CONCRETE MIX PROPORTIONING

IS 10262 : 2009

Dr. S. RAVIRAJ
Professor of Civil Engineering
JSS Science and Technology University
S.J. College of Engineering
Mysuru – 570 006
ravirajs@sjce.ac.in
Introduction

Concrete – indispensable construction material.

- Made from locally available materials
- Can be moulded to any shape
- Excellent resistance to water
- Economically made
Introduction

Concrete – Largest consumed material next to water

Most of the time - Not processed in controlled conditions

Hence, Quality cannot be ensured
A cross over in United States
A cross over in United States
BURJ KHALIFA

- Opened in 2010
- Height 828 m
- Took six year to complete
- World’s tallest tower
- Located in Dubai, UAE
- 160 + Storeys
BURJ KHALIFA
BURJ KHALIFA

- Concrete used: 250,000 cu.m (weight of 110,000 elephants)
- Steel rebars: 39,000 tonnes
- Highest vertical concrete pumping: 601 m (for any construction)
• **High-performance SCC** concrete with a mix designed to provide a low-permeability and high-durability was used in walls and columns.

• **C80 to C60 cube strength** concrete used Portland cement, fly ash, and local aggregates.

• The C80 concrete had a specified Young’s Modulus of 43,800 N/mm at 90 days.
• Two of the largest concrete pumps in the world were used to deliver concrete to heights over 600 m in a single stage.

• To reduce the cracks due to the high temperatures of Dubai (about 50° C), the concrete was poured at night, when the air is cooler and the humidity is higher, with ice added to the mix.
Introduction

Concrete – not just as a four component system.

Six more ingredients – Fly ash, Ground granulated blast furnace slag, Silica fume, Rice husk ash, Metakaoline, and Superplasticisers
Fly ash (Pulverised fuel ash)

Fly ash conforming to Grade I of IS 3812 may be used as part replacement of OPC, provided uniform blending with cement is ensured.

S.G. = 2.4 to 2.65,  B.D = 540 to 860 kg/m³
Ground granulated blast furnace slag (GGBS)

Ground granulated blast furnace slag obtained by grinding granulated blast furnace slag conforming to IS 12089 may be used as part replacement of OPC, provided uniform blending with cement is ensured.

S.G. = 2.85 to 2.95,
B.D = 1050 to 1375 kg/m$^3$
Silica fume

Silica fume (very fine non-crystalline silicon dioxide) is a by-product of the manufacture of silicon, ferrosilicon or the like, from quartz and carbon in electric arc furnace.

Silica fume conforming to a standard approved by the deciding authority may be used as part replacement of OPC, provided uniform blending with cement is ensured.
Silica fume \( \ldots \) \textit{Contd.}

It is usually used in proportion of 5 to 10 percent of the cement content of a mix.

S.G. = 2.2 to 2.5, \hspace{1em} B.D = 130 to 430 kg/m\(^3\)
Rice husk ash

Rice husk ash is produced by burning rice husk and contains large amount of silica.

To achieve amorphous state, rice husk may be burnt at controlled temperature.

Necessary to evaluate the particular source (or it can be as deleterious as silt).

Water demand and drying shrinkage should be studied.
Rice husk ash ... Contd.

Rice husk ash giving required performance and uniformity characteristics may be used with the approval of the deciding authority.

S.G. = 2.10, B.D = 70 to 110 kg/m³
Metakaoline is obtained by calcination of pure or refined kaolinitic clay at a temperature between 650° C and 850° C, followed by grinding to achieve a fineness of 700 to 900 m²/kg.

The resulting material has high pozzolanicity and may be used in concrete.
Metakaoline

S.G. = 2.5 to 2.6,  B.D = 300 kg/m³
Superplasticisers

These are chemical admixtures used to increasing workability

S.G. = 1.15
Other Admixtures

Used to change the properties of concrete:

- Delaying initial setting of concrete
- Accelerating the initial strength of concrete
- Blocking capillary pores and reducing the size of capillary pores
- Entraining small air bubbles (< 45 microns)
Mix design- Definition

- Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the objective of producing concrete of certain minimum strength and durability as economically as possible.
Thus the purpose of mix design is of two folds

- First objective - strength and durability
- Second objective - economical production, cost

**Cost of concrete** - labour and materials

**Labour cost**

- formwork, batching, mixing, transporting and curing
- nearly same for good concrete and bad concrete
Materials cost

- Attention is mainly directed to the cost of materials – particularly cost of cement and admixtures.

