CHAPTER-4

METHODOLOGY
4.1 Mix Proportion Designation

The common method expressing the proportion of ingredients of a concrete in the terms of parts of ratios of cement, fine and coarse aggregates. For e.g. a concrete mix of proportions 1:2:4 means that cement, fine and coarse aggregate are in the ratio 1:2:4. The proportions are either by volume or by mass.

4.1.1 Factors To Be Considered For Mix Design

The design of concrete mix will be based on the following factors:

Table 4.1: Grades Of Concrete (IS456, 2000)clause 6.1)

<table>
<thead>
<tr>
<th>Grade Designation</th>
<th>Specified Characteristic Compressive Grade Designation Strength In N/Mm² At 28 Days Curing</th>
</tr>
</thead>
<tbody>
<tr>
<td>M 10</td>
<td>10</td>
</tr>
<tr>
<td>M 15</td>
<td>15</td>
</tr>
<tr>
<td>M 20</td>
<td>20</td>
</tr>
<tr>
<td>M 25</td>
<td>25</td>
</tr>
<tr>
<td>M 30</td>
<td>30</td>
</tr>
<tr>
<td>M 35</td>
<td>35</td>
</tr>
<tr>
<td>M 40</td>
<td>40</td>
</tr>
<tr>
<td>M 45</td>
<td>45</td>
</tr>
<tr>
<td>M 50</td>
<td>50</td>
</tr>
<tr>
<td>M 55</td>
<td>55</td>
</tr>
<tr>
<td>M 60</td>
<td>60</td>
</tr>
</tbody>
</table>
In the designation of a concrete mix M refers to the mix design and the number to the specified characteristic compressive strength of 15 cm$^3$ cube at 28 days curing expressed in N/mm$^2$. M 15 and less grades of concrete may be used for lean concrete bases and simple foundation for masonry walls. Grades of concrete lower than M 20 shall not be used in reinforced concrete structure as per 456-2000. Grades of concrete lower than M 30 shall not be used in pre stressed concrete structure. (IS456, 2000)

i. **Maximum nominal size of aggregate:** It is found that larger the size of aggregate, smaller is the cement requirement for particular water cement ratio. Aggregates having a maximum nominal size of 20mm or smaller are generally considered satisfactory.

ii. **Minimum water-cement ratio:** The minimum w/c ratio for specified strength depends on the type of cement.

iii. **Workability:** The workability of concrete for satisfactory placing and compaction is related to the size and shape of the section to be concreted.

### 4.1.2 Target Mean Strength

Considering the inherent variability of concrete strength during production it is necessary to design the mix to have a target mean strength which is greater than characteristic strength by a suitable margin.

$$f_t = f_{ck} + 1.65 \times S$$

where,

- $f_t$ = Target mean strength
- $f_{ck}$ = Characteristic strength
S = Standard deviation of the particular mix which is available in IS 456-2000. The value of k is equal to 1.65 as per IS 456-2000 where not more than 5% of the test results are expected to fall below the characteristics strength.

Table: 4.2 Assumed Standard Deviation (S) (IS10262, Concrete mix proportioning, 2009) clauses 3.2.1.2, A-3 and B-3)

<table>
<thead>
<tr>
<th>Grade Of Concrete</th>
<th>M10</th>
<th>M15</th>
<th>M20</th>
<th>M25</th>
<th>M30</th>
<th>M35</th>
<th>M40</th>
<th>M50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Deviation (N/mm²)</td>
<td>3.5</td>
<td>3.5</td>
<td>4.0</td>
<td>4.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
</tr>
</tbody>
</table>

4.1.3 Procedure

i. Determine the mean target strength \( f_t \) from the specified characteristic compressive strength at 28-day \( f_{ck} \) and the level of quality control.

\[ f_t = f_{ck} + 1.65 \, S \]

where S is the standard deviation obtained from the table of approximate content given after the design mix.

ii. Obtain the water cement ratio for the desired mean target using the empirical relationship between compressive strength and water cement ratio so chosen is checked against the limiting water-cement ratio. The water cement ratio so chosen is checked against the limiting water cement ratio for the requirements of durability given in Table and adopt the lower of the two values.
iii. Estimate the amount of entrapped air for maximum nominal size of the aggregate from the table.

iv. Select the water cement, for the required workability and the maximum size of aggregates (for aggregates in saturated surface dry condition) from table.

v. Determine the percentage of fine aggregates in total aggregate by absolute volume from table for the concrete using crushed coarse aggregate.

vi. Adjust the values of water content and percentage of sand as provided in the table for any difference in workability, water cement ratio, grading of fine aggregate and for rounded aggregate, the values are given in table.

vii. Calculate the cement content from the water cement ratio and the final water content as arrived after adjustment. Check the cement against the minimum cement content from the requirements of the durability, and greater of the two values is adopted.

viii. From the quantities of water and cement per unit volume of concrete and the percentage of sand already determined in steps F and G above, calculate the content of coarse and fine aggregate per unit volume of concrete from the following relations:

\[ V = \left[ W + \frac{C}{S_c} + \frac{1}{P} \frac{f_a}{S_{fa}} \right] \times \frac{1}{1000} \]

\[ V = \left[ W + \frac{C}{S_c} + \frac{1}{1 - P} \frac{C_a}{C_{ca}} \right] \times \frac{1}{1000} \]

where \( V \) = Absolute volume of concrete

\[ = \text{Gross volume (1 m}^3\text{)} \text{ minus the volume of entrapped air} \]
\( S_c = \text{Specific gravity of cement} \)

\( W = \text{Mass of water per metre cube of concrete, in kg} \)

\( C = \text{Mass of cement per metre cube of concrete, in kg} \)

\( p = \text{Ratio of fine aggregate to total aggregate by absolute volume} \)

\( f_a, C_a = \text{Total masses of coarse and fine aggregates, per cubic metre of concrete respectively, in kg} \)

\( S_{fa}, S_{ca} = \text{Specific gravities of saturated surface dry fine and coarse aggregates respectively.} \)

ix. Determine the concrete mix proportions for the first trial mix.

x. Prepare the concrete using the calculated proportions and cast three cubes of 150mm size and test them wet after 28-days moist curing and check for the strength.

xi. Prepare trial mixes with suitable adjustments till the final mix proportions are arrived. (IS10262, Concrete Mix Design, 2009)

### 4.2 Various Tests Carried Out For Mix Design

#### 4.2.1 Tests on Cement

#### 4.2.1.1 Determination of Fineness of Cement

A. **Purpose**

To establish the procedure for determination of fineness of cement by dry sieving.
B. Scope

The fineness of cement has an important bearing on the rate of hydration and ultimately the gain of strength.

C. Reference Document

IS:4031 (PART-1)

D. Apparatus

i. 90 micron sieve with lid and pan
ii. Balance 0.01 accuracy
iii. Brush

E. Procedure

i. Weight 100 gm. cement sieve from a standard sieve of 90 micron.

ii. Sieve continuously cement sample giving circular and vertical motion for a period of 15 minutes. Then weigh the retained mass left on sieve.

iii. After sieving the residue by weight on an IS 90 micron shall be weighed.

Acceptance Criteria = Residue on the 90 micron sieve shall not exceed 10% of the total weight of the sample. (IS4031(PART-1), 1996)

Result: 4.38 %

4.2.1.2 Determination of Normal Consistency For Cement

A. Purpose

To find out the normal consistency of cement.

B. Scope
The SOP works method of finding out normal consistency of cement as per IS:4031 Part-4.

C. Reference Document

IS:4031 (PART-4)

D. Apparatus

i. Vicat Apparatus Conforming to IS: 5513-1976.

ii. Balance


iv. Standard Weights

v. Non-Porous Plate

E. Detailed Procedure

i. Take 500 gms. of cement.

ii. Add 24% of water into cement.

iii. The paste must be prepared in a standard manner and filled into vicat mould within 3-5 minutes.

iv. After filling the mould, shake it to expel air.

v. A standard plunger is brought down to touch the surface of the paste in the test block and quickly release allowing it to sink into the paste by its own weight.

vi. Take the reading.

vii. Conduct the 2nd trial with 25% of water and take the reading.

viii. Conduct similar trials with higher w/c ratio till plunger penetrates for a depth of 33-35 mm from the top.
ix. The percentage of water at which penetration gives 33-35 mm from the top or 5-7 mm from the bottom is Standard Consistency.

