APPENDIX 1

MIX DESIGN PROCEDURE FOR CONTROL CONCRETE
BY IS 10262 – 1982

Step 1

For the required characteristic strength of concrete, calculated the target mean strength using the equation

\[ \text{Target mean strength } f_{ck (\text{mean})} = f_{ck} + (t \times s) \]

where

\( f_{ck} \) is the required characteristic strength

\( s \) = standard deviation which is a factor based on quality

\( t \) = a statistics depending upon the proportion of low results.

Step 2

For the calculated target mean strength, the water cement ratio was found as specified in table of IS 456-2000.

Step 3

Estimate the amount of entrapped air to be inspected in the concrete based on the maximum size of coarse aggregate by referring to the mix design table.
Step 4

Calculate the amount of mixing water per $m^3$ of concrete and the % of sand from mix design table.

Step 5

If the condition of design is different for standard condition specified in mix design table, suitable corrections are to be made as per mix design table.

Step 6

From the chosen W/C ratio and the corrected water requirement, calculated the quantity of cement required. Checked this quantity against the minimum specified in table of IS 456-2000.

Step 7

With the known value of water quality, cement quality, air content and sand %, the required quantities of sand was calculated from the following equation.

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

where \( V \) = Gross volume of concrete – the volume of entrapped air

\( C \) – Weight of cement
\( f_a \) – Weight of fine aggregate
\( W \) – Weight of water
\( Sc \) – Specific gravity of cement
\( S_{fa} \) – Specific gravity of fine aggregate
\( P \) – % of corrected sand
Step 8

With the known value of water quantity, cement quantity, air content and sand percentage, the required quantity of coarse aggregate was calculated from the following equation

\[ V = \left( \frac{C}{Sc} + W + \frac{1}{(1-p) \times Ca / Sca} \right) \times 1/1000 \]

where

- \( C \) – Weight of coarse aggregate
- \( Sca \) – Specific gravity of coarse aggregate

MIX DESIGN OF CONTROL CONCRETE BY IS METHOD

Data

<table>
<thead>
<tr>
<th>Concrete grade</th>
<th>M20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree of quality control</td>
<td>Good</td>
</tr>
<tr>
<td>Type of exposure</td>
<td>Mild</td>
</tr>
<tr>
<td>Size of aggregate</td>
<td>20 mm angular</td>
</tr>
<tr>
<td>Specific gravity of cement</td>
<td>3.15</td>
</tr>
<tr>
<td>Specific gravity of sand</td>
<td>2.66</td>
</tr>
<tr>
<td>Specific gravity of coarse aggregate</td>
<td>2.71</td>
</tr>
<tr>
<td>Compaction factor</td>
<td>0.80</td>
</tr>
<tr>
<td>Grading zone for sand</td>
<td>Type II</td>
</tr>
</tbody>
</table>

Step 1

Target Mean Strength

\[ f_{ck, mean} = f_{ck} + t \times s \]
\[ = 20 + (1.65 \times 4.6) \]
\[ = 27.6 \text{ N/mm}^2 \]
Step 2

W/C ratio from graph for $f_{ck} = 27.6$ N/mm$^2$

W/c ratio for mix in mild exposure condition = 0.50

Step 3

Entrapped Air = 3%

Step 4

Calculate the amount of mixing water per cubic meter of concrete as % of sand. For 20 mm aggregate, water content per cu. m of concrete is 208 kg.

Percentage of sand = 40%

Step 5

The corrections for water and sand is given in Table 3.8.

**Table A1.1 Corrections for Water and Sand**

<table>
<thead>
<tr>
<th>S. No</th>
<th>Property</th>
<th>Water</th>
<th>Sand</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Crushed angular aggregate</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2.</td>
<td>Fine aggregate of grading zone II</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3.</td>
<td>W/C ratio correction decrease of 0.1</td>
<td>-</td>
<td>2 (-1) = -2 %</td>
</tr>
<tr>
<td>4.</td>
<td>Increase of workability compacting factor 0.8 – 0.8 = 0</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>5.</td>
<td>Total correction</td>
<td>-</td>
<td>-2%</td>
</tr>
</tbody>
</table>

Corrected quantity of water = 208 kg.

Corrected sand = 40-2 = 38 %

P = 0.38
Step 6

Cement quantity =  Corrected water quantity / water cement ratio

= 208 / 0.5

= 416 kg

Cement required = 416 kg

Step 7

To find $f_a$:

$$V = \frac{(C/Sc + W + 1/P \times f_a / S_{fa})}{1000}$$

$$1-0.03 = \frac{(416/3.15 + 208 + 1/0.38 \times f_a / 2.66)}{1000}$$

$$f_a = 636.95 \text{ kg}$$

Step 8

$$V = \frac{(C/Sc + W + 1/(1-p) \times C_a / Sca)}{1000}$$

$$1-0.03 = \frac{(416/3.15 + 1/(1-0.38) \times C_a / 2.71)}{1000}$$

$$C_a = 1112.97 \text{ kg}$$

Quantity of material per m$^3$ of concrete

By weight

- Cement = 416 kg
- Sand = 636.95 kg
- Coarse aggregate = 1112.97 kg
- Water = 208 kg
- Mix proportion = 1: 1.53: 2.68: 0.5
APPENDIX 2

MIX DESIGN PROCEDURE FOR FLY ASH AGGREGATE CONCRETE

(a) Mean Design Strength of Concrete is computed by dividing the specified 28 days minimum cube strength by Control factors.

