CEMENT AND WATER SAVING WITH WATER REDUCERS

KAUSHAL KISHORE
Materials Engineer, Roorkee, U.K., India

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ABSTRACT
In the production of cement considerable amount of CO2 is emitted in the atmosphere. With the use of water reducers same construction may be done with less cement. Thus less cement will be required to be produce by cement factories resulting less CO2 will be emitted into the atmosphere. The paper gives method of mix design with water reducers.

INTRODUCTION
In India 0.93 kg of CO2 is emitted in the production of one kg of cement. In the financial year 2009-10 India produces 200 million tonnes of cement. In the production of this cement 186 million tonnes of CO2 was emitted in the atmosphere during financial year of 2009-10.

The availability of water in India per person per year in 1950 was 5177 cu.m. In the year 2009 it is reduces to 1700 cu.m.

If 50 million tonnes cement in making concrete uses water reducers 7500000 tonnes of cement can be saved. 3750000 kL of potable water will be saved and the saving of Rs. 3300 crores per year to construction industry. This amount is worked out after adjusting the cost of water reducers. Less cement used means less cement required to be produce by the cement factories resulting 6975000 tonnes of CO2 will be prevented to be emitted to the atmosphere. These are worked out with an average saving of 15% cement and 15% water.

CO2 emission is a global problem, but for India in addition to CO2 it has problems of Air, Water, Soil, Food and Noise pollutions. Less densely populated countries may cope with these problems but for India it is of the top concern. The population figures of 2009 is, India 350 person per sq.km, China 132 person per sq.km and USA only 34 person per sq.km. The figures of 2006 CO2 emissions are USA 658.60 tonnes per sq.km, China 611.76 tonnes per sq.km and India 459.35 tonnes per sq.km. Every one should contribute his or her efforts to save the environment from pollution. Those involved in the construction activities can contribute their share by proper design of concrete Mixes. This is best illustrated by the following examples.

TEST DATA FOR MATERIALS

1. The grading of fine aggregate, 10 & 20 mm aggregates are as given in Table 1. Fine aggregate is
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3. Target strength for all A, B and C mixes

<table>
<thead>
<tr>
<th>Mix</th>
<th>Water Absorption (%)</th>
<th>Water Reduction %</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.8</td>
<td>24%</td>
</tr>
<tr>
<td>B</td>
<td>0.5</td>
<td>24%</td>
</tr>
<tr>
<td>C</td>
<td>0.5</td>
<td>24%</td>
</tr>
</tbody>
</table>

2. Properties of aggregates

- Fly ash replacement: 30% for all mixes
- Maximum nominal size of aggregates: 20 mm crushed aggregate
- Fine aggregate: River sand of Zone-II as per IS:383-1970
- Minimum cement content: 320 kg/m³ including fly ash
- Maximum free W/C Ratio: 0.45
- Workability: 50 mm slump
- Exposure condition: Severe for RCC work
- Degree of supervision: Good
- Maximum cement content: 450 kg/m³
- Chemical admixture: Super plasticizer conforming to IS:9103-1999. The given water requirements and materials, the manufacturer of Normal Super plasticizer recommends dosages of 17 gm per kg of OPC, which reduce 24% of water without loss of workability. For fly-voided cement dosages will be required to be adjusted by 1%

3. Target strength for all A, B and C mixes

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</tr>
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<td>24%</td>
</tr>
<tr>
<td>C</td>
<td>24%</td>
</tr>
</tbody>
</table>

Note: Requirements of all the three mixes are the same. Fine Aggregate, Coarse Aggregate and Normal Super plasticizer are adjusted accordingly for all the three mixes.

DESIGN OF MIX-A WITH PPC

a) Free W/C ratio for the target strength of 38.3 N/mm² as worked out is 0.44. 
b) Free water for 50 mm slump from Table 2 for 20 mm maximum size of aggregate.
   - 24% water without loss of workability
   - 24% water without loss of workability

3 Other data's: The Mixes are to be designed on the basis of saturated and surface dry aggregates. At the time of concreting, moisture content of site aggregates are to be determined. If it carries surface moisture this is to be deducted from the mixing water and if it is dry add in mixing water the quantity of water required for absorption. The weight of aggregates are also adjusted accordingly.

MIX DESIGN DETAILS

<table>
<thead>
<tr>
<th>No.</th>
<th>Details</th>
<th>M-30</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Grad of Concrete</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Cement</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Absorption</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Maximum nominal size of aggregates</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Fine aggregate</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Minimum cement content</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Maximum free W/C Ratio</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Workability</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Exposure condition</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Method of placing</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Degree of supervision</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Maximum cement content</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Chemical admixture</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Planting</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Ash in experiments</td>
<td></td>
</tr>
</tbody>
</table>

Note: Requirements of all the three mixes are the same. Fine Aggregate, Coarse Aggregate and Normal Super plasticizer are adjusted accordingly for all the three mixes.