Acceptance Criteria : Amount of Water as a % by mass of the dry cement. (IS4031(Part-4), 1988)

Result:

Table: 4.3 Consistency for Cement

<table>
<thead>
<tr>
<th>S. No.</th>
<th>% of Water (P)</th>
<th>Initial Reading</th>
<th>Final Reading</th>
<th>Height not penetrated (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>32</td>
<td>6</td>
<td>13</td>
<td>07</td>
</tr>
<tr>
<td>2.</td>
<td>34</td>
<td>6</td>
<td>12</td>
<td>06</td>
</tr>
</tbody>
</table>

Water required for normal consistency, \( P = 34\% \)

4.2.1.3 Determination of Setting Time of Cement

A. Purpose

Determination of Initial and Final Setting Time.

B. Scope

The time interval is retained for the cement paste/mortar/concrete for its workability while mixing, transporting, and placing.
C. **Reference Documents**

IS-4031-1988 (PART-5)

D. **Apparatus**

i. Vicat Needle Apparatus

ii. Trowel Balance

iii. Weights

iv. Stop Watch

E. **Detailed Procedure**

a) **Initial Setting Time**

i. Take 500 gm of sample.

ii. Add 85% of consistency water to produce paste.

iii. Fill paste in vicat mould within 2.5 minutes.

iv. In the beginning needle will pierce through test block but after sometime when the paste starts losing its plasticity, the needle may penetrate only to a depth 33-35 mm from the top.

v. Interval of time at which the needle penetrates to test block to a depth equal to 33-35 mm from the top is taken as initial setting time.

b) **Final Setting Time**

i. Replace vicat needle by a circular attachment.

ii. The cement shall be considered as finally set when upon lowering the attachment gently cover the surface of the test block, the concrete needle makes an impression.
iii. The circular arrangement impression not seen on the mould is considered as final setting time.

Acceptance Criteria: Initial Setting Time should not be less than 30 minutes.

Final Setting Time should not be more than 600 minutes. (IS4031(Part-5), 1988)

Result:
Initial Setting Time = 165 minutes
Final Setting Time = 270 minutes

4.2.1.4 Determination of Compressive Strength of Cement

A. Purpose

To establish the compressive strength of cement mortar.

B. Scope

The scope is to determine compressive strength of hardened cement.

C. Reference Documents

IS-4031 (PART-6) & IS : 8112-1989

D. Apparatus

i. Compression Testing Machine

ii. Cube Moulds(7.06cm)

iii. Vibrating machine/Stapula for hand compaction

iv. Measuring Cylinder and curing tank
E. Detailed Procedure

i. Take 555 grams of standard sand and 185 grams of cement (ratio of cement to sand is 1:3) in a non-porous metallic tray and mix them with the help of trowel for one minute.

ii. Add water having a quantity P/4+35 percentage of combined weight of cement and sand (P is percentage of water required for normal consistency of cement).

iii. Mix the three ingredients thoroughly until the colour of mixture becomes uniform immediately after mixing, the mortar is filled in the cube mould of size 7.06 cm. The area of the face will be equal to 50 cm². Compact the mortar either by hand compaction in a standard specified manner.

iv. Whole assembly is immersed in water at a temperature of 27 ± 2°C and kept for 24 hours.

v. Test the cube for compressive strength at the periods of 3, 7 and 28 days.

(IS4031(Part-6), 1988)

Result

Table: 4.4 Compressive Strength of Cement

<table>
<thead>
<tr>
<th>S.No</th>
<th>Type of Cement</th>
<th>Compressive strength at age of</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>3 days</td>
</tr>
<tr>
<td>1</td>
<td>Ordinary Portland cement(OPC) Grade 43</td>
<td>21 KN/mm²</td>
</tr>
</tbody>
</table>
4.2.2 Tests on Aggregate

4.2.2.1 Determination of Silt Content in Fine Aggregates

A. Purpose

To find out the Silt Content in Fine Aggregates.

B. Scope

Clay or silt may be present in aggregates in the form of surface coatings which interfere with the bond between aggregates and the cement paste and increases the amount of water necessary to wet all the particles in the mix. It is therefore essential that the aggregates should not contain silt and clay.

C. Reference Documents

IS-2386 (PART-II)

D. Apparatus

200 ml glass measuring cylinder

E. Detailed Procedure

i. Place the sample of sand into the cylinder upto 100 mm mark.

ii. prepare salt water by adding teaspoonful of salt to a pint of water.

iii. Add salt water into the cylinder upto 150 ml mark.

iv. Shake the cylinder thoroughly and allow the sand to settle for 30 minutes.
Acceptance Criteria: Silt content should not exceed 5% of the fine aggregate used. (IS2386(Part-2), 1963)

Result:

Table: 4.5 Silt Content in Fine Aggregate

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Silt Level, $h_1$ (ml)</th>
<th>Sand Level, $h_2$ (ml)</th>
<th>Silt Content $(h_1/h_2) \times 100$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>04</td>
<td>96</td>
<td>4.16</td>
</tr>
<tr>
<td>2.</td>
<td>03</td>
<td>97</td>
<td>3.09</td>
</tr>
</tbody>
</table>

Silt content in the given sample of fine sand = 3.625%

4.2.2.2 Determination of Bulking of Sand

A. Purpose

To determine the bulking of sand.

B. Scope

In concrete mix design, when the quantity of sand to be measured volumetrically, correction has to be applied for the volume increase of sand with moisture content. This can only be done if the bulking of sand is known.
C. **Reference Documents**

IS-2386 (PART-II)

D. **Apparatus**

i. Balance

ii. Measuring cylinder, 250 ml capacity

E. **Detailed Procedure**

i. Weigh dry sand 300 gm. and add 2% of water by weight and thoroughly mix.

ii. Pour the damp sand in a 250 ml measuring cylinder until it reaches the 200 ml mark.

iii. Consolidate the sand by shaking.

iv. Fill the cylinder with water and stir the sand, the water must be sufficient to submerge the sand completely. Now read the upper surface of sand.

v. Repeat the process for 2%, 4%, 6% and 8% moisture content by weight.

(IS2386(Part-3), 1963)

**Result**

**Table: 4.6 Bulking of Sand**

<table>
<thead>
<tr>
<th>% moisture content by weight</th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
<th>Sample 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Level of sand after submerging in water</td>
<td>168</td>
<td>151</td>
<td>149</td>
<td>148</td>
</tr>
<tr>
<td>% Bulking [(200-1)/x]*100</td>
<td>118.45</td>
<td>131.78</td>
<td>133.55</td>
<td>134.45</td>
</tr>
</tbody>
</table>
4.2.2.3 Determination Of Particle Size Distribution Of Fine Aggregates By Sieve Analysis

A. Purpose

To study the particle size distribution of fine aggregates by sieve analysis and to find out the fineness modulus of the given sample.

B. Scope

For the purpose of concrete mix design, the information given by sieve analysis is of prime importance.

C. Reference Documents

IS-2386 (PART-1)

D. Apparatus

i. Set of IS Sieves
ii. Balance
iii. Sieve shaker

E. Detailed Procedure

i. Weigh accurately the given air dried sample of aggregate.

ii. Place the weighted sample in the topmost sieve of the nested sieve in the sieve shaker, arranged in the order of decreasing size.

iii. Screw tightly the sieves on the sieve shaker.

iv. Operate the shaker for not less than 15 minutes for manually operated sieves.

v. Stop the shaker by switching off.
vi. Lay the material retained on each sieve on a balance and calculate the cumulative weight retained on each sieve.

vii. Obtain cumulative percentage weight retained on each sieve.

viii. Add all these percentages and divide the total by 100. The resulting figure is the fineness modulus of the given sample. (IS2386(Part-1), 1963)

**Result:**

**Table: 4.7 Fineness Modulus Test For Fine Aggregate**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Sieve Opening Size (mm)</th>
<th>Weight of sand retained (gm)</th>
<th>Percentage weight retained (%)</th>
<th>Cumulative percentage of sand retained (%)</th>
<th>Percentage of fine aggregate passing (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>4.75</td>
<td>11</td>
<td>1.1</td>
<td>1.1</td>
<td>98.9</td>
</tr>
<tr>
<td>2.</td>
<td>2.36</td>
<td>29</td>
<td>2.9</td>
<td>4.0</td>
<td>96</td>
</tr>
<tr>
<td>3.</td>
<td>1.18</td>
<td>91</td>
<td>9.1</td>
<td>13.1</td>
<td>86.9</td>
</tr>
<tr>
<td>4.</td>
<td>0.6</td>
<td>330</td>
<td>33.0</td>
<td>46.1</td>
<td>53.9</td>
</tr>
<tr>
<td>5.</td>
<td>0.3</td>
<td>425</td>
<td>42.5</td>
<td>88.6</td>
<td>11.4</td>
</tr>
<tr>
<td>6.</td>
<td>0.15</td>
<td>94</td>
<td>9.4</td>
<td>98.0</td>
<td>2.0</td>
</tr>
<tr>
<td>7.</td>
<td>Pan</td>
<td>20</td>
<td>2.0</td>
<td>100</td>
<td>0.0</td>
</tr>
</tbody>
</table>
Fineness modulus = Cumulative percentage of sand retained / 100

\[ = \frac{(1.1 + 4.0 + 13.1 + 46.1 + 88.6 + 98.0)}{100} \]

\[ = 250.9 /100 \]

\[ = 2.51 \]