(b) The total water/cement ratio required to achieve the mean design strength is selected from graph showing the relationship between the compressive strength of the water stored cubes and water/cement ratio depending upon the type of light weight aggregate.

(c) Using the water/cement ratio and the required workability, the cement content required for different types of aggregates taken from the graph showing the relationship between the total water/cement ratio and the cement content.

(d) The relative densities of concrete resulting from using the cement content is estimated from the graph showing the relationship between the relative density and the cement content for fully compacted fresh concrete and the relationship between the relative density and the cement content for concrete stored in air for 28 days for different types of aggregates.

(e) The proportion of final fractions in the combined aggregate is varied from 25 to 70 percent by weight depending upon the cement
content and the aggregate grading. For higher cement contents, lower proportion of fines may be used. Starting with a fines percentage of 50 for cement contents in the range of 300 to 500 kg/m$^3$, the mix proportions can be suitably adjusted from the results of trial mixes as for natural aggregates.

**MIX DESIGN OF FLY ASH AGGREGATE CONCRETE**

**Data**

Specified 28 day minimum cube strength = 20 N / mm$^2$

Control Factor = 0.76

Type of aggregate available = Fly ash aggregate

Required workability = Medium to high

Maximum relative density = 2.0 (Air dry concrete)

**Design**

Mean design strength = $20 / 0.76 = 26.32$ N / mm$^2$

Total water cement ratio from the graph showing the relationship between the compressive strength of water stored cubes and the total W/C ratio = 1.1

Using the upper portion of the bands in graph showing the relationship between the total water/cement ratio and the cement content for the given workability and total water cement ratio of 1.1, the cement content comes out to be = 320 kg / m$^3$

Using this cement content, the relative density of air dry concrete obtained from the graph showing the relationship between the total W/C ratio and the cement content is 1.55 to 1.65 using fly ash aggregate.
The corresponding relative density of fully compacted fresh concrete is 1.75 to 1.78

Mean relative density of fresh concrete is 1.765

Batch quantities for one cubic meter of concrete:

Total weight = 1765 kg
Cement = 320 kg
Water = 1.1 x 320 = 352 kg
Total weight of dry aggregates = 1765 – 672 = 1093 kg

The fly ash fine aggregates and fly ash coarse aggregates are used in equal proportions for the first trial mix and suitable adjustments are made, based on the results of trial mixes.

As per the trial mix, the quantity of materials required per m$^3$ of concrete are

Cement = 257 kg
Fly ash fine aggregate = 396 kg
Fly ash coarse aggregate = 691 kg
Water = 123 kg
APPENDIX 3

COST OF CONTROL CONCRETE OF M20 GRADE

Cost for 1 m$^3$

- Cement 432 kg x Rs. 5.5 / kg = 2376.00
- Fine aggregate 0.45 m$^3$ x Rs. 1408 / m$^3$ = 633.60
- Coarse aggregate 0.90 m$^3$ x Rs. 846 / m$^3$ = 761.40
- Mason II class 0.35 Nos x Rs. 300/No. = 105.00
- Mazdoor I 2.12 Nos x Rs.250/No. = 530.00
- Mazdoor II 3.53 Nos x Rs.150/No. = 529.50
- Vibrating charges = 25.20

Total cost per m$^3$ = 4960.70 say 4961.00

COST OF FLY ASH AGGREGATE CONCRETE

(i) Cement Fly Ash Proportion 10: 90

- Cement 257 kg x Rs. 5.5 / kg = 1413.50

Fly ash fine aggregate

- Cement content 35.6 kg x Rs. 5.5 / kg = 195.80
- Fly ash content 320.4 kg x Rs. 0.15 / kg = 48.06

Fly ash coarse aggregate

- Cement content 62.2 kg x Rs. 5.5 / kg = 342.10
- Fly ash content 559.8 kg x Rs. 0.15 / kg = 83.97
- Mason II class 0.35 Nos. x Rs.300 / No. = 105.00
Mazdoor I 2.12 Nos. x Rs. 250 / No = 530.00
Mazdoor II 3.53 Nos x Rs. 150 / No = 529.00
Adding vibrating charges = 25.20

**Formation of fly ash aggregate**
Mazdoor I 1.5 Nos x Rs. 250 / No = 375.00
Mazdoor II 1.5 Nos x Rs. 150 / No = 225.00

Total cost per m\(^3\) = 3872.63 say 3873.00

(ii) **Cement Fly Ash Proportion 12.5:87.5**

Cement 257 kg x Rs. 5.5 / kg = 1413.50

**Fly ash fine aggregate**
Cement content 49.5 kg x Rs. 5.5 / kg = 272.25
Fly ash content 346.5 kg x Rs. 0.15 / kg = 51.97

