parameters ranging from material selection, mixture designs and testing methods like Slump flow test, L-box test, V-funnel test, U-box test, Orimet test and GTM screen stability for determining properties of SCC in fresh state. Most of Indian researchers are following these guidelines to determine the rheological properties of SCC mixes. Table 3.1 gives acceptance criteria as laid down by EFNARC for fresh properties of SCC.
Table 3.1: Acceptance Criteria for testing fresh properties of SCC

<table>
<thead>
<tr>
<th>Sr No</th>
<th>Method</th>
<th>Range of Values</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Slump Flow Test (mm)</td>
<td>650</td>
<td>800</td>
</tr>
<tr>
<td>02</td>
<td>J-Ring Test (mm)</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>03</td>
<td>V-Funnel Test (Sec)</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>04</td>
<td>L-Box Test (h₂/h₁)</td>
<td>0.8</td>
<td>1</td>
</tr>
<tr>
<td>05</td>
<td>U-Box (mm) Test</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>06</td>
<td>Orimet Test (Sec)</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>07</td>
<td>Segregation Ratio (%)</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>08</td>
<td>Fill Box Test</td>
<td>80</td>
<td>100</td>
</tr>
</tbody>
</table>

The tests on designed fresh self compacting concrete were carried out according to EFNARC guidelines for self compacting concrete as reported above. Standard dimensions of equipment as per EFNARC for testing fresh properties of SCC are presented along with photograph of equipment.

3.2.2.1 Slump flow Test

The basic equipment for slump flow test used is the same as for the conventional Slump test. The test method differs from the conventional one with the fact that the concrete sample poured into the mould is not rodded and when the slump cone is removed the sample collapses.

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

Equipment Used

For slump test, the apparatus consists of

- a. Base plate of dimension 900 mm x 900 mm
- b. Slump cone
- c. Trowel
- d. Scoop
- e. Rule
- f. Stop watch

Procedure

About 6 litres of concrete is prepared to perform the test. The cleaned base plate is placed in a stable and level position. The slump cone is kept centrally on base plate and the inner surface of the cone and the test surface of the base plate is moistened using the sponge. The cone is filled with concrete with the help of scoop without any external compactive force and the surplus concrete struck off above the top of the
cone with trowel. The cone is raised vertically and the concrete is allowed to flow freely. The largest diameter of the flow spread \(d_{\text{max}}\) and the one perpendicular to it \(d_{\text{perp}}\) is measured using the ruler or tape. The average of the two diameters is taken as slump flow in mm.

Slump flow value of at least 600 mm is required for SCC as against the accepted range of 600 to 800 mm.

3.2.2.2 J-Ring Test

The J-Ring test is used to determine passing ability of concrete. The equipment consists of steel ring with 300 mm diameter having steel bars of 10 mm diameter, 100 mm length placed at equal distance to simulate the congestion of reinforcement at site. Bars are placed at center to center distance equal to 48 ± 2 mm. (Photograph 3.1)

**Equipment Used**

a. Base plate of dimension 900 mm x 900 mm  
b. Slump cone  
c. Trowel,  
d. Scoop  
e. Rule  
f. J-Ring

**Procedure**

Inside of slump cone is moistened prior to starting of the test. The J-Ring is placed centrally on base plate and the slump cone centrally inside the ring. About 6 liters of concrete is prepared for the test. The slump cone is filled with concrete by scoop without tamping or vibration. Surplus concrete is struck off with trowel. The cone is raised vertically and concrete is allowed to flow through the J-Ring. The difference in height between the concrete just inside the J-Ring bars and just outside the J-Ring is measured at four locations. The average of these four readings is calculated.

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**Photograph 3.1: J-Ring Test Apparatus**

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The acceptable difference in height between inside and outside J-Ring should be between 0 and 10mm.

3.2.2.3 V Funnel Test
The V-funnel test is used to assess the viscosity and filling ability of self-compacting concrete. The V-funnel flow time is time required for concrete to pass a narrow opening and gives an indication of the filling ability of SCC provided that blocking and segregation do not take place.

The flow time of the V-funnel test is related to the plastic viscosity of concrete, whereas t_s test is used to measure segregation resistance. If concrete shows segregation then t_s time increases considerably. The V funnel equipment is as shown in the Photograph 3.2.

Equipment Used
a. V-funnel apparatus
b. Stop watch
c. Straight edge
d. Container
e. Trowel
f.

Procedure
V-funnel (Photograph 3.2)is placed on a stable and flat ground. The interior of the funnel is moistened. About 12 litres of Self compacting concrete is prepared using ingredient proportions as per design requirements. The funnel is completely filled with a concrete without applying any compaction or rodding. The excess concrete is struck off using the straightedge.

The trap door is opened after a waiting period of 10 seconds. The stopwatch is started at the same moment the trap door is opened. Look inside the funnel and stop the time at the moment when clear space is visible through the opening of the funnel. The stopwatch reading is recorded V-funnel flow time t_v in observation sheet.
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Photograph 3.2: V Funnel

As per European Standards V funnel time \( t_V \) should be between 8 to 12 seconds and \( t_S \) time should be \( t_V + 3 \) seconds.

3.2.2.4 U Box Test

U-box test is used to measure filling ability of SCC. The apparatus is shown in the Photograph 3.3.

The apparatus required for U box test consist of:

- U box
- Tape/Scale
- Container/Bucket
- Trowel

Procedure

The apparatus is placed level on firm ground. About 20 litres of concrete is needed to perform the test. The inside surfaces of the apparatus are moistened. One compartment of the apparatus is filled with the concrete and left it to stand for 1 minute. The sliding gate is lifted and the concrete is allowed to flow out into the other compartment. After the concrete had come to rest, height of the concrete in the first compartment \( (H_1) \) is measured. The height of concrete in the other compartment \( (H_2) \) is also measured. The filling height \( (H_1 - H_2) \) is calculated. As per European standard suggested acceptable value of filling height in the range of 0 to 30 mm.

Photograph 3.3: U Box Test Apparatus

As per European Standard suggested acceptable value of filling height in the range of 0 to 30 mm.

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3.2.2.5 L Box Test

The L-box test is also developed in Japan to test underwater concrete, and it has been adopted to test highly flowable concrete. This test consists of an L-shaped boxed in which the vertical and horizontal ends are separated by a sliding door (Photograph 3.4). Concrete is poured into the vertical leg, and the sliding door is raised to allow the concrete to flow into the horizontal section. Typically, reinforcement bars are placed at the entrance of the horizontal section to gauge the passing ability of the concrete.

The L-box test is used to assess the passing ability of self-compacting concrete to flow through tight openings including spaces between reinforcing bars and other obstructions without segregation or blocking.