Table: 4.8 Fineness Modulus Test For Coarse Aggregate

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Sieve Opening Size (mm)</th>
<th>Weight retained (gm)</th>
<th>Percentage weight retained (%)</th>
<th>Cumulative percentage weight retained (%)</th>
<th>Percentage of aggregate passing (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>20</td>
<td>207</td>
<td>4.14</td>
<td>4.14</td>
<td>95.86</td>
</tr>
<tr>
<td>2.</td>
<td>16</td>
<td>288</td>
<td>5.76</td>
<td>9.9</td>
<td>90.1</td>
</tr>
<tr>
<td>3.</td>
<td>12.5</td>
<td>690</td>
<td>13.8</td>
<td>23.7</td>
<td>76.3</td>
</tr>
<tr>
<td>4.</td>
<td>10</td>
<td>2156</td>
<td>43.12</td>
<td>66.82</td>
<td>33.18</td>
</tr>
<tr>
<td>5.</td>
<td>4.75</td>
<td>1590</td>
<td>31.8</td>
<td>98.62</td>
<td>1.38</td>
</tr>
<tr>
<td>6.</td>
<td>2.36</td>
<td>59</td>
<td>1.18</td>
<td>99.80</td>
<td>0.2</td>
</tr>
<tr>
<td>7.</td>
<td>1.18</td>
<td>10</td>
<td>0.2</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>8.</td>
<td>0.6</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>9.</td>
<td>0.3</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>10.</td>
<td>0.15</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>
Fineness modulus = Cumulative percentage of aggregate retained / 100

\[
= \frac{(4.14 + 9.9 + 23.7 + 98.62 + 99.80 +100 +100 +100 +100)}{100}
\]

\[
= 702.98 /100
\]

\[
= 7.02
\]

4.2.2.4 Determination of Specific Gravity Index of Aggregates

A. Purpose

To determine the Specific Gravity of Aggregate.

B. Scope

Specific Gravity of aggregate is used in the design calculation of design mix.

C. Reference Documents

IS-2386 (PART-3)

D. Apparatus

Pycnometer

E. Detailed Procedure

i. Weigh the pycnometer (W1).

ii. Fill 1/3rd of pycnometer with aggregate sample and weigh it (W2).

iii. Fill the remaining 2/3rd of pycnometer with water and weigh it (W3).

iv. Empty the contents of pycnometer, fill it entirely with water and weigh it (W4).

v. Calculate the specific gravity of aggregate by the formula:

\[
\text{Specific Gravity, } G_s = \frac{(W2 - W1)}{[(W4 - W1) - (W3 - W2)]}
\]
Result

Table: 4.9 Specific Gravity Test Of Fine Aggregate

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Observation</th>
<th>Trial</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Weight of specific gravity bottle, ( W_1 ) (gm)</td>
<td>21</td>
</tr>
<tr>
<td>2.</td>
<td>Weight of specific gravity bottle and one-third aggregate, ( W_2 ) (gm)</td>
<td>48</td>
</tr>
<tr>
<td>3.</td>
<td>Weight of specific gravity bottle and one-third aggregate and water, ( W_3 ) (gm)</td>
<td>88</td>
</tr>
<tr>
<td>4.</td>
<td>Weight of specific gravity bottle and water, ( W_4 ) (gm)</td>
<td>71</td>
</tr>
<tr>
<td>5.</td>
<td>Specific Gravity of the Coarse aggregate</td>
<td>2.62</td>
</tr>
</tbody>
</table>

Specific Gravity, \( G_s = \frac{(W_2 - W_1)}{\{(W_4 - W_1) - (W_3 - W_2)\}} \)

\[ = \frac{(48 - 21)}{\{(71 - 21) - (88 - 48)\}} \]

\[ = 2.65 \]
Table: 4.10 Specific Gravity Test of Coarse Aggregate

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Observation</th>
<th>Trial</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Weight of specific gravity bottle, $W_1$ (gm)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>491.0</td>
<td>2</td>
</tr>
<tr>
<td>2.</td>
<td>Weight of specific gravity bottle and one-third aggregate, $W_2$ (gm)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>811.0</td>
<td>2</td>
</tr>
<tr>
<td>3.</td>
<td>Weight of specific gravity bottle and one-third aggregate and water, $W_3$ (gm)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1407.0</td>
<td>2</td>
</tr>
<tr>
<td>4.</td>
<td>Weight of specific gravity bottle and water, $W_4$ (gm)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1198.0</td>
<td>2</td>
</tr>
<tr>
<td>5.</td>
<td>Specific Gravity of the Coarse aggregate</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2.88</td>
<td>2</td>
</tr>
</tbody>
</table>

Specific Gravity, $G_s = \frac{(W_2 - W_1)}{(W_4 - W_1) - (W_3 - W_2)}$

\[
= \frac{(811 - 491)}{(1198 - 491) - (1407 - 811)}
\]

\[= 2.88\]

4.2.2.5 Determination of Water Absorption of Aggregates

A. Purpose

To determine the water absorption of aggregates.
B. Scope

Water absorption capacity of aggregate affects the water cement ratio and hence needs to derived for concrete mix design.

C. Reference Documents

IS-2386 (PART-3)

D. Apparatus

i. Oven

ii. Weighing Machine

E. Detailed Procedure

i. Dry the specimen.

ii. Weigh the dry specimen about 1 kg or so.

iii. Immerse in portable water at room temperature for 24 hours.

iv. After 24 hours, weigh the specimen in SSD (Surface Saturated Dry condition).

v. Place the specimen in oven and dry at constant rate.

vi. Calculate % absorption of aggregate by the given formula:

\[
\frac{(B-A)}{B} \times 100
\]

where, B = weight in SSD condition

A = weight in dry condition
Result

Table: 4.11 Water Absorptions Test of Aggregate

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Weight of Dry Aggregate (gm)</th>
<th>Weight of Wet Aggregate (gm)</th>
<th>Water Absorption Capacity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>1000</td>
<td>1005</td>
<td>0.5</td>
</tr>
<tr>
<td>2.</td>
<td>1000</td>
<td>1006</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Water Absorption Capacity = \( \frac{(\text{Weight of wet aggregate} - \text{Weight of dry aggregate})}{\text{Weight of dry Aggregate}} \times 100 \)

\[ = \frac{(1005 - 1000)}{1000} \times 100 \]

\[ = 0.5\% \]

4.2.3 Workability

Workability is the ability of a fresh (plastic) concrete mix to fill the form/mould properly with the desired work (vibration) and without reducing the concrete's quality. Workability depends on water content, aggregate (shape and size distribution), cementitious content and age (level of hydration), and can be modified by adding chemical admixtures. Raising the water content or adding chemical admixtures will increase concrete workability. Excessive water will lead to increased bleeding (surface water) and/or segregation of aggregates (when the cement and aggregates start to separate), with the resulting concrete having reduced quality. The use of an aggregate with an undesirable gradation can result in a very harsh mix
design with a very low slump, which cannot be readily made more workable by addition of reasonable amounts of water.

Workability can be measured by the Concrete Slump Test, a simplistic measure of the plasticity of a fresh batch of Concrete following the IS 4926:2003 test standards. Slump is normally measured by filling an "ABRAMS cone" with a sample from a fresh batch of concrete. The cone is placed with the wide end down onto a level, non-absorptive surface. It is then filled in three layers of equal volume, with each layer being tamped with a steel rod in order to consolidate the layer. When the cone is carefully lifted off, the enclosed material will slump a certain amount due to gravity. A relatively dry sample will slump very little, having a slump value of one or two inches (25 or 30 cm). A relatively wet concrete sample may slump as much as 8 inches.