- Cement used should be as minimum as possible (Minimize cement)
Objective of Mix Proportioning

- Produce Concrete – most economical and practical combination
- Satisfy the performance requirements under specified conditions of use.
- Concrete – Satisfactory both in its fresh and hardened states.
- Trial mixes – integral part of concrete mix proportioning
Proportioning of Concrete Mixes

Procedure is available to proportion the most economical concrete mix for specified durability and grade for required site conditions.

The structural engineer stipulates certain minimum strength for concrete.
• **Concrete technologist** should **design** the concrete taking all properties of materials, exposure condition, field condition, standard deviation, minimum strength and durability.

• Finally **concrete** is to be **prepared** based on the mix design and this concrete is to be actually **tested** **(laboratory)** for the requirements.

• **Engineer-in-charge** should **approve** the mix so proportioned.
Proportioning of Concrete Mixes

The method gives the guidelines only to arrive at an acceptable product, which satisfies the requirements of placement required with development of strength with age, and ensures the requirements of durability.

Different countries have their own standardized mix design methods.
Proportioning of Concrete Mixes

These methods are mostly based on empirical relations, charts, graphs, and tables developed as outcomes of extensive experiments and investigations of locally available materials.

All the standards and methods follow the same basic trial and error principles.
Requirements which form the basis for the selection and proportioning of concrete mix:

- Minimum compressive strength
- Adequate workability
- Maximum W/C ratio and/or Maximum cement content
- Maximum cement content
Salient feature of IS 10262 : 2009

Applicable to ordinary and standard concrete grades only.

Durability requirements, Limitations on W/C ratio and Maximum cement contents are as per IS 456 : 2000.
Salient feature of IS 10262 : 2009

Requirements for selection of W/C ratio, water content and estimations of coarse aggregate content and fine aggregate content have been reviewed and accordingly modified.

Consideration of air content has been deleted.
1. Data for mix proportioning
   - Grade designation
   - Type of cement
   - Maximum nominal size of aggregate (MSA)
   - Minimum cement content
   - Maximum water-cement ratio
   - Workability
Data for mix proportioning ... *Contd.*

- Exposure conditions as per Table 4 and Table 5 of IS: 456-2000
- Maximum temperature of concrete at the time of placing
- Method of transporting and placing
- Early age strength requirements, if required
Data for mix proportioning ... *Contd.*

- Type of aggregate
- Maximum cement content, and
- Whether an admixture shall or shall not be used and the type of admixture and the condition of use.
Target strength for mix proportioning

Target strength is computed by

\[ f_{ck}^1 = f_{ck} + 1.65 \, s \]

- \( f_{ck}^1 \) = target mean compressive strength at 28 days in N/mm\(^2\)
- \( f_{ck} \) = characteristic compressive strength at 28 days in N/mm\(^2\)
- \( s \) = standard deviation in N/mm\(^2\)
Mean and standard deviation of comp. strength
### Example to find Mean and SD of comp. strength