Photograph 3.4: L Box Equipment Used
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For L box test the apparatus required consists of
a. L Box
b. Container/Bucket
c. Trowel
d. Tape/Scale

**Procedure**
The L-box is placed in a stable and level position. The gate between the vertical and horizontal sections of L-box is closed. About 14 litres of concrete is needed to perform the test. The vertical part of the L-box is filled with fresh concrete left to stand for one minute and the sliding gate is lifted. When movement of concrete in horizontal section stopped, the depth of concrete immediately at the start of section (behind the gate) ($H_1$) and vertical height at the end of the horizontal section of the L box ($H_2$) are measured. The blocking ratio ($H_2/H_1$) is calculated.

Minimum acceptable value of blocking ratio as per EFNARC guideline is 0.8.

3.2.2.6 Orimet Test

This test measures the ease of flow of the concrete; shorter flow times indicate greater flowability. The apparatus is shown in the Photograph 3.5.

**Equipment Used**
For Orimet Test the apparatus required consist of
- Orimet Test Apparatus
- Stop watch
- Straight edge
- Container/Bucket
- Trowel

**Procedure**
Orimet Test Apparatus is placed vertically on a stable and flat ground, with the top opening horizontally positioned. The apparatus is moistened with sponge. About 8 litres of concrete is needed to perform the test. The Orimet is completely filled with concrete without applying any compaction or rodding. Excess concrete is removed from the top using the straightedge. The gate is opened after a waiting period of 10 seconds. The Orimet flow time, time for complete discharge of concrete $t_0$ is recorded in the observation sheet.
Permissible limit for Orimet flow time of 5 seconds or less is considered appropriate as per European standards. The prolonged flow time may give some indication of the susceptibility of the mix to blocking or segregation.

3.2.2.7 Fill Box Test
This test is also known as the ‘Kajima test’. The test is used to measure the filling ability of self-compacting concrete. The apparatus is shown in the Photograph 3.6.

For Fill box test the apparatus consists of:
- Fill box
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- Tape/Scale
- Container/Bucket
- Trowel
- Scoop

Procedure

The apparatus is placed on level and firm ground. The apparatus consists of a container (transparent) with a flat and smooth surface. In the container are 35 obstacles made of PVC pipes with a diameter of 20mm at a centre to centre distance of 50mm. The apparatus is moistened with sponge. The apparatus is filled by pouring fresh concrete into the funnel until the concrete has just covered the first top obstacle. The height of the concrete in the fill box \(H_1\) at which the container is filled and the height of concrete in the opposite side \(H_2\) is measured. The average filling percentage is calculated by using formula

\[
\text{Average filling \%: } F= \frac{(H_1 + H_2)}{2*H_1} \times 100
\]

The European standards have suggested minimum acceptable value of filling height between 90 to 100 \%.

3.2.2.8 GTM Screen Stability Test

GTM Screen Stability test is used to assess the stability and segregation resistance of concrete

Equipment Used

Bucket, 5 mm sieve, pan, balance, stopwatch

Procedure

About 10 l of concrete is needed to perform this test. The concrete in the bucket is covered with a lid to prevent evaporation and is kept at rest for 15 minutes. Then, top 2 litres approximately (5 Kg) of the concrete sample within the bucket is poured into a container and the mass of filled container is determined. The mass of empty sieve pan is also noted. After this, all the concrete is poured on to the sieve from 500 mm height. The mass poured on to the sieve is measured \(M_1\). Then concrete is allowed to flow through the sieve into the sieve pan for period of 2 minutes. Then the mass \(M_2\) of concrete on the pan is noted. The segregation ratio is given by \(\frac{M_1}{M_2} \times 100\). For self
compacting concrete segregation ratio should lie between 5 and 15% of weight of sample.

After discussing the procedures for fresh properties of SCC the tests procedures adopted for determining properties of SCC in hardened state are discussed hereunder.

3.3 TEST PROCEDURES FOR HARDENED CONCRETE

Concrete has to have satisfactory properties both in the fresh and hardened states. Strength is a measure of the ability of concrete to resist stresses or forces at a given age. It is often used as the basis for assessing concrete quality. Tests on hardened concrete are well known test and are carried out as per Indian Standard Codes.

3.3.1 Compressive Strength

The compressive strength of concrete is very important, as it is used more often in compression than in any other way. The compressive strength of hardened concrete is considered to be the most important property. It can be measured easily on standard sized cube or cylindrical specimens and is often taken as an index of the overall ‘quality’ of concrete. Compressive strength test were carried out as per IS: 516-1959 on Compression Testing Machine with loading capacity of 3000 kN.

3.3.2 Flexural Tensile Strength

The tensile strength is one of the basic and important properties of the concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However, the determination of tensile strength of concrete is necessary to determine the load at which the concrete members may crack. The cracking is a form of tension failure. Flexural tensile strength test gives knowledge about tensile strength of concrete.

Flexural strength is the ability of a beam or slab to resist failure in bending. Flexural Tensile Strength or Modulus of Rupture tests were carried out as per IS: 516-1959 using Automatic Compression Testing Machine with a loading capacity of 3000 KN. The bed of the testing machine is to be provided with two steel rollers, 38 mm in diameter, on which the specimen is to be supported, and these rollers are so mounted that the distance from centre to centre is 60 cm for 15 cm specimens or 40 cm for 10 cm specimens. The load is applied through two similar rollers mounted at the third points of the supporting span, that is, spaced at 20 or 13.3 cm centre to centre as the case may be. The load is divided equally between two loading rollers, and all rollers are to be mounted in such a manner that the load is applied axially and without subjecting the specimen to any torsional stresses or restraints (Photograph 3.7)
Test specimens are stored in water at a temperature of 24° to 30°C for 48 hours before testing and tested immediately on removal from the water whilst they are still in the wet condition. The dimensions of each specimen are being noted before the start of the test.

The flexural strength of the specimen is expressed as the modulus of rupture $f_b$, which, if $a$ equals the distance between the line of fracture and the nearer support, measured on the centre line of the tensile side of the specimen, in cm, and is calculated to the nearest 0.5 kg/sq cm as follows:

$$f_b = \frac{P \times L}{b \times d^2}$$

when $a$ is greater than 20.0 cm for 15.0 cm specimen, or greater than 13.3 cm for a 10.0 cm specimen, or

$$f_b = \frac{3 \times p \times a}{b \times d^2}$$

when $a$ is less than 20.0 cm but greater than 17.0 cm for 15.0 cm specimen or less than 13.3 cm but greater than 11.0 cm for a 10.0 cm specimen.

Where $b =$ measured width in cm of the specimen,

$d =$ measured depth in cm of the specimen at the point of failure,

$l =$ length in cm of the span on which the specimen is supported and

$p =$ maximum load in kg applied to the specimen.

Photograph 3.7: Flexural Strength Test

3.3.3 Split Tensile Strength

Apart from the flexure test the other methods to determine the tensile strength of concrete can be broadly classified as (a) direct methods, and (b) indirect methods. The
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direct method suffers from a number of difficulties related to holding the specimen properly in the testing machine without introducing stress concentration, and to the application of uniaxial tensile load which is free from eccentricity to the specimen. As there are many difficulties associated with the direct tension test, a number of indirect methods have been developed to determine the tensile strength. In these tests in general a compressive force is applied to a concrete specimen in such a way that the specimen fails due to tensile stresses developed in the specimen. The tensile stress at which the failure occurs is termed the tensile strength of concrete.