Slump can be increased by adding chemical admixtures such as mid-range or high-range water reducing agents (super-plasticizers) without changing the water-cement ratio. It is a bad practice to add water on-site which exceeds the water-cement ratio of the mix design, however in a properly designed mixture it is important to reasonably achieve the specified slump prior to placement as design factors such as air content, internal water for hydration/strength gain, etc. are dependent on placement at design slump values.

High-flow concrete, like self-consolidating concrete, is tested by other flow-measuring methods. One of these methods include placing the cone on the narrow end and observing how the mix flows through the cone while it is gradually lifted. After mixing, concrete is a fluid and can be pumped to where it is needed. (M.S.Shetty, 2006)
4.2.3.1 Concrete Slump Test

In construction and civil engineering, the Concrete Slump Test (or simply Slump Test) is an in-situ test or a laboratory test used to determine and measure how hard and consistent is a given sample of concrete is, before curing.

The concrete slump test is, in essence, a method of quality control. For a particular mix, the slump should be consistent. A change in slump height would demonstrate an undesired change in the ratio of the concrete ingredients, the proportions of the concrete are then adjusted to keep a concrete batch consistent. This homogeneity improves the quality and structural integrity of the cured concrete.

A. Concept

"Slump" is simply a term coined to describe how consistent a concrete sample is, rather than using obscure descriptions such as "wet" or "runny". The height of the concrete mix after being placed in the slump cone differs from one sample to another. Samples with lower heights are predominantly used in construction, with samples having high slumps commonly used to construct roadway pavements.

B. Purpose

The goal of the test is to measure the consistency of concrete. Many factors are taken into account when satisfying requirements of concrete strength, and to make sure a consistent mixture of cement is being used during the process of construction. The test also determines the "workability" of concrete, which provides a scale on how easy is it to handle, compact, and cure concrete. Engineers use the results to then
alter the concrete mix by adjusting the water-cement ratio or adding plasticizers to increase the slump of the concrete mix.

C. Procedure

The slump test has witnessed many technological advances, and some countries even perform the test using automated machinery. To simplify, generally accepted method to perform the test is as follows:

D. Apparatus

i. Large Pan

ii. Trowel to mix concrete mixture

iii. Steel tamping rod

iv. Slump cone

v. Ruler

vi. Concrete (Cement, water, sand & aggregates)

E. Steps

i. Place the mixing pan on the floor and moisten it with some water. Make sure it is damp but no free water is left.

ii. Firmly hold the slump cone in place using the 2 foot holds.

iii. Fill one-third of the cone with the concrete mixture. Then tamp the layer 25 times using the steel rod in a circular motion, making sure not to stir.

iv. Add more concrete mixture to the two-thirds mark. Repeat tamping for 25 times again. Tamp just barely into the previous layer (1").
v. Fill up the whole cone up to the top with some excess concrete coming out of top, then repeat tamping 25 times (if there is not enough concrete from tamping compression, stop tamping, add more, then continue tamping).

vi. Remove excess concrete from the opening of the slump cone by using tamping rod in a rolling motion until flat.

vii. Slowly and carefully, remove the cone by lifting it vertically (5 seconds ± 2 seconds), making sure that the concrete sample does not move.

viii. Wait for the concrete mixture as it slowly slumps.

ix. After the concrete stabilizes, measure the slump height by turning the slump cone upside down next to the sample, placing the tamping rod on the slump cone and measuring the distance from the rod to the original displaced centre. (IS4926, 2003)

4.3 Design Mix

4.3.1 Design Mix for M20 Grade Concrete:

A mix M20 grade was designed as per IS 10262:2009 and the same was used to prepare the test samples. (IS10262, Concrete mix proportioning, 2009)

A. Data for Mix Proportion:

The following data are required for mix proportion of a particular grade of concrete:

i. Grade designation.

ii. Type of cement.

iii. Maximum nominal size of aggregate.

iv. Minimum cement content.
v. Maximum water cement ratio.

vi. Workability.

vii. Exposure condition as per table 4 and 5 of IS 456.

viii. Max temperature of concrete at the time of placing.

ix. Method of transporting and placing.

x. Early age strength requirements, if required.

xi. Type of aggregate.

xii. Max cement content.

B. Target strength of mix proportioning (IS10262, Concrete Mix Design, 2009), 3.2):

Target mean compressive strength \( f'_{ck} \) is given by:

\[
f'_{ck} = f_{ck} + 1.65s
\]

where

\( f'_{ck} \) = Target mean compressive strength at 28 days in N/mm\(^2\)

\( f_{ck} \) = Characteristic compressive strength at 28 days strength in N/mm\(^2\)

\( s \) = Standard deviation N/mm\(^2\)

C. Concrete mix proportion:

\[
f'_{ck} = f_{ck} + 1.65s
\]

\[= 20 + 1.65 \times 4\]  \text{ (IS10262, Concrete Mix Design, 2009) clauses 3.2.1.2}

\[= 26.60 \text{N/mm}^2\]

D. Calculation of water content:

\( W/C = 0.46 \)

Water content for 25-50 mm slump = \textbf{186 liters} \text{ (IS10262, Concrete mix proportioning, 2009) clause 4.2, A-5 and B-5) }
Water content for 120 mm slump = 186+6/120*186
= 195 liters

E. Calculation of cement content:

W/C = 0.46

Cement content = 195/0.46 = 424 kg.

424>300 (ok) (from (IS456, 2000)Table 5)

F. Proportioning of coarse and fine aggregate:

From Table 3 of (IS10262, Concrete mix proportioning, 2009) volume of coarse aggregate for 0.5 W/C = 0.62

Present W/C = 0.46

Therefore volume of coarse aggregate need to increase to decrease fine aggregate by 0.08

The coarse aggregate increase by the formula:

+ 0.01 for every + 0.05 change of W/C ratio

Coarse aggregate for 0.42 W/C ratio = 0.008+0.62 = 0.628

For pump able reduce by 10%

Volume of coarse aggregate = 0.628*0.9 = 0.565

Volume of fine aggregate = 1-0.565 = 0.435

G. Mix calculation:

a) Volume of concrete = 1 m³

b) Volume of cement = Mass/sp.gravity*1/1000

= 424/3.15*1/1000

= 0.135 m³

c) Volume of water = Mass/ sp. gravity* 1/1000
\[ \frac{63}{1000} = 0.195 \text{ m}^3 \]

d) Volume of all aggregate = 1 - (0.14+0.195)
\[ e = 0.670 \text{ m}^3 \]

e) Mass of coarse aggregate = e*volume of coarse*sp.gravity*1000
\[ = 0.670*0.565*2.88*1000 \]
\[ = 1090 \text{ kg} \]

f) Mass of fine aggregate = e*volume of fine*sp.gravity*1000
\[ = 0.670*0.435*2.65*1000 \]
\[ = 773 \text{ kg} \]

H. Mix proportion:

Cement = 424 kg
Water = 195 liters
Fine aggregate = 773 kg
Coarse aggregate = 1090 kg
W/C ratio = 0.46
Ratio = 1:1.82:2.57

4.3.2 Design Mix for M25 Grade Concrete

A mix M25 grade was designed as per (IS10262, Concrete Mix Design, 2009) and the same was used to prepare the test samples.

A. Data for mix proportion:

The following data are required for mix proportion of a particular grade of concrete:
i. Grade designation.
ii. Type of cement.
iii. Maximum nominal size of aggregate.
iv. Minimum cement content.
v. Maximum water cement ratio.
vi. Workability.
vii. Exposure condition as per table 4 and 5 of IS 456.
viii. Max temperature of concrete at the time of placing.
ix. Method of transporting and placing.
x. Early age strength requirements, if required.
xi. Type of aggregate.
xii. Max cement content.