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Compressive strength of concrete (x), MPa</th>
<th>Average strength ( \bar{X} = \frac{\Sigma x}{n} )</th>
<th>Deviation ( (X - \bar{X}) )</th>
<th>Square of deviation ( (X - \bar{X})^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>43</td>
<td></td>
<td>2.8</td>
<td>7.84</td>
</tr>
<tr>
<td>2</td>
<td>48</td>
<td></td>
<td>7.8</td>
<td>60.84</td>
</tr>
<tr>
<td>3</td>
<td>40</td>
<td></td>
<td>-0.2</td>
<td>0.04</td>
</tr>
<tr>
<td>4</td>
<td>38</td>
<td></td>
<td>-2.2</td>
<td>4.84</td>
</tr>
<tr>
<td>5</td>
<td>36</td>
<td></td>
<td>-4.2</td>
<td>16.64</td>
</tr>
<tr>
<td>6</td>
<td>39</td>
<td></td>
<td>-1.2</td>
<td>1.44</td>
</tr>
<tr>
<td>7</td>
<td>42</td>
<td>40.2</td>
<td>1.8</td>
<td>3.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>45</td>
<td>4.8</td>
<td>23.04</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>37</td>
<td>-3.2</td>
<td>10.24</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>35</td>
<td>-5.2</td>
<td>27.04</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>39</td>
<td>-1.2</td>
<td>1.44</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>41</td>
<td>0.8</td>
<td>0.64</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>49</td>
<td>8.8</td>
<td>77.44</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>46</td>
<td>5.8</td>
<td>33.64</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>36</td>
<td>-4.2</td>
<td>16.64</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>38</td>
<td>-2.2</td>
<td>4.84</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>32</td>
<td>-8.2</td>
<td>67.24</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>39</td>
<td>-1.2</td>
<td>1.44</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>41</td>
<td>0.8</td>
<td>0.64</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>40</td>
<td>-0.2</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td><strong>Total 804</strong></td>
<td><strong>40.2</strong></td>
<td><strong>Total 359.20</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Statistical values

• **Average strength** = \( \frac{804}{20} = 40.2 \text{ MPa} \)

• **Standard deviation**, \( \sigma \) = \( \sqrt{\frac{(359.20)/(N-1)}{}} \)
  
  \[= \sqrt{\frac{359.2}{19}}\]
  
  = 4.34 MPa

• **Coeff. of variation**, \( \delta \) = \( \frac{\text{S.D.}}{\text{Avg. stg.}} \)
  
  \[= \frac{4.34}{40.2}\]
  
  = 0.108

• **Target strength** = \( \text{Ch. comp. strength} + k \cdot s \)
  
  \[= 30 + 1.65 \times 4.34\]
  
  = 37.16 MPa
Characteristic strength of concrete

\[ f_g(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-a)^2}{2\sigma^2}} \]

- Lower limit (min. x)
- Target strength or mean strength \( \bar{x} \)
- Normal or 'Gaussian' distribution curve
- Compressive strength

\[ f_{ck}(\text{characteristic strength}) \]

- \( f_{ck} \) at 5%
- 1.65 S
# Values for k

<table>
<thead>
<tr>
<th>Percentage of results allowed to fall below the minimum</th>
<th>Value of k</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>3.09</td>
</tr>
<tr>
<td>0.6</td>
<td>2.50</td>
</tr>
<tr>
<td>1.0</td>
<td>2.33</td>
</tr>
<tr>
<td>2.5</td>
<td>1.96</td>
</tr>
<tr>
<td>5.0</td>
<td>1.65</td>
</tr>
<tr>
<td>6.6</td>
<td>1.50</td>
</tr>
<tr>
<td>16.0</td>
<td>1.00</td>
</tr>
</tbody>
</table>

\[
f_{ck}^{1} = f_{ck} + k \cdot s \\
f_{ck}^{1} = f_{ck} + 1.65 \cdot s
\]
Standard deviation based on test strength of sample

a) Number of test results of samples – N ≥ 30

Collect as early as possible, when a mix is used for the first time.

b) When significant changes are made in the production of concrete batches – ‘S’ shall be separately calculated for such batches.
Standard deviation based on test strength of sample

c) Standard deviation to be brought up-to-date – after every change in mix proportioning.

d) When sufficient test results for a particular grade of concrete are not available – Table 1.
### Table 1 Assumed Standard Deviation
*(Clauses 3.2.1.2, A-3 and B-3)*