The splitting tests are well known indirect tests used for determining the tensile strength of concrete sometimes referred to as split tensile strength of concrete. The test consists of applying a compressive line load along the opposite generators of a concrete cylinder placed with its axis horizontal between the compressive platens. Due to the compression loading a fairly uniform tensile stress is developed.

Split tensile strength of concrete is obtained by placing a cylindrical specimen horizontally between the loading surfaces of Automatic Compression Testing Machine. (Photograph 3.8) Plywood strips mm thick, 1 mm wide are sandwiched between the platens and the cylindrical surface. The load is applied at a uniform rate of 100 kN/minute until failure of the test specimen. The test is carried out as per specification of IS: 586-1970 on cylindrical specimens. The Split tensile strength of concrete is calculated by the formula

\[ \sigma = \frac{1}{\pi i} \times \frac{2P}{LD} \]

Where \( \sigma \) is Split Tensile Strength in MPa

\( P \) is failure load in N

\( D \) is diameter of cylindrical specimen in mm

\( L \) is Length of cylindrical specimen in mm

\( \pi i = 3.142 \)
3.3.4 Abrasion Resistance Test

Deterioration of concrete surfaces occurs due to various forms of wear such as erosion, cavitation, and abrasion due to various exposures. Abrasion wear occurs due to rubbing, scraping, skidding, or sliding of objects on the concrete surface. This form of wear is observed in pavements, floors, or other surfaces on which friction forces are applied due to relative motion between the surfaces and moving objects. Concrete abrasion resistance is markedly influenced by a number of factors including concrete strength, aggregate properties, surface finishing, and type of hardeners or toppings. This test measures abrasion resistance of concrete.

**Preparation of Test Specimens** — The test specimens are square in shape and of size $7.06 \times 7.06$ cm (that is, 50 cm$^2$ in area) with 2.5 cm thickness. The deviation in the length of the specimen is within ±2 percent. The test is conducted as per code 1237.

**Apparatus and Accessories**

a. Abrasion Testing Machine— The abrasion of specimens is carried out in a machine conforming essentially to the requirements of BIS code 1237.

b. The abrasive powder used for the test conformed to the requirements given in IS Code.

c. Measuring Instrument— A suitable instrument capable of making measurement to the accuracy of 0.01 mm is used for determining the change in the thickness of the specimen after abrasion.
Procedure of Test — The specimens is dried at 110° ± 5°C for 24 hours and then weighed to the nearest 0.1 g. The specimen after initial drying and weighing is placed in the thickness-measuring apparatus with its wearing surface upwards and the reading of the measuring instrument taken.

The grinding path of the disc of the abrasion testing machine (see F-2) is evenly strewn with 20 g of the abrasive powder. The specimen is then fixed in the holding device with the surface to be ground facing the disc, and loaded at the centre with 300 N (30 kgf). The grinding disc is then be put in motion at a speed of 30 rev/min and the abrasive powder is continuously fed back on to the grinding path so that it remained uniformly distributed in a track corresponding to the width of the test piece. After every 22 revolutions, the disc is stopped, the abraded tile powder and the remainder of the abrasive powder is removed from the disc, and fresh abrasive powder in quantities of 20 g applied each time. After every 22 revolutions the specimen is turned about the vertical axis through an angle of 90° in the clockwise direction and it is repeated 9 times thereby giving total number of revolutions of 220. The disc, the abrasive powder and the specimen is kept dry throughout the duration of the test. After the abrasion is over, the specimen is reweighed to the nearest 0.1 g. It is then placed in the thickness measuring apparatus once again in an identical manner and the reading taken with the same position and setting of the dial gauge as for the measurement before abrasion.

Determination of Wear — The wear is determined from the difference in readings obtained by the measuring instrument before and after the abrasion of the specimen. The value is checked up with the average loss in thickness of the specimen obtained by the following formula:

\[ t = \frac{(W_1 - W_2) \times V_1}{W_1 \times A} \]

where:
- \( t \) = average loss in thickness in mm,
- \( W_1 \) = initial mass of the specimen in g,
- \( W_2 \) = final mass of the abraded specimen in g,
- \( V_1 \) = initial volume of the specimen in mm³, and
- \( A \) = surface area of the specimen in mm².
3.3.5 Impact Test on SCC
A large amount of energy is often imparted to the structure during an impact event. If the structure is not capable of absorbing the incoming energy, a failure will ensue often during the event itself. Concrete, unfortunately, is a very brittle material with a poor energy absorption capacity. Hence it is necessary to measure impact resistance of concrete. The impact resistance of SCC concrete mixes is investigated using the repeated drop-weight impact test recommended by ACI Committee 544 with slight modification. The test is carried out by dropping a hammer weighing 5 kg from a height of 457 mm repeatedly on a 64mm diameter hardened steel ball, which is placed on the top of the centre of the cylindrical specimen. (Photograph 3.9) For each specimen, two values are recorded corresponding to initial and ultimate failure. The first value measures the number of blows required to initiate a visible crack, whereas second value measures the number of blows required to initiate and propagate cracks until ultimate failure. Endurance limit is calculated by taking difference of these two values. For this experiment the point of ultimate failure of the specimen is declared only when it separated completely into halves.

Photograph 3.9: Impact Test

3.3.6 NON-DESTRUCTIVE TESTING OF CONCRETE
Non-destructive test have been in use for about four decades. These methods are considered effective for evaluating existing structures with regard to their strength and durability apart from assessment and control of quality of hardened concrete. Rebound hammer test from surface hardness method and Ultrasonic pulse velocity method are used for present investigation.
3.3.6.1 Rebound hammer test

Rebound hammer test is used to measure surface hardness of concrete surface. Rebound hammer can be used for:

1. assessing the likely compressive strength of concrete with the help of suitable correlations between rebound number and compressive strength,
2. assessing the uniformity of concrete,
3. assessing the quality of one element of concrete in relation to other.

Schmidt hammer is used in the present investigation to find out rebound number and establish correlation with the compressive strength of concrete. This test is conducted as per IS 13311 (part 2): 1992.