**B. Target strength of mix proportioning:**

Target mean compressive strength $f'_{ck}$ is given by:

$$f'_{ck} = f_{ck} + 1.65s$$  
(IS10262, Concrete Mix Design, 2009), 3.2

where

- $f'_{ck} = \text{Target mean compressive strength at 28 days in N/mm}^2$
- $f_{ck} = \text{Characteristic compressive strength at 28 days strength in N/mm}^2$
- $S = \text{Standard deviation N/mm}^2$

**C. Concrete mix proportion:**

$$f'_{ck} = f_{ck} + 1.65s$$

$$= 25 + 1.65 \times 4$$

(IS10262, Concrete Mix Design, 2009) clauses 3.2.1.2, A-3 and B-3)
\[
= 31.60 \text{N/mm}^2
\]

D. Calculation of water content:

W/C = 0.42

Water content for 25-50 mm slump = 186 liters (IS10262, Concrete Mix Design, 2009) clause 4.2, A-5 and B-5

Water content for 120 mm slump = \[186 + \frac{6}{120} \times 186\]

= 195 liters

E. Calculation of cement content:

W/C = 0.42

Cement content = \[\frac{195}{0.42} = 465 \text{ kg.}\]

465 > 300 (ok) (IS456, 2000) table 5

F. Proportioning of coarse and fine aggregate:

From table 3 of (IS10262, Concrete Mix Design, 2009) table-5) volume of coarse aggregate for 0.5 W/C = 0.62

Present W/C = 0.42

Therefore volume of coarse aggregate need to increase to decrease fine aggregate by 0.08

The coarse aggregate increase by the formula:

\[+- 0.01 \text{ for every } + - 0.05 \text{ change of W/C ratio}\]

Coarse aggregate for 0.42 W/C ratio = \[0.016 + 0.62 = 0.636\]

For pump able reduce by 10%

Volume of coarse aggregate = \[0.636 \times 0.9 = 0.57\]

Volume of fine aggregate = \[1 - 0.57 = 0.43\]
G. Mix calculation:

a) Volume of concrete = 1 m$^3$

b) Volume of cement = \( \frac{\text{Mass}}{\text{sp. gravity}} \times \frac{1}{1000} \)
\[
= \frac{465}{3.15} \times \frac{1}{1000} \\
= 0.14 \text{ m}^3
\]

c) Volume of water = \( \frac{\text{Mass}}{\text{sp. gravity}} \times \frac{1}{1000} \)
\[
= \frac{195}{1000} \\
= 0.195 \text{ m}^3
\]

d) Volume of all aggregate = 1 - (0.14+0.195)
\[
e = 0.665 \text{ m}^3
\]

e) Mass of coarse aggregate = \( e \times \text{volume of coarse} \times \text{sp. gravity} \times 1000 \)
\[
= 0.665 \times 0.57 \times 2.88 \times 1000 \\
= 1092 \text{ kg}
\]

f) Mass of fine aggregate = \( e \times \text{volume of fine} \times \text{sp. gravity} \times 1000 \)
\[
= 0.665 \times 0.43 \times 2.65 \times 1000 \\
= 758 \text{ kg}
\]

H. Mix proportion:

Cement = **465 kg**

Water = 195 liters

Fine aggregate = **758 kg**

Coarse aggregate = **1092 kg**

W/C ratio = **0.42**

**Ratio = 1:1.63:2.35**
4.3.3 **Design Mix:**

A mix M30 grade was designed as per (IS10262, Concrete Mix Design, 2009) and the same was used to prepare the test samples.

**A. Data for mix proportion:**

The following data are required for mix proportion of a particular grade of concrete:

i. Grade designation.

ii. Type of cement.

iii. Maximum nominal size of aggregate.

iv. Minimum cement content.

v. Maximum water cement ratio.

vi. Workability.

vii. Exposure condition as per table 4 and 5 of IS 456.

viii. Max temperature of concrete at the time of placing.

ix. Method of transporting and placing.

x. Early age strength requirements, if required.

xi. Type of aggregate.

xii. Max cement content.

**B. Target strength of mix proportioning:**

Target mean compressive strength $f'_{ck}$ is given by:

$$f'_{ck} = f_{ck} + 1.65s$$

(IS10262, Concrete Mix Design, 2009) 3.2

where

$f'_{ck} = \text{Target mean compressive strength at 28 days in N/mm}^2$
\[ f_{ck} = \text{Characteristic compressive strength at 28 days strength in N/mm}^2 \]
\[ s = \text{Standard deviation N/mm}^2 \]

**C. Concrete mix proportion:**

\[ f'_{ck} = f_{ck} + 1.65s \]
\[ = 30 + 1.65 \times 5 \quad \text{(IS10262, Concrete Mix Design, 2009) clause 3.2.1.2, A-3 and B-3)} \]
\[ = 38.25 \text{N/mm}^2 \]

**D. Calculation of water content:**

\[ \text{W/C} = 0.38 \]

Water content for 25-50 mm slump = **186 liters**

\[ \text{Water content for 120 mm slump} = 186 + \frac{6}{120} \times 186 \]
\[ = 195 \text{ liters} \]

**E. Calculation of cement content:**

\[ \text{W/C} = 0.38 \]

Cement content = \[\frac{195}{0.38} = 513 \text{ kg.}\]

513 > 300 (ok) \quad \text{(IS456, 2000) Table 5)}

**F. Proportioning of coarse and fine aggregate:**

From table 3 of (IS10262, Concrete Mix Design, 2009) volume of coarse aggregate for 0.5 W/C = 0.62

Present W/C = 0.38

Therefore volume of coarse aggregate need to increase to decrease fine aggregate by 0.08
The coarse aggregate increase by the formula:

\[ +0.01 \text{ for every } +0.05 \text{ change of W/C ratio} \]

Coarse aggregate for 0.42 W/C ratio = 0.024 + 0.62 = 0.644

For pump able reduce by 10%

Volume of coarse aggregate = 0.644 * 0.9 = 0.58

Volume of fine aggregate = 1 - 0.58 = 0.42

G. Mix calculation:

a) Volume of concrete = 1 \text{ m}^3

b) Volume of cement = \text{Mass}/\text{sp. gravity} * 1/1000

\[ = 513/3.15 * 1/1000 \]
\[ = 0.162 \text{ m}^3 \]

c) Volume of water = \text{Mass}/\text{sp. gravity} * 1/1000

\[ = 195/1000 \]
\[ = 0.195 \text{ m}^3 \]

d) Volume of all aggregate = 1 - (0.162 + 0.195)

\[ e = 0.643 \text{ m}^3 \]

e) Mass of coarse aggregate = \( e \times \text{volume of coarse} \times \text{sp. gravity} \times 1000 \)

\[ = 0.643 \times 0.58 \times 2.88 \times 1000 \]
\[ = 1074 \text{ kg} \]

f) Mass of fine aggregate = \( e \times \text{volume of fine} \times \text{sp. gravity} \times 1000 \)

\[ = 0.643 \times 0.42 \times 2.65 \times 1000 \]
\[ = 716 \text{ kg} \]
H. Mix proportion:

Cement = 513 kg

Water = 195 liters

Fine aggregate = 716 kg

coarse aggregate = 1074 kg

W/C ratio = 0.38

Ratio = 1:1.4:2.09
Table: 4.12 design mix proportion for M20 Grade Concrete replacing Fly Ash

<table>
<thead>
<tr>
<th>Grade</th>
<th>W/C</th>
<th>% Replaced</th>
<th>Cement (kg)</th>
<th>Fly Ash (FA) (kg)</th>
<th>FA (kg)</th>
<th>CA (kg)</th>
<th>Water (kg)</th>
<th>Slump (mm)</th>
<th>No. Of cubes</th>
</tr>
</thead>
<tbody>
<tr>
<td>M20</td>
<td>0.46</td>
<td>0%</td>
<td>22.988</td>
<td>0</td>
<td>42.75</td>
<td>16.275</td>
<td>37.975</td>
<td>10.57</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5%</td>
<td>21.839</td>
<td>1.149</td>
<td>42.75</td>
<td>16.275</td>
<td>37.975</td>
<td>10.57</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10%</td>
<td>20.689</td>
<td>2.299</td>
<td>42.75</td>
<td>16.275</td>
<td>37.975</td>
<td>10.57</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15%</td>
<td>19.539</td>
<td>3.449</td>
<td>42.75</td>
<td>16.275</td>
<td>37.975</td>
<td>10.57</td>
<td>115</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20%</td>
<td>18.39</td>
<td>4.598</td>
<td>42.75</td>
<td>16.275</td>
<td>37.975</td>
<td>10.57</td>
<td>110</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25%</td>
<td>17.241</td>
<td>5.747</td>
<td>42.75</td>
<td>16.275</td>
<td>37.975</td>
<td>10.57</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30%</td>
<td>16.091</td>
<td>6.897</td>
<td>42.75</td>
<td>16.275</td>
<td>37.975</td>
<td>10.57</td>
<td>95</td>
</tr>
<tr>
<td></td>
<td></td>
<td>35%</td>
<td>14.942</td>
<td>8.046</td>
<td>42.75</td>
<td>16.275</td>
<td>37.975</td>
<td>10.57</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40%</td>
<td>13.792</td>
<td>9.196</td>
<td>42.75</td>
<td>16.275</td>
<td>37.975</td>
<td>10.57</td>
<td>90</td>
</tr>
</tbody>
</table>
Table: 4.13 design mix proportion for M20 Grade Concrete replacing Brick Dust