<table>
<thead>
<tr>
<th>Sl No.</th>
<th>Grade of Concrete</th>
<th>Assumed Standard Deviation N/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>(I)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i)</td>
<td>M 10</td>
<td>3.5</td>
</tr>
<tr>
<td>ii)</td>
<td>M 15</td>
<td></td>
</tr>
<tr>
<td>iii)</td>
<td>M 20</td>
<td>4.0</td>
</tr>
<tr>
<td>iv)</td>
<td>M 25</td>
<td></td>
</tr>
<tr>
<td>v)</td>
<td>M 30</td>
<td></td>
</tr>
<tr>
<td>vi)</td>
<td>M 35</td>
<td></td>
</tr>
<tr>
<td>vii)</td>
<td>M 40</td>
<td></td>
</tr>
<tr>
<td>viii)</td>
<td>M 45</td>
<td>5.0</td>
</tr>
<tr>
<td>ix)</td>
<td>M 50</td>
<td></td>
</tr>
<tr>
<td>x)</td>
<td>M 55</td>
<td></td>
</tr>
</tbody>
</table>
Value of ‘S’ correspond to the site control with

- Proper storage of cement
- Weigh batching of all materials
- Controlled addition of water
- Regular checking of all materials
- Aggregate grading
- Determination of moisture content in aggregates
- Periodical checking of workability and strength
Assumed standard deviation

• When there is a deviation in the standard conditions, values given in Table 1 shall be increased by 1 N/mm$^2$.

• After the availability of results, actual calculated value of ‘S’ shall be used.

• If adequate records for ‘S’ exist for a similar grade of concrete the same shall be used instead of that given in Table 1.
Selection of mix proportions

For the **same water-cement ratio**, the **strength** of concrete **depends on**:

- Type of cement
- Supplementary cementitious materials
- Maximum size of aggregates
- Grading of aggregates
- Shape of aggregates
- Surface texture of aggregates, etc.
• Hence, relationship between strength and free water-cement ratio should preferably be established for the materials actually to be used.

• During its absence, preliminary free water-cement ratio (by mass) may be selected from the established relationship, if available.
Selection of mix proportions ... Contd.

• Otherwise, the w/c ratio given in Table 5 of IS 456 : 2000 for respective environment exposure conditions (starting point).
### Requirements of durability: Limiting W/C ratio

- Lower of the two values to be adopted
Selection of mix proportions … Contd.

• The supplementary cementitious materials, i.e., mineral admixtures shall also be considered in W/C ratio calculations in accordance with Table 5 of IS 456 : 2000.
Selection of water content

Water content is influenced by a number of factors:

• Size and shape of aggregates
• Surface texture of aggregates
• Workability requirements
• Water-cement ratio considerations
• Cement type and content
Selection of water content ... Contd.

Water demand reduces as

- Aggregate size increases
- Reduction in water-cement ratio
- Reduction in slump
- Use of rounded aggregates
- Use of water reducing admixtures
Selection of water content  ...  Contd.

Water demand increases as

• Increase in cement content
• Increase in water-cement ratio
• Increase in slump
• Increase in aggregate angularity
• Decrease in the proportion of CA to FA
• Increase in temperature
Selection of water content ... Contd.

Quantity of mixing water - Table 2

<table>
<thead>
<tr>
<th>Nominal Maximum Size of Aggregate (mm)</th>
<th>Maximum Water Content (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) 10</td>
<td>208</td>
</tr>
<tr>
<td>(2) 20</td>
<td>186</td>
</tr>
<tr>
<td>(3) 40</td>
<td>165</td>
</tr>
</tbody>
</table>

Aggregates in Saturated Surface Dry (SSD) state
Selection of water content ... Contd.

Quantity of mixing water in Table 2

- Angular aggregates

- Slump range – 25 to 50 mm

Modifications to be made for change in the above quantities
Selection of water content  ... Contd.

Important to test local materials

• Each aggregate source is different

• Influence concrete properties differently
Selection of water content … Contd.

Modifications for value of water content for different aggregates (for same workability)

- Reduction by 10 kg for sub angular aggregates
- Reduction by 20 kg for gravel with some crushed particles
- Reduction by 25 kg for rounded gravel
Selection of water content ... Contd.

Modifications for value of water content for different slumps

• Water content to be established by trials
• Increase by about 3 percent for every additional slump of 25 mm
Selection of water content ... Contd.

Modifications for value of water content for use chemical admixtures conforming to IS 9103 : 1999

• Water content to be established by trials
• Increase by about 3 percent for every additional slump of 25 mm
• Use chemical admixtures conforming to IS 9103 : 1999
Selection of water content ... Contd.