3.3.6.2 Ultrasonic Pulse Velocity Method

Ultrasonic pulse velocity method consists of measuring the time of travel of an ultrasonic wave, passing through the concrete to be tested. The pulse generator circuit consists of electronic circuit for generating pulses and transducers for transforming these pulses into mechanical energy having vibration frequencies in the range of 15 to 50 KHz. The time of travel between initial onset and the reception of the pulse is recorded electronically. The path length between transducers divided by time of travel gives average velocity of propagation. This test can be used to establish:

1. the homogeneity of concrete,
2. the presence of cracks, voids and other imperfections,
3. the quality of concrete in relation to standard requirements,
4. assessing the quality of one element of concrete in relation to other

Photograph 3.10: Ultra Sonic Pulse Velocity Test
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Ultrasonic pulse velocity method is used in the present investigation to find out ultrasonic pulse velocity and establish correlation with the compressive strength of concrete. This test is conducted as per IS 13311 (part 1): 1992 (Photograph 3.10)

3.3.7 TEMPERATURE TEST OF CONCRETE

In the case of unexpected fire, the concrete will be subjected to extreme temperatures. Hence, it is necessary to study the effect of high temperature on the compressive strength of concrete. On the basis of fire test on specially built houses Gary (1917) found that fire spalling could occur in the following forms:

- Aggregate spalling
- Surface spalling
- Corner spalling
- Explosive spalling

Sometime when concrete is exposed to fire exposed surface is flaked away in a more or less violent manner. Under some circumstances, the whole cross section of an element exposed from more than one direction can disintegrate.

In the present study concrete cubes of 100 mm dimensions are casted and cured for 28 days. Then cubes are exposed to 200 °C, 400 °C and 600 °C temperature and maintained at this temperature for one hour. The cubes are tested for residual compressive strength. Efforts have also been made by researchers to study the effect of high temperature on self-compacting concrete.

3.3.8 WATER PERMEABILITY OF CONCRETE

Concrete is generally considered as three phase material i.e. paste phase, aggregate phase and transition zone. Aggregates are dispersed in a matrix of cement paste. Third phase, transition zone represents the interfacial region between the coarse aggregate and hardened cement paste. In concrete, aggregates tend to trap a large amount of mixing water. During vibration of the concrete a part of the extra water appears on the surface as the bleed water, but large amount of water still remains internally trapped near aggregates. This results in high porosity and low density structure in transition zone than paste matrix. Micro cracks are developed in transition zone due to drying shrinkage. When structure is loaded, these micro cracks propagate and bigger cracks are formed resulting in the failure of bond. These cracks are also responsible for permeability in concrete. These cracks interconnect to form channels of flow for outside aggressive chemicals such as chloride and sulphate get to get into concrete.
causing deterioration processes. In practice, several degradation mechanisms can act simultaneously with possible synergetic effects. Figure 3.3 illustrates how different degradation mechanisms can act on concrete.

**Figure 3.3: Degradation Mechanisms of Concrete**

Water Permeability tests is carried out as per specification laid down in IS 3085-1965 on 15 cm cube size. The permeability apparatus consist of permeability cell, control panel and glass bottles for collecting water. Figure of permeability apparatus is appended as Annexure III

**Procedure:**

1. **Preparation of specimen** - Concrete cube of 15 cm size is placed in the permeability cell. The space between cell and the specimen is tightly caulked to a depth of about 10mm using cotton soaked in sealing compound. A mixture of bee-wax and rosin are effective sealing compound.

2. **Testing the seal** - For checking water tightness of seal, the cell is inverted and air pressure of 1-2 kg/cm$^2$ is applied. A little water is poured on the exposed faces of specimen to detect leakage. In the case of leakage the specimen is taken out and resealed.

3. **Assembling the Permeability apparatus** - After satisfactory sealing of the specimen the funnel is secured in position. The cell assembly is connected to the water reservoir. Water is drained through the drain cock. Drain cock is closed and water reservoir is filled. The reservoir water inlet and air bleeder valves are closed.

4. **Running the test** - With the system completely filled with water desire pressure (between 5 to 15 kg/cm$^2$) is applied to water and initial reading of the gauge glass is recorded. A glass bottle is placed glass bottle in position to collect water.
Quantity of water collected and the gauge glass reading is recorded at periodic intervals. In the beginning rate of water intake is larger than the rate of outflow. When the steady state is reached the two rates tend to become equal and the outflow reaches maximum. With passage of time flow register a drop. The test is continued for 100 hours after reaching steady state of flow. The coefficient of permeability is calculated by formula

\[
K = \frac{Q}{AT \frac{H}{L}}
\]

Where
- \( K \) = Coefficient of permeability in cm/sec
- \( Q \) = Quantity of water collected in ml
- \( A \) = Area of specimen in cm\(^2\)
- \( T \) = Time in seconds over which \( Q \) is collected
- \( \frac{H}{L} \) = Ratio of pressure head to thickness of specimen in same unit

**Photograph 3.11: Permeability Test**

After the discussions on the test procedures for determining the properties of self-compacting concrete in fresh and hardened state the flow chart of the experimental investigation has been presented in figure 3.4.

Properties of ingredients/ materials used in the present study have been determined using relevant BIS codes.
3.4 PROPERTIES OF INGREDIENTS/MATERIALS

Materials required for self-compacting concrete are cement, fine aggregate, coarse aggregate, chemical admixtures, fillers and water. Maximum size of coarse aggregate has been limited to 20 mm. However, size more than 20 mm could also have been used if need developed. Fine aggregates have to be natural or manufactured. Chemical admixtures like superplasticizer are essential components of self-compacting concrete, required to provide necessary workability. In most cases viscosity modifying agents are also used in the development of self-compacting concrete as it allows more fluid mixtures without the risk of segregation and improving the placing rate of concrete. It also compensates small changes in the properties of ingredient as also the variation in the moisture content of aggregate with more filler or powder content. Use of waste materials like flyash, rice husk ash, and granulated blast furnace slag etc., helps in the effective utilisation of available resources in future.

This project work is an attempt to find out an alternative to the productive utilization of agricultural waste Rice Husk Ash and thermal power plant byproduct flyash as part replacement of cement in developing self compacting concrete, which would otherwise have to be disposed of harming the ecology. The material used in the present investigation confirmed to the specifications laid down in the relevant Indian Standard Codes. The detailed characteristics of the materials are as follows:

3.4.1 Cement

Ordinary Portland cement 43 grade (OPC 43) (J. K. Lakshmi make) was used for investigation. The physical properties of the cement conforming to Indian Standard IS: 8112-1989 are listed in Table3.2. All the tests were carried out as per recommendations of IS: 4031-1988.
Chapter 3  Experimental Programme

Flow Chart for Work

Properties of Ingredients

Mortar Flow Test

SCC Trial Mixes

Tests on Fresh Properties of SCC
1. Slump flow Test
2. J-Ring Test
3. V Funnel Test
4. U-Box Test
5. L-Box Test
6. Orimet Test
7. Fill Box Test
8. GTM Screen Stability Test

Tests on Hardened Properties of SCC
1. Compressive Strength
2. Split Tensile Strength
3. Flexural Tensile Strength
4. Abrasion Resistance Test
5. Impact Test on SCC
6. Non-Destructive Testing of Concrete
7. Temperature Test of Concrete
8. Water Permeability of concrete

Analysis and Discussion of Test Results

Conclusion

Figure 3.4 Flow Chart of Work

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### Table 3.2: Physical Properties of Cement