<table>
<thead>
<tr>
<th>Grade</th>
<th>W/C</th>
<th>% Replaced</th>
<th>Cement (kg)</th>
<th>Brick Dust(BD) (kg)</th>
<th>FA (kg)</th>
<th>CA (kg)</th>
<th>Water (kg)</th>
<th>Slump (mm)</th>
<th>No. of cubes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.46</td>
<td>0%</td>
<td>22.988</td>
<td>0</td>
<td>42.75</td>
<td>16.275</td>
<td>37.975</td>
<td>10.57</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5%</td>
<td>21.839</td>
<td>1.149</td>
<td>42.75</td>
<td>16.275</td>
<td>37.975</td>
<td>10.57</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10%</td>
<td>20.689</td>
<td>2.299</td>
<td>42.75</td>
<td>16.275</td>
<td>37.975</td>
<td>10.57</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15%</td>
<td>19.539</td>
<td>3.449</td>
<td>42.75</td>
<td>16.275</td>
<td>37.975</td>
<td>10.57</td>
<td>110</td>
</tr>
<tr>
<td>M20</td>
<td></td>
<td>20%</td>
<td>18.39</td>
<td>4.598</td>
<td>42.75</td>
<td>16.275</td>
<td>37.975</td>
<td>10.57</td>
<td>105</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25%</td>
<td>17.241</td>
<td>5.747</td>
<td>42.75</td>
<td>16.275</td>
<td>37.975</td>
<td>10.57</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30%</td>
<td>16.091</td>
<td>6.897</td>
<td>42.75</td>
<td>16.275</td>
<td>37.975</td>
<td>10.57</td>
<td>95</td>
</tr>
<tr>
<td></td>
<td></td>
<td>35%</td>
<td>14.942</td>
<td>8.046</td>
<td>42.75</td>
<td>16.275</td>
<td>37.975</td>
<td>10.57</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40%</td>
<td>13.792</td>
<td>9.196</td>
<td>42.75</td>
<td>16.275</td>
<td>37.975</td>
<td>10.57</td>
<td>80(0.5)</td>
</tr>
</tbody>
</table>

(0.5) Refers that to maintain the slump of 80-120, 0.5% suprplasticiser was used
Table: 4.14 design mix proportion for M20 Grade Concrete replacing Rice Husk Ash

<table>
<thead>
<tr>
<th>Grade</th>
<th>W/C</th>
<th>% Replaced</th>
<th>Cement (kg)</th>
<th>Rice Husk Ash (RHA) (kg)</th>
<th>FA (kg)</th>
<th>CA (kg)</th>
<th>Water (kg)</th>
<th>Slump (mm)</th>
<th>No. Of cubes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0%</td>
<td>22.988</td>
<td>0</td>
<td>42.75</td>
<td>16.275</td>
<td>37.975</td>
<td>10.57</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5%</td>
<td>21.839</td>
<td>1.149</td>
<td>42.75</td>
<td>16.275</td>
<td>37.975</td>
<td>10.57</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10%</td>
<td>20.689</td>
<td>2.299</td>
<td>42.75</td>
<td>16.275</td>
<td>37.975</td>
<td>10.57</td>
<td>120</td>
</tr>
<tr>
<td>M20</td>
<td>0.46</td>
<td>15%</td>
<td>19.539</td>
<td>3.449</td>
<td>42.75</td>
<td>16.275</td>
<td>37.975</td>
<td>10.57</td>
<td>115</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20%</td>
<td>18.39</td>
<td>4.598</td>
<td>42.75</td>
<td>16.275</td>
<td>37.975</td>
<td>10.57</td>
<td>110</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25%</td>
<td>17.241</td>
<td>5.747</td>
<td>42.75</td>
<td>16.275</td>
<td>37.975</td>
<td>10.57</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30%</td>
<td>16.091</td>
<td>6.897</td>
<td>42.75</td>
<td>16.275</td>
<td>37.975</td>
<td>10.57</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>35%</td>
<td>14.942</td>
<td>8.046</td>
<td>42.75</td>
<td>16.275</td>
<td>37.975</td>
<td>10.57</td>
<td>80(0.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40%</td>
<td>13.792</td>
<td>9.196</td>
<td>42.75</td>
<td>16.275</td>
<td>37.975</td>
<td>10.57</td>
<td>80(0.8)</td>
</tr>
</tbody>
</table>

(0.5) and (0.8) Refers that to maintain the slump of 80-120, 0.5% and 0.8% superplasticiser was used
Table: 4.15 design mix proportion for M25 Grade Concrete replacing Fly Ash

<table>
<thead>
<tr>
<th>Grade</th>
<th>W/C</th>
<th>% Replaced</th>
<th>Cement (kg)</th>
<th>FA Ash (kg)</th>
<th>CA (kg)</th>
<th>Water (kg)</th>
<th>Slump (mm)</th>
<th>No. Of cubes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.42</td>
<td>0%</td>
<td>24.742</td>
<td>0</td>
<td>40.82</td>
<td>16.33</td>
<td>10.39</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5%</td>
<td>23.505</td>
<td>1.237</td>
<td>40.82</td>
<td>16.33</td>
<td>10.39</td>
<td>12</td>
</tr>
<tr>
<td>M25</td>
<td></td>
<td>10%</td>
<td>22.268</td>
<td>2.474</td>
<td>40.82</td>
<td>16.33</td>
<td>10.39</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15%</td>
<td>21.03</td>
<td>3.711</td>
<td>40.82</td>
<td>16.33</td>
<td>10.39</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20%</td>
<td>19.794</td>
<td>4.948</td>
<td>40.82</td>
<td>16.33</td>
<td>10.39</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25%</td>
<td>18.556</td>
<td>6.186</td>
<td>40.82</td>
<td>16.33</td>
<td>10.39</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30%</td>
<td>17.319</td>
<td>7.423</td>
<td>40.82</td>
<td>16.33</td>
<td>10.39</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>35%</td>
<td>16.082</td>
<td>8.660</td>
<td>40.82</td>
<td>16.33</td>
<td>10.39</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40%</td>
<td>14.845</td>
<td>9.897</td>
<td>40.82</td>
<td>16.33</td>
<td>10.39</td>
<td>12</td>
</tr>
<tr>
<td>Grade</td>
<td>W/C</td>
<td>% Replaced</td>
<td>Cement (kg)</td>
<td>Brick Dust (BD) (kg)</td>
<td>FA (kg)</td>
<td>CA (kg)</td>
<td>Water (kg)</td>
<td>Slump (mm)</td>
</tr>
<tr>
<td>---------</td>
<td>-----</td>
<td>------------</td>
<td>-------------</td>
<td>----------------------</td>
<td>---------</td>
<td>---------</td>
<td>------------</td>
<td>------------</td>
</tr>
<tr>
<td>M25</td>
<td>0.42</td>
<td>0%</td>
<td>24.742</td>
<td>0</td>
<td>40.82</td>
<td>16.33</td>
<td>38.102</td>
<td>10.39</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5%</td>
<td>23.505</td>
<td>1.237</td>
<td>40.82</td>
<td>16.33</td>
<td>38.102</td>
<td>10.39</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10%</td>
<td>22.268</td>
<td>2.474</td>
<td>40.82</td>
<td>16.33</td>
<td>38.102</td>
<td>10.39</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15%</td>
<td>21.03</td>
<td>3.711</td>
<td>40.82</td>
<td>16.33</td>
<td>38.102</td>
<td>10.39</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20%</td>
<td>19.794</td>
<td>4.948</td>
<td>40.82</td>
<td>16.33</td>
<td>38.102</td>
<td>10.39</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25%</td>
<td>18.556</td>
<td>6.186</td>
<td>40.82</td>
<td>16.33</td>
<td>38.102</td>
<td>10.39</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30%</td>
<td>17.319</td>
<td>7.423</td>
<td>40.82</td>
<td>16.33</td>
<td>38.102</td>
<td>10.39</td>
</tr>
<tr>
<td></td>
<td></td>
<td>35%</td>
<td>16.082</td>
<td>8.660</td>
<td>40.82</td>
<td>16.33</td>
<td>38.102</td>
<td>10.39</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40%</td>
<td>14.845</td>
<td>9.897</td>
<td>40.82</td>
<td>16.33</td>
<td>38.102</td>
<td>10.39</td>
</tr>
</tbody>
</table>