**Fly ash coarse aggregate**
Cement content 86.37 kg x Rs. 5.5 / kg = 475.06
Fly ash content 604.63 kg x Rs. 0.15 / kg = 90.69
Mason II class 0.35 Nos. x Rs.300/No. = 105.00
Mazdoor I 2.12 Nos. x Rs. 250 / No. = 530.00
Mazdoor II 3.53 Nos x Rs. 150 / No = 529.00
Adding vibrating charges = 25.20

**Formation of fly ash aggregate**
Mazdoor I 1.5 Nos x Rs. 250 / No = 375.00
Mazdoor II 1.5 Nos x Rs. 150 / No = 225.00

Total cost per m\(^3\) = 4067.47 say 4068.00
(iii) Cement fly ash proportion 15:85

Cement 257 kg x Rs. 5.5 / kg = 1413.50

**Fly ash fine aggregate**

Cement content 59.4 kg x Rs. 5.5 / kg = 326.70
Fly ash content 336.6 kg x Rs. 0.15 / kg = 50.49

**Fly ash coarse aggregate**

Cement content 103.65 kg x Rs. 5.5 / kg = 570.07
Fly ash content 587.35 kg x Rs. 0.15 / kg = 88.10
Mason II class 0.35 Nos. x Rs.300/ No = 105.00
Mazdoor I 2.12 Nos. x Rs. 250 / No = 530.00
Mazdoor II 3.53 Nos x Rs. 150 / No = 529.00
Adding vibrating charges = 25.20

**Formation of fly ash aggregate**

Mazdoor I 1.5 Nos x Rs. 250 / No = 375.00
Mazdoor II 1.5 Nos x Rs. 150 / No = 225.00

**Total cost per m³ = 4238.06 say 4238.00**

(iv) Cement fly ash proportion 17.5:82.5

Cement 257 kg x Rs. 5.5 / kg = 1413.50

**Fly ash fine aggregate**

Cement content 69.3 kg x Rs. 5.5 / kg = 381.15
Fly ash content 326.7 kg x Rs. 0.15 / kg = 49.00
Fly ash coarse aggregate
Cement content 120.92 kg x Rs. 5.5 / kg = 665.08
Fly ash content 570.07 kg x Rs. 0.15 / kg = 85.51
Mason II class 0.35 Nos. x Rs.300/ No = 105.00
Mazdoor I 2.12 Nos. x Rs. 250 / No = 530.00
Mazdoor II 3.53 Nos x Rs. 150 / No = 529.00
Adding vibrating charges = 25.20

Formation of fly ash aggregate
Mazdoor I 1.5 Nos x Rs. 250 / No = 375.00
Mazdoor II 1.5 Nos x Rs. 150 / No = 225.00

Total cost per m³ = 4358.24 say 4359.00

(v) Cement Fly Ash Proportion 20:80
Cement 257 kg x Rs. 5.5 / kg = 1413.50

Fly ash fine aggregate
Cement content 79.2 kg x Rs. 5.5 / kg = 435.60
Fly ash content 316.8 kg x Rs. 0.15 / kg = 47.52

Fly ash coarse aggregate
Cement content 138.2 kg x Rs. 5.5 / kg = 760.00
Fly ash content 552.8 kg x Rs. 0.15 / kg = 82.92
Mason II class 0.35 Nos. x Rs.300/ No = 105.00
Mazdoor I 2.12 Nos. x Rs. 250 / No = 530.00
Mazdoor II 3.53 Nos x Rs. 150 / No = 529.00
Adding vibrating charges = 25.20
Formation of fly ash aggregate

Mazdoor I 1.5 Nos x Rs. 250 / No = 375.00
Mazdoor II 1.5 Nos x Rs. 150 / No = 225.00

Total cost per $m^3 = 4528.74$ say $4529.00$

(vi) Cement Fly Ash Proportion 22.5:77.5

Cement 257 kg x Rs. 5.5 / kg = 1413.50

Fly ash fine aggregate

Cement content 89.1 kg x Rs. 5.5 / kg = 490.05
Fly ash content 306.9 kg x Rs. 0.15 / kg = 46.03

Fly ash coarse aggregate

Cement content 155.47 kg x Rs. 5.5 / kg = 855.08
Fly ash content 535.52 kg x Rs. 0.15 / kg = 80.32
Mason II class 0.35 Nos. x Rs.300/ No = 105.00
Mazdoor I 2.12 Nos. x Rs. 250 / No = 530.00
Mazdoor II 3.53 Nos x Rs. 150 / No = 529.00
Adding vibrating charges = 25.20

Formation of fly ash aggregate

Mazdoor I 1.5 Nos x Rs. 250 / No = 375.00
Mazdoor II 1.5 Nos x Rs. 150 / No = 225.00

Total cost per $m^3 = 4648.48$ say $4649.00$