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Units</th>
<th>Results Obtained</th>
<th>Specified Value as Per IS:8112-1989</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blaine’s Fineness</td>
<td>cm²/gm</td>
<td>3050</td>
<td>3500 (Maximum)</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>-</td>
<td>3.15</td>
<td>-</td>
</tr>
<tr>
<td>Soundness (Le Chatelier Test)</td>
<td>mm</td>
<td>2.1</td>
<td>10 (Maximum)</td>
</tr>
<tr>
<td>Normal Consistency (Percent of cement by weight)</td>
<td>%</td>
<td>28</td>
<td>-</td>
</tr>
<tr>
<td>Setting Time</td>
<td>minutes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Initial</td>
<td>100</td>
<td>30 (minimum)</td>
<td>600 (Maximum)</td>
</tr>
<tr>
<td>2. Final</td>
<td>190</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compressive Strength</td>
<td>MPa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. 3 days</td>
<td>25.5</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>2. 7 days</td>
<td>35</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>3. 28 days</td>
<td>44.5</td>
<td>43</td>
<td></td>
</tr>
</tbody>
</table>

3.4.2 Flyash, Rice husk ash and Micro-silica

A low calcium flyash obtained from the electrostatic precipitator of Shri Guru Gobind Singh Super Thermal Plant at Ropar was used.

The Rice husk ash was obtained from Punjab Chemical and Crop Protection Ltd. PCPL, Derabassi. Physical and chemical properties obtained are presented in Table 3.3 and Table 3.4.

### Table 3.3: Physical Properties of Flyash, RHA and Micro silica

<table>
<thead>
<tr>
<th>S No</th>
<th>Property</th>
<th>Flyash</th>
<th>RHA</th>
<th>Micro Silica</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Specific Gravity</td>
<td>2.08</td>
<td>2.06</td>
<td>2.20</td>
</tr>
<tr>
<td>2</td>
<td>Blaine’s Fineness</td>
<td>3260</td>
<td>3000</td>
<td>22000</td>
</tr>
</tbody>
</table>

### Table 3.4: Chemical Composition of RHA and Flyash

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Rice Husk Ash (%)</th>
<th>Flyash From GGSTP, Ropar (%)</th>
<th>Micro silica</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>86.01</td>
<td>60.53</td>
<td>95</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>01.40</td>
<td>27.27</td>
<td>-</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>00.01</td>
<td>04.18</td>
<td>-</td>
</tr>
<tr>
<td>CaO</td>
<td>01.90</td>
<td>01.04</td>
<td>-</td>
</tr>
<tr>
<td>MgO</td>
<td>0</td>
<td>00.40</td>
<td>-</td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>05.66</td>
<td>2.11</td>
<td>2.80</td>
</tr>
</tbody>
</table>
Microsilica from APEX India Ltd was used for experimental investigations. The physical and chemical properties of flyash satisfied the requirements of IS: 3812-1981, RHA satisfied requirements of BIS Code whereas Micro-silica satisfies requirement of IS 15388-2003.

3.4.3 Fine Aggregate and Coarse aggregate

Locally available river sand was used as fine aggregate and locally available crushed stone aggregates were used as coarse aggregates. Physical properties of fine and coarse aggregates are listed in Table 3.5.

Table 3.5: Physical Properties of Aggregates

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Property</th>
<th>Results Obtained</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Coarse Aggregate</td>
</tr>
<tr>
<td>1</td>
<td>Specific Gravity</td>
<td>2.68</td>
</tr>
<tr>
<td>2</td>
<td>Loose Bulk Density (Kg/m³)</td>
<td>1480</td>
</tr>
<tr>
<td>3</td>
<td>Packed Bulk Density (Kg/m³)</td>
<td>1604</td>
</tr>
</tbody>
</table>

Results of sieve analysis of fine aggregate and coarse aggregate are highlighted in Table 3.7 and Table 3.6 respectively.

Table 3.6: Sieve Analysis of Fine Aggregates

<table>
<thead>
<tr>
<th>IS Sieve Designation</th>
<th>Weight Retained (Grams)</th>
<th>Cumulative Percentage Weight Retained</th>
<th>Cumulative Percentage Weight Passing</th>
<th>Recommended Permissible Values as per IS:383 for Grading Zone III</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 mm</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>4.75 mm</td>
<td>54</td>
<td>5.4</td>
<td>94.6</td>
<td>90-100</td>
</tr>
<tr>
<td>36 mm</td>
<td>42</td>
<td>9.6</td>
<td>90.4</td>
<td>85-100</td>
</tr>
<tr>
<td>1.18 mm</td>
<td>124</td>
<td>22</td>
<td>78</td>
<td>75-100</td>
</tr>
<tr>
<td>600 micron</td>
<td>142</td>
<td>36.2</td>
<td>63.8</td>
<td>60-79</td>
</tr>
<tr>
<td>300 micron</td>
<td>402</td>
<td>76.4</td>
<td>23.6</td>
<td>12-40</td>
</tr>
<tr>
<td>150 micron</td>
<td>206</td>
<td>97</td>
<td>3</td>
<td>0-10</td>
</tr>
<tr>
<td>Residue</td>
<td>30</td>
<td>100</td>
<td>0</td>
<td>-</td>
</tr>
</tbody>
</table>

80
### Table 3.7: Sieve Analysis of Coarse Aggregates

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Cumulative Percentage Weight Passing</th>
<th>Recommended Permissible Values as per IS:383 for 20 mm Graded Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20 mm</td>
<td>10mm</td>
</tr>
<tr>
<td>20 mm</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>16 mm</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>12.5 mm</td>
<td>98.5</td>
<td>98.2</td>
</tr>
<tr>
<td>10mm</td>
<td>87.3</td>
<td>95</td>
</tr>
<tr>
<td>4.75 mm</td>
<td>39.4</td>
<td>34.7</td>
</tr>
<tr>
<td>2.36 mm</td>
<td>0.2</td>
<td>17.85</td>
</tr>
<tr>
<td>1.18 mm</td>
<td>8.4</td>
<td>0</td>
</tr>
<tr>
<td>600 micron</td>
<td>7.5</td>
<td>0</td>
</tr>
<tr>
<td>300 micron</td>
<td>6.14</td>
<td></td>
</tr>
<tr>
<td>150 micron</td>
<td>4.4</td>
<td></td>
</tr>
</tbody>
</table>

### 3.4.4 Water

The water used for both mixing and curing purpose was free from deleterious impurities. Potable tap water was used in the present investigation.

### 3.4.5 Superplasticizer

A commercially available Polycarboxylic Ether based superplasticizer (Glenium B233) was used for experimentation.