(0.6) Refers that to maintain the slump of 80-120, 0.6% superplasticiser was used.
Table: 4.17 Design mix proportion for M25 Grade Concrete replacing Rice Husk Ash

<table>
<thead>
<tr>
<th>Grade</th>
<th>W/C</th>
<th>% Replaced</th>
<th>Cement (kg)</th>
<th>Rice Husk Ash (RHA) (kg)</th>
<th>FA (kg)</th>
<th>CA (kg)</th>
<th>Water (kg)</th>
<th>Slump (mm)</th>
<th>No. Of cubes</th>
</tr>
</thead>
<tbody>
<tr>
<td>M25</td>
<td>0.42</td>
<td>0%</td>
<td>24.742</td>
<td>0</td>
<td>40.82</td>
<td>16.33</td>
<td>38.102</td>
<td>10.39</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5%</td>
<td>23.505</td>
<td>1.237</td>
<td>40.82</td>
<td>16.33</td>
<td>38.102</td>
<td>10.39</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10%</td>
<td>22.268</td>
<td>2.474</td>
<td>40.82</td>
<td>16.33</td>
<td>38.102</td>
<td>10.39</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15%</td>
<td>21.03</td>
<td>3.711</td>
<td>40.82</td>
<td>16.33</td>
<td>38.102</td>
<td>10.39</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20%</td>
<td>19.794</td>
<td>4.948</td>
<td>40.82</td>
<td>16.33</td>
<td>38.102</td>
<td>10.39</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25%</td>
<td>18.556</td>
<td>6.186</td>
<td>40.82</td>
<td>16.33</td>
<td>38.102</td>
<td>10.39</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30%</td>
<td>17.319</td>
<td>7.423</td>
<td>40.82</td>
<td>16.33</td>
<td>38.102</td>
<td>10.39</td>
<td>8(0.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>35%</td>
<td>16.082</td>
<td>8.660</td>
<td>40.82</td>
<td>16.33</td>
<td>38.102</td>
<td>10.39</td>
<td>8(0.7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40%</td>
<td>14.845</td>
<td>9.897</td>
<td>40.82</td>
<td>16.33</td>
<td>38.102</td>
<td>10.39</td>
<td>8(1)</td>
</tr>
</tbody>
</table>

(0.5), (0.7), (1) Refers that to maintain the slump of 80-120, 0.5% , 0.7% and 1% superplasticiser was used
Table: 4.18 design mix proportion for M30 Grade Concrete replacing Fly Ash

<table>
<thead>
<tr>
<th>Grade</th>
<th>W/C</th>
<th>% Replaced</th>
<th>Cement (kg)</th>
<th>Fly Ash (FA) (kg)</th>
<th>FA (kg)</th>
<th>CA (kg)</th>
<th>Water (kg)</th>
<th>Slump (mm)</th>
<th>No. Of cubes</th>
</tr>
</thead>
<tbody>
<tr>
<td>M30</td>
<td>0.38</td>
<td>0%</td>
<td>27.65</td>
<td>0</td>
<td>38.709</td>
<td>16.092</td>
<td>37.548</td>
<td>10.507</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5%</td>
<td>26.267</td>
<td>1.383</td>
<td>38.709</td>
<td>16.092</td>
<td>37.548</td>
<td>10.507</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10%</td>
<td>24.885</td>
<td>2.765</td>
<td>38.709</td>
<td>16.092</td>
<td>37.548</td>
<td>10.507</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15%</td>
<td>23.505</td>
<td>4.147</td>
<td>38.709</td>
<td>16.092</td>
<td>37.548</td>
<td>10.507</td>
<td>110</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20%</td>
<td>22.12</td>
<td>5.53</td>
<td>38.709</td>
<td>16.092</td>
<td>37.548</td>
<td>10.507</td>
<td>105</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25%</td>
<td>20.737</td>
<td>6.913</td>
<td>38.709</td>
<td>16.092</td>
<td>37.548</td>
<td>10.507</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>35%</td>
<td>17.972</td>
<td>9.678</td>
<td>38.709</td>
<td>16.092</td>
<td>37.548</td>
<td>10.507</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40%</td>
<td>16.59</td>
<td>11.06</td>
<td>38.709</td>
<td>16.092</td>
<td>37.548</td>
<td>10.507</td>
<td>85</td>
</tr>
<tr>
<td>Grade</td>
<td>W/C</td>
<td>% Replaced</td>
<td>Cement (kg)</td>
<td>Brick Dust (BD) (kg)</td>
<td>FA (kg)</td>
<td>CA (kg)</td>
<td>Water (kg)</td>
<td>Slump (mm)</td>
<td>No. Of cubes</td>
</tr>
<tr>
<td>-------</td>
<td>-----</td>
<td>------------</td>
<td>-------------</td>
<td>---------------------</td>
<td>---------</td>
<td>---------</td>
<td>------------</td>
<td>------------</td>
<td>-------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0%</td>
<td>27.65</td>
<td>0</td>
<td>38.709</td>
<td>16.092</td>
<td>37.548</td>
<td>10.507</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5%</td>
<td>26.267</td>
<td>1.383</td>
<td>38.709</td>
<td>16.092</td>
<td>37.548</td>
<td>10.507</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10%</td>
<td>24.885</td>
<td>2.765</td>
<td>38.709</td>
<td>16.092</td>
<td>37.548</td>
<td>10.507</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15%</td>
<td>23.505</td>
<td>4.147</td>
<td>38.709</td>
<td>16.092</td>
<td>37.548</td>
<td>10.507</td>
<td>110</td>
</tr>
<tr>
<td>M30</td>
<td>0.38</td>
<td>20%</td>
<td>22.12</td>
<td>5.53</td>
<td>38.709</td>
<td>16.092</td>
<td>37.548</td>
<td>10.507</td>
<td>105</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25%</td>
<td>20.737</td>
<td>6.913</td>
<td>38.709</td>
<td>16.092</td>
<td>37.548</td>
<td>10.507</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>35%</td>
<td>17.972</td>
<td>9.678</td>
<td>38.709</td>
<td>16.092</td>
<td>37.548</td>
<td>10.507</td>
<td>80(0.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40%</td>
<td>16.59</td>
<td>11.06</td>
<td>38.709</td>
<td>16.092</td>
<td>37.548</td>
<td>10.507</td>
<td>80(0.8)</td>
</tr>
</tbody>
</table>

(0.5), (0.8) Refers that to maintain the slump of 80-120, 0.5% and 0.8% superplasticiser was used.
### Table: 4.20 design mix proportion for M30 Grade Concrete replacing Rice Husk Ash

<table>
<thead>
<tr>
<th>Grade</th>
<th>W/C</th>
<th>% Replaced</th>
<th>Cement (kg)</th>
<th>Rice Husk Ash (RHA) (kg)</th>
<th>FA (kg)</th>
<th>CA (kg)</th>
<th>Water (kg)</th>
<th>Slump (mm)</th>
<th>No. Of cubes</th>
</tr>
</thead>
<tbody>
<tr>
<td>M30</td>
<td>0.38</td>
<td>0%</td>
<td>27.65</td>
<td>0</td>
<td>38.709</td>
<td>16.092</td>
<td>37.548</td>
<td>10.507</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5%</td>
<td>26.267</td>
<td>1.383</td>
<td>38.709</td>
<td>16.092</td>
<td>37.548</td>
<td>10.507</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10%</td>
<td>24.885</td>
<td>2.765</td>
<td>38.709</td>
<td>16.092</td>
<td>37.548</td>
<td>10.507</td>
<td>115</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15%</td>
<td>23.505</td>
<td>4.147</td>
<td>38.709</td>
<td>16.092</td>
<td>37.548</td>
<td>10.507</td>
<td>110</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20%</td>
<td>22.12</td>
<td>5.53</td>
<td>38.709</td>
<td>16.092</td>
<td>37.548</td>
<td>10.507</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30%</td>
<td>19.355</td>
<td>8.295</td>
<td>38.709</td>
<td>16.092</td>
<td>37.548</td>
<td>10.507</td>
<td>80(0.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>35%</td>
<td>17.972</td>
<td>9.678</td>
<td>38.709</td>
<td>16.092</td>
<td>37.548</td>
<td>10.507</td>
<td>80(0.8)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40%</td>
<td>16.59</td>
<td>11.06</td>
<td>38.709</td>
<td>16.092</td>
<td>37.548</td>
<td>10.507</td>
<td>80(1)</td>
</tr>
</tbody>
</table>