- Modifications for value of water content for use chemical admixtures conforming to IS 9103 : 1999

- At appropriate dosages, reduction of water content can be
  - 5 to 10 percent – Water reducing admixtures
  - 20 percent and above – Superplasticizers
Calculation of cementitious material content

Cementitious material

- Cement
- Cement + Supplementary cementitious materials

Values are known for the following:

- Water-cement ratio (w/c)
- Water content (w)

Cementitious material content can be found
Calculation of cementitious material content

Check – 1

• Durability considerations – Minimum cement content (Table 5 of IS 456 : 2000)
Table 5 Minimum Cement Content, Maximum Water-Cement Ratio and Minimum Grade of Concrete for Different Exposures with Normal Weight Aggregates of 20 mm Nominal Maximum Size

(Clause 6.1.2, 8.2.4.1 and 9.1.2)

<table>
<thead>
<tr>
<th>Exposure</th>
<th>1)</th>
<th>2)</th>
<th>3)</th>
<th>4)</th>
<th>5)</th>
<th>6)</th>
<th>7)</th>
<th>8)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Minimum</td>
<td>Maximum</td>
<td>Minimum</td>
<td>Minimum</td>
<td>Minimum</td>
<td>Minimum</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cement</td>
<td>Water-Cement</td>
<td>Grade of</td>
<td>Cement</td>
<td>Water-Cement</td>
<td>Grade of</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Content</td>
<td>Ratio</td>
<td>Concrete</td>
<td>Content</td>
<td>Ratio</td>
<td>Concrete</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>kg/m³</td>
<td></td>
<td></td>
<td>kg/m³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i) Mild</td>
<td>220</td>
<td>0.60</td>
<td>–</td>
<td>300</td>
<td>0.55</td>
<td>300</td>
<td>M 20</td>
<td></td>
</tr>
<tr>
<td>iii) Moderate</td>
<td>240</td>
<td>0.60</td>
<td>M 15</td>
<td>300</td>
<td>0.50</td>
<td>300</td>
<td>M 25</td>
<td></td>
</tr>
<tr>
<td>iii) Severe</td>
<td>250</td>
<td>0.50</td>
<td>M 20</td>
<td>320</td>
<td>0.45</td>
<td>320</td>
<td>M 30</td>
<td></td>
</tr>
<tr>
<td>iv) Very severe</td>
<td>260</td>
<td>0.45</td>
<td>M 20</td>
<td>340</td>
<td>0.45</td>
<td>340</td>
<td>M 35</td>
<td></td>
</tr>
<tr>
<td>v) Extreme</td>
<td>280</td>
<td>0.40</td>
<td>M 25</td>
<td>360</td>
<td>0.40</td>
<td>360</td>
<td>M 40</td>
<td></td>
</tr>
</tbody>
</table>
Calculation of cementitious material content

Check – 1

• Durability considerations – Minimum cement content (Table 5 of IS 456 : 2000)

Greater of the two values to be adopted
Calculation of cementitious material content

Check – 2

  (450 kg/m³)

Lesser of the two values to be adopted
# Estimation of coarse aggregate proportion

## Table 3 Volume of Coarse Aggregate per Unit Volume of Total Aggregate for Different Zones of Fine Aggregate

*(Clauses 4.4, A-7 and B-7)*

<table>
<thead>
<tr>
<th>Sl No.</th>
<th>Nominal Maximum Size of Aggregate (mm)</th>
<th>Zone IV</th>
<th>Zone III</th>
<th>Zone II</th>
<th>Zone I</th>
</tr>
</thead>
<tbody>
<tr>
<td>i)</td>
<td>10</td>
<td>0.50</td>
<td>0.48</td>
<td>0.46</td>
<td>0.44</td>
</tr>
<tr>
<td>ii)</td>
<td>20</td>
<td>0.66</td>
<td>0.64</td>
<td>0.62</td>
<td>0.60</td>
</tr>
<tr>
<td>iii)</td>
<td>40</td>
<td>0.75</td>
<td>0.73</td>
<td>0.71</td>
<td>0.69</td>
</tr>
</tbody>
</table>

Aggregates in Saturated Surface Dry (SSD) state
Estimation of coarse aggregate proportion