### 3.5 Mortar Flow Test for Present Investigation

Mortar mixes were prepared by taking powder content consisting of cement and flyash equal to 400 gm and fine aggregate 580 gm. Proportion of cement and flyash was taken as 50:50. The powder /fine aggregate ratio was maintained at 1:1.45. The superplasticizer added was 1.5 % by weight of powder. The dosage was decided to achieve reasonable degree of spread. Water/powder ratio by volume was varied from 1 to 1.3 to determine \( \beta \) i.e. water/powder ratio for zero flow. The mixing process for all the mixes was kept the same. The process involved mixing of the powder and sand for a minute in pan mixer. Then three quarters of the mixing water was added and mixed for an extra minute. Later on, the premixed chemical admixture and remaining water were added and the mortar was mixed for an additional three minutes. The flow cone was lubricated by applying oil. After the mixing was complete, slump flow diameters \( d_1 \) and \( d_2 \) were measured.

The relative slump flow was calculated using formula...
Chapter 3 Experimental Programme

Relative Slump Flow

Figure 3.5: Graph of Relative Slump Flow for Cement, Flyash and Mortar

The W/P ratio obtained from graph corresponding to zero slump flow is 0.81.

\[ W/P = \left( \frac{d}{d_0} \right)^2 \] where \[ d = \frac{d_1 + d_2}{2} \] and \[ d_0 = 100 \text{mm} \] i.e. bottom dia of flow cone

Results thus obtained have been reproduced in Table 3.8

<table>
<thead>
<tr>
<th>W/P ratio</th>
<th>Average Flow Dia d</th>
<th>Relative Slump flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>155</td>
<td>1.40</td>
</tr>
<tr>
<td>1.1</td>
<td>188</td>
<td>2.53</td>
</tr>
<tr>
<td>1.2</td>
<td>220</td>
<td>3.84</td>
</tr>
<tr>
<td>1.3</td>
<td>242</td>
<td>4.86</td>
</tr>
</tbody>
</table>

Graph of W/P ratio vs. Relative Slump flow has also been plotted and shown as figure 3.5

![Graph of W/P ratio vs. Relative Slump flow](image)

Figure 3.5: Graph of Relative Slump Flow for Cement, Flyash and Mortar

The W/P ratio obtained from graph corresponding to zero slump flow is 0.81.

- Water = Volume of Powder * 0.81

\[ \begin{align*}
W &= (\frac{200}{3.15} + \frac{200}{2.08}) \times 0.81 \\
&= 159.65 \times 0.81 \\
&= 129.3 \text{ ml by Volume} \\
&= 129.3 \text{ gm}
\end{align*} \]

- Water/ Powder ratio by weight = 129.3 gm/400 gm

- Water/ Powder ratio by weight = 0.32

Prabir Basu (2007) at el. carried out mortar test by this method for verifying the impact of fine aggregate particle size on mortar rheology for SCC.

Mortar test was repeated on blend of Cement, flyash and Rice husk ash to study the effect of Rice husk ash on rheology of mortar. The proportion Cement, Flyash and
Rice husk ash was taken as 50: 40:10, taking the powder/fine aggregate ratio same as 1: 1.45 by weight. The results are given below in Table 3.9.

<table>
<thead>
<tr>
<th>W/P ratio</th>
<th>Average Flow Dia</th>
<th>Relative Slump flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>115</td>
<td>0.32</td>
</tr>
<tr>
<td>1.1</td>
<td>148</td>
<td>1.19</td>
</tr>
<tr>
<td>1.2</td>
<td>180</td>
<td>2.24</td>
</tr>
<tr>
<td>1.3</td>
<td>115</td>
<td>3.08</td>
</tr>
</tbody>
</table>

Graph of W/P ratio vs. Relative Slump flow was plotted (Figure 3.6)

The W/P ratio obtained from graph corresponding to zero slump flow is 0.9.

\[ \text{Water} = \text{Volume of Powder} \times 0.9 \]

\[ = \left( \frac{200}{3.15} + \frac{160}{2.08} + \frac{40}{2.06} \right) \times 0.9 \]

\[ = 159.83 \times 0.9 \]

\[ = 143.85 \]

- Water/Powder ratio by weight = 143.85/400
- Water/Powder ratio by weight = 0.36

The mortar flow test result shows the approximate minimum dose of superplastizer as 1.5 % and water/powder ratio as 0.81 to 0.90 for flowability.
3.6 MIXING PROCESS

The mixing sequence of SCC is different from that of ordinary concrete due to high powder content and hence high dose of superplasticizer to achieve self compactability was desirable. Literature review shows that mixing order is one of the important factors affecting rheological and hardened properties of self compacting concrete. The proper mixing order depends on the type of mineral admixture, mix proportion and the type of superplasticizer used. Two mixing order which have been mostly used by researchers have been verified for this research (figure 3.7 and 3.8). In the present study a tilting drum type of laboratory mixer was used for mixing the material.

First Mixing Order:

```
Fine Aggregate + Coarse Aggregate + Cement

Mixing for 1 Minute

Flyash + Rice husk ash + ½ Water + ½ Super plasticizer

Mixing for 1 Minute

Remaining ½ Water + ½ Super plasticizer

Mixing for 2 Minutes

Finish
```

Figure 3.7: First Mixing Order
Second Mixing Order:

```
<table>
<thead>
<tr>
<th>Fine Aggregate + Coarse Aggregate + 1/3 water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixing for 1 Minute</td>
</tr>
<tr>
<td>Cement + Flyash + Rice husk ash + 1/3 water + ½ Superplasticizer</td>
</tr>
<tr>
<td>Mixing for 1 Minute</td>
</tr>
<tr>
<td>Remaining 1/3 Water + ½ Superplasticizer</td>
</tr>
<tr>
<td>Mixing for 2 Minutes</td>
</tr>
<tr>
<td>Finish</td>
</tr>
</tbody>
</table>
```

**Figure 3.8: Second Mixing Order**

Out of the two mixing order, the second mixing order was found to be more suitable for producing self compacting concrete under test. Addition of the aggregates followed by the addition of cementing materials increases the effectiveness of superplasticizer and avoids the loss of superplasticizer through adsorption by the aggregates. (Photograph 3.12)

**Photograph 3.12: Mixing of Self Compacting Concrete**
3.7 SPECIMEN DETAILS

Cubes, cylinders and beams were casted for testing various properties.

Table 3.10: Details of Specimen used for Experimentation

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Testing Details</th>
<th>Type of Specimen (Size)</th>
<th>No of Specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Compressive strength</td>
<td>Cube (150 X 150 X 150 mm)</td>
<td>780</td>
</tr>
<tr>
<td>2</td>
<td>Split Tensile Test</td>
<td>Cylinder (150 mm dia X 300 mm)</td>
<td>195</td>
</tr>
<tr>
<td>3</td>
<td>Flexural Strength Test</td>
<td>Beam (150 X 150 X 700 mm)</td>
<td>195</td>
</tr>
<tr>
<td>4</td>
<td>Water Permeability</td>
<td>Cube (150 X 150 X 150 mm)</td>
<td>195</td>
</tr>
<tr>
<td>5</td>
<td>Temperature Test</td>
<td>Cube (100 X 100 X 100 mm)</td>
<td>260</td>
</tr>
<tr>
<td>6</td>
<td>Impact Test</td>
<td>Cylindrical Sample (150 mm dia X 62 mm)</td>
<td>195</td>
</tr>
<tr>
<td>7</td>
<td>Abrasion Test</td>
<td>Cube (70 X 70 X 25 mm)</td>
<td>195</td>
</tr>
<tr>
<td>8</td>
<td>Non-destructive Test</td>
<td>Cube (150 X 150 X 150 mm)</td>
<td>195</td>
</tr>
</tbody>
</table>

3.8. CASTING AND CURING OF SPECIMEN

The casting of various specimens was done under laboratory conditions using standard equipment. After the specimens were demoulded, they were placed for curing for the desired duration.