4. For Mix A and B free W/C ratio with crushed aggregate and required target strength of 38.3 N/mm² from 28 days from Fig. 1 Curve D found to be 0.45. Taking into the consideration of water in admixture, it is 0.44. This is lower than specified maximum W/C ratio value of 0.45.

Note: In absence of cement strength, but cement conforming to IS Codes, assume from Fig. 1 and 2.

5. Other data's: The Mixes are to be designed on the basis of saturated and surface dry aggregates. At the time of concreting, moisture content of site aggregates are to be determined. If it carries surface moisture this is to be deducted from the mixing water and if it is dry add in mixing water the quantity of water required for absorption. The weight of aggregates are also adjusted accordingly.

MIX C WITH OPC

a) Free W/C ratio for the target strength of 38.3 N/mm² as worked out is 0.44. 
b) Free water for 50 mm slump from Table 2 for 20 mm maximum size of aggregate.
   - 24% water without loss of workability

Note: The exact density may be obtained by filling and fully compacting constant volume suitable metal container from the trial batches of calculated design mixes. The mix be altered with the actual obtained density of the mix.

\[
U_n = 10 \times G_i (100 - A) + C_m (1 - G_i/G_m) - W_m (G_i - 1) = 10 \times 2.65 (100 - 1) + 330(1 - 2.65/3.00) = 45.65 = 140.96 \text{ kg/m}^3
\]

e) Aggregate = 450 - 330 = 120 kg/m³

f) Fine aggregate = From Table 3 for zone-II Fine aggregate and 20 mm maximum size of aggregate.

Free water for 50 mm slump from Table 2 for 20 mm maximum size of aggregate.

Note: Requirements of all the three mixes are the same. Fine Aggregate, Coarse Aggregate and Normal Super plasticizer are adjusted accordingly for all the three mixes.

MIX B WITH OPC

a) Water = 190 - (190 x 0.24) = 144.4 kg/m³ for trials say 145 kg/m³
b) OPC = 145/0.44 = 329.5 kg/m³

c) PPC = 145/0.44 = 329.5 kg/m³

Say 330 kg/m³. This is higher than minimum requirement of 320 kg/m³

d) Formula for calculation of fresh concrete weight

\[
U_m \times 10 x G_i (100 - A) + C_m (1 - G_i/G_m) - W_m (G_i - 1)
\]

Let it be 0.44. This is lower than specified maximum W/C ratio value of 0.45.

Note: In absence of cement strength, but cement conforming to IS Codes, assume from Fig. 1 and 2.

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<table>
<thead>
<tr>
<th>OPC kg/m³</th>
<th>PPC kg/m³</th>
<th>Water kg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>330</td>
<td>330</td>
<td>114</td>
</tr>
</tbody>
</table>

1. Specific gravity of Normal Superplasticizer = 1.15
2. The W/C ratio of PPC and OPC is taken the same assuming that the strength properties of both are the same. If it is found that the PPC is giving the low strength then W/C ratio of PPC have to be reduce, which will increase the cement content. For getting early strength and in cold climate the W/C ratio of PPC shall also be required to be reduced.

3. PPC shall also be required to be reduced.

4. If the trial mixes does not gives the required properties of the mix, it is then required to be altered accordingly. However, when the experiences grows with the particular set of materials and site conditions very few trials will be required and a expert of such site very rarely will be required a 2nd trial.

CONCLUSION

E) Thus for M-30 Grade of concrete having same material and requirement, but without water reducer, the PPC and OPC required will be 190/0.45 = 422kg/m³.

F) With the use of superplasticizer the saving in cement is 92 kg/m³ and water 45 lit/m³ for PPC and OPC.

G) In the Fly ash concrete the saving in cement is 163 kg/m³ and water 52 lit/m³ including utilization of 111 kg/m³ of fly ash which is a waste material.

4. If 50 million tonnes cement in making concrete uses Water Reducers 7500000 tonnes of cement can be prevented to be emitted to the atmosphere. The estimated savings could be Rs. 3300 crores per year to the construction Industry. 6975000 tonnes of CO₂ will be saved. 3750000 KL of potable water will be saved due to this uses Water Reducers 7500000 tonnes of cement can be prevented to be emitted to the atmosphere. The estimated savings could be Rs. 3300 crores per year to the construction Industry. 6975000 tonnes of CO₂ will be saved. 3750000 KL of potable water will be saved due to this.
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