Volume of CA in Table 2

• Water-cement ratio of 0.5

Modifications to be made for other W/C ratios

• + 0.01 for every - 0.05 change in W/C ratio
• - 0.01 for every + 0.05 change in W/C ratio
Estimation of coarse aggregate proportion

Volume of CA in Table 2 should be modified for more workable mixes

- Pumping of concrete
- Congested reinforcements

Reduce CA content by up to 10 percent
Estimation of fine aggregate proportion

- Coarse Aggregate shall conform to IS 383
- Coarse Aggregates of different sizes may be combined in suitable proportions – Conforms to Table 2 of IS 383 for a particular nominal maximum size aggregate
Combination of different C.A. fractions

The mass for the following materials are known

- Cementitious material
- Water content
- Chemical admixture

Determine the absolute volume of the above quantities

\[
\text{Absolute volume} = \frac{\text{mass}}{\text{specific gravity}} \times \frac{1}{1000}
\]
Combination of different C.A. fractions

The absolute volume of total aggregates can be found as

\[
\begin{align*}
\left\{ \text{Absolute volume of total aggregates} \right\} &= 1 - (a + b + c)
\end{align*}
\]

where

\[a = \text{Volume of cementitious material}\]

\[b = \text{Volume of water content}\]

\[c = \text{Volume of chemical admixtures}\]
Combination of different C.A. fractions

Values are known for the following:

• Absolute volume of total aggregates
• Volume of CA per unit volume of TA

Hence,

Absolute volume of CA can be found

Absolute volume of FA can be found
Combination of different C.A. fractions

Mass of Coarse aggregate and Fine aggregate contents can be determined from the relation

\[
\text{Mass} = \left\{ \text{Absolute volume} \right\} \times \left\{ \text{Specific gravity} \right\} \times \{1000\} 
\]
Trial Mixes

Calculated mix proportions shall be checked by means of trial batches

Trial Mix No. 1

• Measure workability

• Observe for freedom from bleeding and segregation

• Observe its finishing properties
Trial Mixes

Observations in Trial Mix No. 1

• Measured workability is different from stipulated value

Remedy

• Adjust suitably water and/or admixture content
Trial Mixes

Trial Mix No. 2

• With the revised water content, mix proportion shall be recalculated keeping the free water-cement ratio at the pre-selected value.

Two more Trial Mixes, i.e., No. 3 and No. 4 are to be calculated
Trial Mixes

Trial Mix No. 3

• With the revised water content and varying the free water-cement ratio by – 10 percent

Trial Mix No. 4

• With the revised water content and varying the free water-cement ratio by + 10 percent
Trial Mixes

Trial Mixes No. 2 to 4 normally provides sufficient information

- Workability characteristics
- Relation between compressive strength and water-cement ratio

Based on the above results and observations, mix proportion for field may be arrived at.

The trials shall be produced by methods of actual concrete production.
Numerical Example – 1

Design stipulations for proportioning

Grade designation : M20
Type of cement : OPC 43
(grade confirming to IS 8112)
Maximum nominal size of aggregates : 20 mm
Minimum cement content : 320 kg/m$^3$
Maximum water cement ratio : 0.55
Workability : 75 mm (slump)
Exposure condition : Mild
Design stipulations for proportioning

Degree of supervision : Good
Type of aggregate : Crushed angular aggregate
Maximum cement content : 450 kg/m$^3$
Chemical admixture : Not recommended
Test data for materials

Cement used : OPC 43 grade conforming to IS 8112

S. G. of cement : 3.15
S. G. of C.A. : 2.68
S. G. of F.A. : 2.65

Water absorption

Coarse aggregate : 0.6 percent
Fine aggregate : 1.0 percent
Test data for materials

Free (surface) moisture
Coarse aggregate : Nil (absorbed moisture full)
Fine aggregate : Nil

Sieve analysis
Coarse aggregate : Conforming to Table 2 of IS: 383
Fine aggregate : Conforming to Zone I of IS: 383
Target strength for mix proportioning