Photograph 3.13: Cylindrical Samples Used for Split Tensile Test
3.9 SCC MIX TRIAL MIXES
After determining the approximate dose of superplasticizer and water powder ratio for zero flow. Trials mixes were designed and tested for fresh properties of Self Compacting Concrete.

3.9.1 SCC Trial Mix Design
SCC Trial mixes were designed. The procedure adopted is as follows.
Using Japanese method of mix design, initial mix design was carried out at coarse aggregate content of 50 percent by volume of concrete and fine aggregate content of 40 percent by volume of mortar in concrete, the water/powder ratio was kept at 0.81.
Pratibha Aggarwal et al. (2008) has used Japanese Method for mix design.
Anduri Sreenivasaulu, Dr. R. Rama Seshu & Ch. Ch. Srinivas (2007) having reviewed different mix design methods of SCC adopted Japanese method was the mix design.
Vengala et al. (2004) have described Japanese method of designing SCC mix. Most of Indian researchers have used this method for designing SCC mixes.

**SCC MIX DESIGN BY JAPANESE METHOD**

- **Mix Designation** | M1
- **Total Concrete Volume** | 1000 litres
- **Assume Air Content %** | 2.0 %
- **Air** | 20 litres
- **Net Concrete Volume** | 980 litres
- **Assume Coarse Aggregate By Volume** | 50 %
- **Coarse Aggregate** | 490 litres
- **Let Bulk Density (Rodded) of Coarse Aggregate** | 1.6 Kg/l
- **Mass of Coarse Aggregate** | 786 Kg
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- Specific Gravity of Coarse Aggregate 2.68
- Absolute Volume of Coarse Aggregate 293 litres
- Volume of Mortar In Concrete 687 litres
- Assume Fine Aggregate Content In Mortar 40 %
- Volume of Paste(Cement+Water+Filler) 60 %
- Volume of Paste(Cement+Water+Filler) 412 liters
- Let Water/Paste Ratio 0.81
- Water 184 litres
- Powder 228 litres
- Let % of Cement In Powder be 72.49 %
- % of Filler In Powder 27.51 %
- Volume of Cement 165 litres
- Volume of Filler 63 litres
- Specific Gravity of Cement 3.15
- Specific Gravity of Filler 2.08
- Mass of Cement=Volume x Sp.Gr 520 Kg
- Mass of Filler=Volume x Sp.Gr 130 Kg
- Total Powder 650 Kg
- Fine Aggregate Volume 275 litres
- Specific Gravity of Fine Aggregate 2.626
- Mass of Fine Aggregate=Volume x Sp.Gr 721 Kg
- Total Mass of Concrete=Ca+Fa+Water+Powder 2343 Kg

Summary of Volume Fractions
- Volume of Coarse Aggregate Vca 0.29
- Volume of Fine Aggregate Vfa 0.27
- Volume of Paste Vpaste 0.41
- Volume of Air 0.02
- Water Powder Ratio By Volume 0.81

First Trial Mix Proportion obtained was

<table>
<thead>
<tr>
<th>Cement (Kg/m³)</th>
<th>Flyash (Kg/m³)</th>
<th>FA (Kg/m³)</th>
<th>CA (Kg/m³)</th>
<th>Water (Kg/m³)</th>
<th>SP (%)</th>
<th>VMA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>520</td>
<td>130</td>
<td>721</td>
<td>786</td>
<td>184</td>
<td>1.5</td>
<td>0.03</td>
</tr>
</tbody>
</table>

These trial mixes were tested for fresh properties of self-compacting concrete.
After determining the dosage of superplasticizer and water powder ratio the trial mix for developing SCC was designed using Japanese method. Initial mix design was developed using coarse aggregate content of 50 percent by volume of concrete and fine aggregate content of 40 percent by volume of mortar in concrete and the water/powder ratio was kept at 0.81. The first trial mix proportion obtained according to mix design has been detailed as under:

<table>
<thead>
<tr>
<th>Cement (Kg/m³)</th>
<th>Flyash (Kg/m³)</th>
<th>FA (Kg/m³)</th>
<th>CA (Kg/m³)</th>
<th>Water (Kg/m³)</th>
<th>SP (Kg/m³)</th>
<th>VMA (%)</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>520</td>
<td>130</td>
<td>721</td>
<td>786</td>
<td>184</td>
<td>1.5</td>
<td>0.03</td>
<td></td>
</tr>
</tbody>
</table>

As these proportions of Self compacting concrete properties did not yield the desired results, the subsequent trial mixes were developed and tested for the desired properties. The second trial mix was obtained by reducing the coarse aggregate content to 45% by volume of concrete whereas fine aggregate content was kept constant at 40% by volume of mortar in concrete and the proportion of ingredients so obtained were:

<table>
<thead>
<tr>
<th>Cement (Kg/m³)</th>
<th>Flyash (Kg/m³)</th>
<th>FA (Kg/m³)</th>
<th>CA (Kg/m³)</th>
<th>Water (Kg/m³)</th>
<th>SP (Kg/m³)</th>
<th>VMA (%)</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>513</td>
<td>129</td>
<td>724</td>
<td>708</td>
<td>184</td>
<td>1.5</td>
<td>0.03</td>
<td></td>
</tr>
</tbody>
</table>

However, using these proportions gave unsatisfactory slump, flow and high segregation in concrete. This mix also could not satisfy V funnel, L box, U box and Orimet test.

In order to achieve desired SCC, further trials were conducted by reducing the contents of coarse aggregate from 45% to 37% and increasing fine aggregate contents from 40% to 47.5% and subsequently increasing superplasticizer content from 1.5 to 2%. The changes in the aggregate content and fine aggregate content have been affected in the tune with the research work carried out by other researchers as highlighted in the literature review. Mix Design using Japanese Method has been appended as Annexure-1. Third trial mix proportions are given as under:

<table>
<thead>
<tr>
<th>Cement (Kg/m³)</th>
<th>Flyash (Kg/m³)</th>
<th>FA (Kg/m³)</th>
<th>CA (Kg/m³)</th>
<th>Water (Kg/m³)</th>
<th>SP (Kg/m³)</th>
<th>VMA (%)</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>480</td>
<td>120</td>
<td>950</td>
<td>582</td>
<td>192</td>
<td>2</td>
<td>0.03</td>
<td></td>
</tr>
</tbody>
</table>

This mix proportion satisfied acceptance criteria for rheological properties of SCC conforming to EFNARC standards. Considering this mix as reference mix few trials were conducted by altering the mix proportions details of which are shown in Table 3.11.
3.9.2 Determination of properties in fresh state and Compressive Strength for Trial Mixes

However, total powder content was kept constant at 600 Kg/m³ for all mixes. Trials were conducted by replacing cement content in varying proportions of 40%, 30%, 25% and 20% of the powder content and altering proportions of flyash and raw RHA thereby increasing water powder ratio till acceptance criteria for rheological properties of SCC laid down by EFNARC was satisfied. Trial mixes are shown in Table 3.11.

