APPENDIX 1

Concrete Mix Design – Based on IS 10262-2009

Design Stipulations

M30 grade of concrete mix design was done as per Indian standard method for control specimen.

Characteristic compressive strength = 30 N/mm²
Type of cement = OPC 53 grade
Maximum size of aggregate = 12.5 mm
Type of exposure = mild
Specific gravity of cement = 3.11
Specific gravity of fine aggregate = 2.60
Specific gravity of coarse aggregate = 2.70
Fineness modulus of fine aggregate = 2.70
Sieve analysis:
Fine aggregate – Zone II
OPC was partially replaced with 20% FA, 10% RHA and 10% LP by weight of cement.

Target strength for mix

\[ f_{ck}' = f_{ck} + 1.65 s \] (s = standard deviation)
\[ = 30 + 1.65 \times 5 \] (s=5N/mm² for M30, Table No. 8 of IS 456-2000)

\[ f_{ck}' = 38.25 \text{ N/mm}^2 \]
Selection of water cement ratio

For M30 concrete mix water cement ratio = 0.48 (Table No.5 of IS456-2000)

Selection of water content

Maximum water content for 12.5 mm aggregate = 202.5 lit (for 25 to 50 mm slump)

Increase 3% of water content for every 25mm slump range
To attain maximum of 75 mm slump range = 3% increase in water content
Estimated water content for 75 mm slump = 202.5+ [(202.5) x (3/100)]
= 208.575 litre

Calculation of cement, Fly ash, RHA and LP content

Water cement ratio = 0.48
Cementitious material (cement, Fly ash, RHA and LP) content = 208.575/0.48
=434.53 kg/m³

From Table No. 5 IS 456-2000, minimum cement content for mild exposure condition=300kg/m³
Calculated cement content value > 300kg/m³
Hence ok.

Mix calculations

Mix calculations per unit volume of concrete shall be as follows.
Volume of concrete = 1m³

Volume of cement = \( \frac{\text{Mass of cement}}{\text{Specific gravity}} \times \frac{1}{1000} \)
= \( \frac{434.53}{3.11} \times \frac{0.6}{1000} \)
= 0.084 m³
Volume of Fly ash  
\[
= \frac{\text{Mass of fly ash}}{\text{Specific gravity}} \times \frac{1}{1000}
\]
\[
= \frac{434.53}{2.12} \times \frac{0.2}{1000}
\]
\[
= 0.041 \text{ m}^3
\]
Volume of RHA  
\[
= \frac{\text{Mass of RHA}}{\text{Specific gravity}} \times \frac{1}{1000}
\]
\[
= \frac{434.53}{2.3} \times \frac{0.1}{1000}
\]
\[
= 0.019 \text{ m}^3
\]
Volume of LP  
\[
= \frac{\text{Mass of LP}}{\text{Specific gravity}} \times \frac{1}{1000}
\]
\[
= \frac{434.53}{2.8} \times \frac{0.1}{1000}
\]
\[
= 0.016 \text{ m}^3
\]
Volume of water  
\[
= \frac{\text{Mass of water}}{\text{Specific gravity}} \times \frac{1}{1000}
\]
\[
= \frac{434.53}{1} \times \frac{1}{1000}
\]
\[
= 0.209 \text{ m}^3
\]
Volume of all in aggregate  
\[
= (1-(0.084 +0.041+0.019+0.016+0.209))
\]
\[
= 1- 0.369
\]
\[
= 0.631 \text{ m}^3
\]

Proportion of volume of coarse aggregate and fine aggregate content

Volume of coarse aggregate corresponding to 12.5 mm size aggregate and fine aggregate(Zone II) for water cement ratio of 0.5 = 0.56.

This value is taken from ACI 211.1 Table No. 6.3.6.

In the present case w/c = 0.48

So, correction is applied as w/c is lowered, volume of coarse aggregate is increased.

The corrected proportion of volume of coarse aggregate for the w/c of 0.48 = 0.564.
The volume of fine aggregate = 0.436
Mass of coarse aggregate = 0.631 x 0.564 x 2.7 x 1000
= 960.89 kg
Mass of fine aggregate = 0.631 x 0.436 x 2.6 x 1000
= 715.30 kg

Based on the above material ingredients trial mixtures were prepared and necessary adjustments were made and the final mix proportion arrived.
The mix proportion for control concrete including SCMs is given below.
Cement: FA: RHA: LP: Fine aggregate: Coarse aggregate is 0.6: 0.2: 0.1: 0.1:1.61: 2.25 with w/c ratio of 0.48.

The quantities of cementitious materials in mix per m³ of concrete are as follows:

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>260.72 kg/ m³</td>
</tr>
<tr>
<td>FA</td>
<td>86.91 kg/ m³</td>
</tr>
<tr>
<td>RHA</td>
<td>43.45 kg/ m³</td>
</tr>
<tr>
<td>LP</td>
<td>43.45 kg/ m³</td>
</tr>
<tr>
<td>Fine aggregate</td>
<td>698.90 kg/ m³</td>
</tr>
<tr>
<td>Coarse aggregate</td>
<td>977.92 kg/ m³</td>
</tr>
<tr>
<td>Water</td>
<td>208.6 kg/ m³</td>
</tr>
</tbody>
</table>