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

\[ = 20 + 1.65 \times 4 \]

\[ = 26.60 \text{ N/mm}^2 \]
<table>
<thead>
<tr>
<th>Sl No. (1)</th>
<th>Grade of Concrete (2)</th>
<th>Assumed Standard Deviation N/mm² (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i)</td>
<td>M 10</td>
<td>3.5</td>
</tr>
<tr>
<td>ii)</td>
<td>M 15</td>
<td></td>
</tr>
<tr>
<td>iii)</td>
<td>M 20</td>
<td>4.0</td>
</tr>
<tr>
<td>iv)</td>
<td>M 25</td>
<td></td>
</tr>
<tr>
<td>v)</td>
<td>M 30</td>
<td></td>
</tr>
<tr>
<td>vi)</td>
<td>M 35</td>
<td></td>
</tr>
<tr>
<td>vii)</td>
<td>M 40</td>
<td></td>
</tr>
<tr>
<td>viii)</td>
<td>M 45</td>
<td>5.0</td>
</tr>
<tr>
<td>ix)</td>
<td>M 50</td>
<td></td>
</tr>
<tr>
<td>x)</td>
<td>M 55</td>
<td></td>
</tr>
</tbody>
</table>

*Table 1: Assumed Standard Deviation (Clauses 3.2.1.2, A-3 and B-3)*
Selection of water cement ratio

From Table 5 of IS 456 : 2000

Maximum W/C ratio = 0.55 (Mild)

Based on experience adopt W/C = 0.50

(< 0.55 – O.K.)
Selection of water content

From Table-2,
Maximum water content = 186 liters
(25mm – 50mm slump range, MSA = 20 mm)

Table 2 Maximum Water Content per Cubic Metre of Concrete for Nominal Maximum Size of Aggregate
(Clause 4.2, A-5 and B-5)

<table>
<thead>
<tr>
<th>Sl No.</th>
<th>Nominal Maximum Size of Aggregate</th>
<th>Maximum Water Content</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mm</td>
<td>kg</td>
</tr>
<tr>
<td>i)</td>
<td>10</td>
<td>208</td>
</tr>
<tr>
<td>ii)</td>
<td>20</td>
<td>186</td>
</tr>
<tr>
<td>iii)</td>
<td>40</td>
<td>165</td>
</tr>
</tbody>
</table>
Selection of water content

Increase by about 3 percent for every additional slump of 25 mm

Estimated water content for 75 mm slump

\[ = 186 + \frac{3}{100} \times 186 \]

\[ = 191.6 \text{ liters} \]
Calculation of cement content

W/C ratio = 0.50

Cement content = 191.6/0.5

= 383 kg/m$^3$ > 320 kg/m$^3$

(Given – Min. cement content)

From Table 5 of IS: 456
Min. cement content = 300 kg/m$^3$ (Mild Exposure)

Hence, O.K.
Proportion of volume of coarse aggregate and fine aggregate content

From Table 3,
Volume of CA/ unit vol. of TA = 0.6
(MSA = 20 mm, FA = Zone I, W/C = 0.50)
<table>
<thead>
<tr>
<th>SI No.</th>
<th>Nominal Maximum Size of Aggregate (mm)</th>
<th>Volume of Coarse Aggregate per Unit Volume of Total Aggregate for Different Zones of Fine Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>Zone IV</td>
</tr>
<tr>
<td>i)</td>
<td>10</td>
<td>0.50</td>
</tr>
<tr>
<td>ii)</td>
<td>20</td>
<td>0.66</td>
</tr>
<tr>
<td>iii)</td>
<td>40</td>
<td>0.75</td>
</tr>
</tbody>
</table>
Proportion of volume of coarse aggregate and fine aggregate content

From Table 3,

Volume of CA/ unit vol. of TA = 0.6
(MSA = 20 mm, FA = Zone I, W/C = 0.50)
Actual W/C = 0.50
Corrections – Nil
Hence,
Volume of FA/ unit vol. of TA = 1 – 0.6
= 0.4
**Mix calculations**

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

Volume of cement (b) = \((\frac{383.16}{3.15}) \times \frac{1}{1000}\)  
= 0.122 m$^3$