Table 3.11: MIX PROPORTIONS FOR SCC TRIAL MIXES

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Mix</th>
<th>Cement (Kg/m³)</th>
<th>Flyash (Kg/m³)</th>
<th>RHA (Kg/m³)</th>
<th>FA (Kg/m³)</th>
<th>CA (Kg/m³)</th>
<th>Water (Kg/m³)</th>
<th>SP (%)</th>
<th>W/P Ratio (By Volume)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SCC1</td>
<td>360</td>
<td>216</td>
<td>24</td>
<td>951</td>
<td>583</td>
<td>180</td>
<td>1.5</td>
<td>0.78</td>
</tr>
<tr>
<td>2</td>
<td>SCC2</td>
<td>450</td>
<td>142.5</td>
<td>7.5</td>
<td>920</td>
<td>614</td>
<td>210</td>
<td>2</td>
<td>0.98</td>
</tr>
<tr>
<td>3</td>
<td>SCC3</td>
<td>450</td>
<td>135</td>
<td>15</td>
<td>920</td>
<td>614</td>
<td>215</td>
<td>2</td>
<td>1.00</td>
</tr>
<tr>
<td>4</td>
<td>SCC4</td>
<td>450</td>
<td>127.5</td>
<td>22.5</td>
<td>920</td>
<td>614</td>
<td>225</td>
<td>2</td>
<td>1.05</td>
</tr>
<tr>
<td>5</td>
<td>SCC5</td>
<td>450</td>
<td>120</td>
<td>30</td>
<td>920</td>
<td>614</td>
<td>225</td>
<td>2</td>
<td>1.05</td>
</tr>
<tr>
<td>6</td>
<td>SCC6</td>
<td>480</td>
<td>120</td>
<td>0</td>
<td>950</td>
<td>582</td>
<td>192</td>
<td>2</td>
<td>0.91</td>
</tr>
<tr>
<td>7</td>
<td>SCC7</td>
<td>420</td>
<td>162</td>
<td>18</td>
<td>951</td>
<td>583</td>
<td>240</td>
<td>2</td>
<td>1.09</td>
</tr>
</tbody>
</table>

For each mix as highlighted above, Slump flow test, V-funnel test, U box test, L-Box, Orimet test and GTM Screen stability test were carried out and the test results of rheological properties have been summarized and placed under the Table 3.12

Table 3.12: Rheological Properties of SCC Trial Mixes

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Mix</th>
<th>Slump Flow (mm)</th>
<th>V-funnel Flow Time (Seconds)</th>
<th>U-box (h₂-h₁) Filling height (mm)</th>
<th>L-box (h₂/h₁) (Blocking Ratio)</th>
<th>Orimet Flow Time (Seconds)</th>
<th>GTM Screen Test (Segregation Ratio %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Values</td>
<td>Min-Max</td>
<td>600-800</td>
<td>0-10</td>
<td>0-30</td>
<td>0.8-1</td>
<td>0-5</td>
<td>5-15</td>
</tr>
<tr>
<td>1</td>
<td>SCC1</td>
<td>400</td>
<td>15</td>
<td>40</td>
<td>0.78</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>SCC2</td>
<td>735</td>
<td>8</td>
<td>05</td>
<td>1.0</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>SCC3</td>
<td>670</td>
<td>9</td>
<td>10</td>
<td>0.95</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>SCC4</td>
<td>650</td>
<td>10</td>
<td>12</td>
<td>0.90</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>SCC5</td>
<td>615</td>
<td>12</td>
<td>20</td>
<td>0.89</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>SCC6</td>
<td>750</td>
<td>10</td>
<td>10</td>
<td>0.90</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>SCC7</td>
<td>650</td>
<td>12</td>
<td>12</td>
<td>0.85</td>
<td>5</td>
<td>08</td>
</tr>
</tbody>
</table>

The slump flow characteristics of the trial mixes were found to be between 615 and 750 mm, which were within the EFNARC requirements (Figure 3.9). It has been observed that slump flow improves with increase in flyash content whereas V funnel
time increased from 8 to 12 seconds with increasing Rich husk ash content indicating increase in viscosity of concrete(Figure 3.10). U- Box filling height results were within range of 8 to 20 mm and satisfy the standard requirement. The results obtained have been reproduced in the form of bar chart and compared with the standard values as laid down by EFNARC standards by drawing a longitudinal dotted line for ready reference of the behaviour of concrete properties. (Figure 3.11)
Orimet flow time for different trial mixes has been obtained in the range of 3 to 5 seconds which is within the acceptable range as laid down by EFNARC. (Figure 3.12) L-Box blocking ratio which indicates the degree to which the passage of concrete through the bars is restricted has been observed to decrease with increasing Rice husk ash content. However, the blocking ratios achieved in the L-box test have been as per requirement of desired SCC mixes (Figure 3.13). GTM screen stability test results found to vary from 5 to 15% as per requirements of SCC. Thus mix SCC1 does not fulfill all the requirements of the SCC mix whereas SCC2 to SCC7 trial mixes satisfied all the properties of SCC mixes. (Figure 3.14)

SCC trial mixes when tested for 7 and 28 days compressive strength results, show that an increase in Rice husk ash content in mixes (SCC2 to SCC5) from 7.5 kg/m³ to 30 kg/m³ increases the water requirement of mixes, thereby decreasing 7 day strength from 28 to 23.56 MPa and 28 days strength from 38 MPa to 27 MPa. (Table 3.13).
The ambient temperature during study was in the range of 10°C to 12°C which could have possibly retarded the strength gain of concrete. Higher ambient temperature conditions could have helped in better gain in concrete strength at early ages. Higher strength can be also achieved by using of finer flyash and rice husk ash.

### 3.8 CONCLUSIONS

The testing programme and methodology to be adopted as planned has been explained in this chapter to achieve the listed objectives of the present investigation. The procedure adopted for testing fresh and hardened properties of concrete have also been described. Hardened and fresh properties of SCC trial mixes have been discussed in the chapter. Experimental investigations on cement–flyash and cement-flyash–RHA mortar has been carried out to determine superplasticizer dosage and water-powder ratio. SCC trial mix design details, specimen details and method of casting and curing have been discussed in details. Fresh and hardened properties of SCC trail mixes have been investigated experimentally. The test data and results of experimental investigation as obtained have been explained and analysed in detail in the ensuing chapters.