(0.5), (0.8), (1) Refers that to maintain the slump of 80-120, 0.5%, 0.8% and 1% superplasticiser was used
4.4 Cube Moulds: (As per IS: 516 – 1959)

The mould shall be of metal, preferably steel or cast iron, and stout enough to prevent distortion. It shall be constructed in such a manner as to facilitate the removal of the moulded specimen without damage, and shall be so machined that, when it is assembled ready for use, the dimensions and internal faces shall be accurate within the following limits: The height of the mould and the distance between opposite faces shall be the specified size + 0.2mm. The angle between adjacent internal faces and between internal faces and top and bottom planes of the mould shall be 900 + 0.50. The interior faces of the mould shall be plane surfaces with a permissible variation of 0.03 mm. Each mould shall be provided with a metal base plate having a plane surface. The base plate shall be such dimensions as to support the mould during the filling without leakage and it shall be preferably attached to the mould by spring or screws. The parts of the mould when assembled shall be positively and rigidly held together, and suitable methods of ensuring this, both during the filling and on subsequent handling of the filled mould shall be provide

In assembling the mould for use, the joints between the sections of mould shall be thinly shall be thinly coated with mould oil and a similar coating of mould oil shall be applied between the contact surfaces of the bottom of the mould and the base plate in order to ensure that no water escapes during the filling. The interior surfaces of the assembled mould shall be thinly coated with mould oil to prevent adhesion of the concrete.
4.5 Casting of Test Specimens: (IS516, 1959)

4.5.1 Preparation of Materials:

All materials shall be brought to room temperature, preferably 270+ 30C before commencing the results.

The cement samples, on arrival at the laboratory, shall be thoroughly mixed dry either by hand or in a suitable mixer in such a manner as to ensure the greatest possible blending and uniformity in the material, care is being taken to avoid the intrusion of foreign matter. The cement shall then be stored in a dry place, preferably in air-tight metal containers.

Samples of aggregates for each batch of concrete shall be of the desired grading and shall be in an air-dried condition. In general, the aggregate shall be separated into fine and coarse fraction and recombined for each concrete batch in such a manner as to produce the desired grading. IS sieve 480 shall be normally for separating the fine and coarse fractions, but where special grading are being
investigated, both fine and coarse fractions shall be further separated into different sizes.

**Fig:4.2 Moulds in Laboratory**

4.5.2 Proportioning:

The proportions of the materials, including water, in concrete mixes used for determining the suitability of the materials available, shall be similar in all respects to those to be employed in the work. Where the proportions of the ingredients of the concrete as used on the site are to be specified by volume, they shall be calculated from the proportions by weight used in the test cubes and the unit weights of the materials.

4.5.3 Weighing:

The quantities of cement, each size of aggregate, and water for each batch shall be determined by weight, to an accuracy of 0.1 percent of the total weight of the batch.
4.5.4 Mixing Concrete:

The concrete shall be mixed by hand or preferably in a laboratory batch mixer, in such a manner as to avoid loss of water or other materials. Each batch of concrete shall be of such a size as to leave about 10 percent excess after moulding the desired number of test specimens.
4.5.4.1 Machine Mixing:

The concrete batch shall be mixed on a electrically operated mixing machine or similar suitable implement, using the following procedure:

i. The cement and fine aggregate shall be mixed dry until the mixture is thoroughly blended and is uniform in color.

ii. The coarse aggregate shall then be added and mixed with the cement and fine aggregate until the coarse aggregate is uniformly distributed throughout the batch.

iii. The water shall then be added and the entire batch mixed until the concrete appears to be homogenous and has the desired consistency. If repeated mixing is necessary, because of the addition of water in increments while adjusting the consistency, the batch shall be discarded and a fresh batch made without interrupting the mixing to make trial consistency tests.

Fig: 4.4 Mixing Machine
4.5.5 Compaction of Test Specimens: (IS516, 1959)

The test specimens shall be made as soon as practicable after mixing, and in such a way as to produce full compaction of the concrete with neither segregation nor excessive laitance. The concrete shall be filled into the mould in layers approximately 5 cm deep. In placing each scoopful of concrete, the scoop shall be moved around the top edge of the mould as the concrete slides from it, in order to ensure a symmetrical distribution of the concrete within the mould. Each layer shall be compacted either by hand or by vibration as described below. After the top layer has been compacted, the surface of the concrete shall be finished level with the top of the mould, using a trowel, and covered with a glass or metal plate to prevent evaporation.

4.5.5.1 Compaction by Hand: (IS516, 1959)

When compacting by hand, the standard tamping bar shall be used and the strokes of the bar shall be distributed in a uniform manner over the cross section of the mould. The number of strokes per layer required to produce specified conditions will vary according to the type of concrete. For cubical specimens, in no case shall the concrete be subjected to less than 35 strokes per layer for 15 cm cubes or 25 strokes per layer for 10 cm cubes. The strokes shall penetrate into the underlying layer and the bottom layer shall be rodded throughout its depth. Where voids are left by tamping bar, the sides of the mould shall be tapped to close the voids.
Fig: 4.5 Compaction by Hand

Fig: 4.6 Material Mixing in Mixing Machine
4.5.6 Curing of Test Specimens: (IS516, 1959)

The test specimens shall be stored on the site at a place free from vibration, under damp matting, sacks or other similar material for 24 hours + ½ hour from the time of adding the water to the other ingredients. The temperature of the place of storage shall be within the range of 220 to 320°C. After the period of 24 hours, they shall be marked for later identification, removed from the moulds and, unless required for testing within 24 hours, stored in clean water at a temperature of 240 to 300°C until they are transported to the testing laboratory. They shall be sent to the testing laboratory well packed in damp sand, damp sacks, or other suitable material so as to arrive there in a damp condition not less than 24 hours before the time of test. On arrival at the testing laboratory, the specimens shall be stored in water at a temperature of 270+ 20°C until the time of test. Records of the daily maximum and minimum temperature shall be kept both during the period of the specimens remain on the site and in the laboratory.

Fig: 4.7 Test specimens being cured in curing tank
4.6 Test for Compressive Strength of Concrete Specimen: (IS516, 1959)

4.6.1 Testing Machine:

The testing machine may be of any reliable type, of sufficient capacity for the tests and capable of applying the load at the specified rate. The permissible error shall be not greater than + 2 percent of the maximum load. The testing machine shall be equipped with two steel bearing platens with hardened faces. One of the platens shall be fitted with a ball seating in the form of a portion of a sphere, the centre of which coincides platen shall be plain rigid bearing block. The bearing faces of the both platens shall be at least as large as, and preferably larger than the nominal size of the specimen to which the load is applied. The bearing surface of the platens, when new, shall not depart from a plane by more than 0.01 mm at any point, and they shall be maintained with a permissible variation limit of 0.02 mm.

![Compression Testing Machine](image)

Fig:4.8 Compression Testing Machine
Fig: 4.9 Cube Testing Compression Testing Machine

Fig: 4.10 Concrete Cube After Failure
4.6.2 Procedure:
Specimens stored in water shall be tested immediately on removal from the water and while they are still in the wet condition. Surface water and grit shall be wiped off the specimens and any projecting fins removed. Specimens when received dry shall be kept in water for 24 hours before they are taken for testing. The dimensions of the specimens to the nearest 0.2 mm and their weight shall be noted before testing.

4.6.3 Placing the Specimen in the Testing machine: (IS516, 1959)
The bearing surfaces of the testing machine shall be wiped clean and any loose sand or other material removed from the surfaces of the specimen which are to be in contact with the compression platens. In the case of cubes, the specimen shall be placed in the machine in such a manner that the load shall be applied to opposite sides of the cubes as cast, that is, not to the top and bottom. The axis of the specimen shall be carefully aligned with the centre of thrust of the spherically seated platen. No packing shall be used between the faces of the test specimen and the steel plates of the testing machine. As the spherically seated block is brought to bear on the specimen, the movable portion shall be rotated gently by hand so that uniform seating may be obtained. The load shall be applied without shock and increased continuously at a rate of approximately 140 kg/sq cm/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The maximum load applied to the specimen shall be recorded and the appearance of the concrete and any unusual features in the type of failure shall be noted.
4.7 **Calculation:** (IS516, 1959)

The measured compressive strength of the specimen shall be calculated by dividing the maximum load applied to the specimen during the test by the cross-sectional area, calculated from the mean dimensions of the section and shall be expressed to the nearest kg per sq cm. Average of three values shall be taken as the representative of the batch provided the individual variation is not more than +15 percent of the average. Otherwise repeat tests shall be made.