Volume of water (c) = \((\frac{192}{1}) \times \frac{1}{1000}\)  
= 0.192 m$^3$

Vol. of all in aggs. (d) = a – (b + c)  
= 1 – (0.122 + 0.192)  
= 0.686 m$^3$
Mix calculations

Mass of CA = \( d \times \text{Vol. of CA} \times \text{SG of CA} \times 1000 \)
\[ = 0.686 \times 0.6 \times 2.68 \times 1000 \]
\[ = 1103 \text{ kg} \]

Mass of FA = \( d \times \text{Vol. of FA} \times \text{SG of FA} \times 1000 \)
\[ = 0.686 \times 0.4 \times 2.65 \times 1000 \]
\[ = 727 \text{ kg} \]
Mix proportions for Trial Mix No. 1.

Cement = 383.0 kg/m³
Water = 191.6 kg/m³
Fine aggregate = 727.0 kg/m³
Coarse aggregate = 1103.0 kg/m³
Water cement ratio = 0.50
Yield = 2404.6 kg/m³

(1 : 1.90 : 2.88 : 0.5)
Observations of Trial Mix No. 1.

Slump = 90 mm

Compacting Factor = 0.93

Workability slightly more than specified (75 mm)

Mix is accepted without any modification to reduce slump (No Trial Mix 2)
Proportions per cubic meter of concrete

<table>
<thead>
<tr>
<th>Trial</th>
<th>Water (lts)</th>
<th>Cement (kg)</th>
<th>Water/cement ratio</th>
<th>Fine aggregate (kg)</th>
<th>Coarse aggregate (kg)</th>
<th>Yield (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>191.6</td>
<td>383</td>
<td>0.50</td>
<td>727</td>
<td>1103</td>
<td>2405</td>
</tr>
<tr>
<td>2</td>
<td>191.6</td>
<td>426</td>
<td>0.45</td>
<td>713</td>
<td>1082</td>
<td>2413</td>
</tr>
<tr>
<td>3</td>
<td>191.6</td>
<td>348</td>
<td>0.55</td>
<td>739</td>
<td>1121</td>
<td>2400</td>
</tr>
</tbody>
</table>
# Workability and compressive strength results

<table>
<thead>
<tr>
<th>Trial</th>
<th>Water/cement ratio</th>
<th>Slump mm</th>
<th>Compacting factor</th>
<th>7-day strength</th>
<th>28-day strength</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.50</td>
<td>90</td>
<td>0.93</td>
<td>29.6</td>
<td>41.8</td>
<td>Cohesive mix</td>
</tr>
<tr>
<td>2</td>
<td>0.45</td>
<td>70</td>
<td>0.91</td>
<td>34.8</td>
<td>47.2</td>
<td>Cohesive mix</td>
</tr>
<tr>
<td>3</td>
<td>0.55</td>
<td>100</td>
<td>0.91</td>
<td>23.8</td>
<td>34.2</td>
<td>Cohesive mix</td>
</tr>
</tbody>
</table>

- All the three mixes resulted in higher strength and desired workability.
- Trial Mix No. 3 can be recommended (still uneconomical)
**Trial Mix No. 4**

- 5 percent water is reduced using 0.5 percent plasticiser

<table>
<thead>
<tr>
<th>Trial</th>
<th>Water (lts)</th>
<th>Cement (kg)</th>
<th>Water/cement ratio</th>
<th>Fine aggregate (kg)</th>
<th>Coarse aggregate (kg)</th>
<th>Yield (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>180</td>
<td>327</td>
<td>0.55</td>
<td>1151</td>
<td>759</td>
<td>2417</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trial</th>
<th>Water/cement ratio</th>
<th>Slump mm</th>
<th>Compacting Factor</th>
<th>7-day strength</th>
<th>28-day strength</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0.55</td>
<td>70</td>
<td>0.89</td>
<td>21.6</td>
<td><strong>30.2</strong></td>
<td>Cohesive mix</td>
</tr>
</tbody>
</table>

- **Trial Mix No. 4** is recommended (still can be modified)
Conclusion

- Design economical mixes
- Use judiciously the materials in the making of concrete
- Do not waste materials (save energy)
- Save natural resources to next generation
- GO GREEN
Thank You