APPENDIX 1

CONCRETE MIX DESIGN WITH QUARRY ROCK DUST AS FINE AGGREGATE

A1.1 IS METHOD OF CONCRETE MIX DESIGN

The Indian Standard code IS 10262 - 1982 presents guidelines for mix design, which includes design of normal concrete mixes (non-air entrained) both for medium and high strength concrete. The basic assumption made in the mix design is that the compressive strength of workable concrete is by and large governed by water / cement ratio. In this method of mix design the water content and proportion of fine aggregate corresponding to maximum size of aggregate are first determined for reference value of workability, water / cement ratio and grading of fine aggregate. The water content and proportion of fine aggregate are then adjusted for any difference in workability, water / cement ratio and grading of fine aggregate in any particular case from reference value.

1. An example illustrating the mix design for a concrete of M20 grade with quarry rock dust as fine aggregate is given below.

CONCRETE MIX DESIGN

Step 1: Design stipulations

a) Characteristic compressive strength $20 \text{ N/mm}^2$
   
   Required in the field at 28 days.
b) Maximum size of aggregate 20 mm (angular)
c) Degree of workability 0.92 compacting factor
d) Degree of quality control good
e) Type of exposure Mild

**Step 2: Test data for materials**

a) Cement used- ordinary Portland cement((IS 8112-1989)

b) Specific gravity of cement 3.14
c) Specific gravity
   1. Coarse aggregate 2.65
   2. Quarry rock dust 2.60
d) Water absorption
   1. Coarse aggregate 1.50 percent
   2. Quarry rock dust. 4.00 percent
e) Free (surface) moisture
   1. Coarse aggregate Nil
   2. Quarry rock dust Nil
f) Sieve analysis
   1. Coarse aggregate - Conforming to Table 3 of IS 383 - 1970
   2. Quarry rock dust - Confirming to Zone II Grading of Table 4 of IS 383-1970
Step 3: Target mean strength of concrete

For a tolerance factor of 1.65 and using Table 1 of IS 10262-1952, the target mean strength for the specified characteristics cube strength is

\[ 20 + 4.60 \times 1.65 = 27.6 \text{N/mm}^2 \]

Step 4: Selection of water cement ratio

From Figure 1 of IS 10262 the free water-cement ratio required for the target mean strength of 27.6 N/mm\(^2\) is 0.50. This is lower than the maximum value of 0.60 prescribed for ‘Mild’ exposure in Table 5 IS 456-2000.

Step 5: Selection of water and sand content

From table 4 of IS 10262-1982 for 20 mm nominal maximum size of aggregate and quarry rock dust conforming to grading zone II. Water content per cubic meter of concrete = 186 kg and Fine aggregate content as percentage of total aggregate by absolute volume = 35%. 

ADJUSTMENT OF VALUES IN WATER CONTENT AND FINE AGGREGATE (FA) PERCENTAGE FOR BETTER CONDITIONS (TABLE 6 IS 10262-1982)

<table>
<thead>
<tr>
<th>Change in condition</th>
<th>Water content Percent</th>
<th>Adjustment required in FA percentage in total Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) For FA conforming to Zone II of Table 4 of IS: 383-1970</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>b) For increase in compacting factor (0.92-0.8) That is 0.12</td>
<td>+3.6%</td>
<td>0</td>
</tr>
<tr>
<td>c) For decrease in water-cement ratio By (0.55-0.50) that is 0.05</td>
<td>0</td>
<td>-1%</td>
</tr>
<tr>
<td>Total</td>
<td>+3.6%</td>
<td>-1%</td>
</tr>
</tbody>
</table>

Therefore, required FA content as percentage of total aggregate by absolute volume = 35 -1 = 34 percent.

186 x 3.6

Required water content = 186 + -------- = 192.70 lit / m³
100
Step 6: Determination of cement content

Water cement Ratio = 0.50

Water = 192.70

Cement = 192.70 / 0.50 = 385.40 kg/m³

Step 7: Determination of coarse and fine aggregate content

From Table 3 IS 10262-1982 for the specified maximum size of aggregate of 20 mm, the amount of entrapped air in the wet concrete is 2%.

Quarry rock dust content ($f_a$)

\[
0.98 \text{ m}^3 = 192.70 + \left(\frac{385.40}{3.14} + \frac{1}{0.34} \times \frac{f_a}{2.60}\right) \times \frac{1}{1000}
\]

\[
980 = 192.70 + 122.70 + \frac{f_a}{0.884}
\]

\[
980 = 315.40 + \frac{f_a}{0.884}
\]

\[
f_a = \frac{587.5 \text{ kg/m}^3}{.884}
\]

Coarse aggregate content ($C_a$)

\[
0.98 \text{ m}^3 = (192.70 + 385.4/3.14 + 1/0.66 .C_a /2.65) \times 1/1000
\]

\[
980 = 192.70 + 122.70+C_a/1.749
\]

\[
980 = 192.70 + 122.70+\Box C_a/1.749
\]
\[ 980 = 315.4 + \frac{Ca}{1.749} \]

\[ Ca = 1162.40 \text{ kg/m}^3 \]

The mix proportion then becomes:

<table>
<thead>
<tr>
<th>Water</th>
<th>Cement</th>
<th>Fine aggregate</th>
<th>Coarse aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>192.70</td>
<td>385.4 kg</td>
<td>587.5 kg</td>
<td>1162.40 kg</td>
</tr>
<tr>
<td>0.50</td>
<td>1</td>
<td>1.52</td>
<td>3.01</td>
</tr>
</tbody>
</table>

A1.2 \hspace{1em} ACI METHOD

The American Concrete Institute (ACI) method is based on the water content, which determines the workability of concrete mix for different maximum size of aggregate. The bulk volume of coarse aggregate per unit volume of concrete is determined for different maximum sizes of aggregate and fineness modulus of fine aggregate. The water-cement ratio is determined to satisfy the requirements of strength and durability. The volume of fine aggregate is determined per unit volume of concrete, from the difference in volume between the concrete and other ingredients. Allowance for air content in concrete is made prior to calculating the volume of fine aggregate. The step-by-step procedure followed according to ACI 211-1.77 for the design of mix is: (ACI committee 211- Standard recommended practice for selecting proportions for normal and heavy weight concrete)

- The water-cement ratio is selected from Table 31 (SP 23 - 1982) for the target mean 28-day compressive strength.
• The water content is selected from Table 32 (SP 23 -1982) for the desired workability and maximum size of aggregate.

• The cement content is calculated from the water content and water-cement ratio required for durability or strength.

• The Coarse aggregate (CA) content is estimated from Table 33 (SP 23-1982) for the maximum size of aggregate and fineness modulus of sand.

• The fine aggregate (FA) content is determined by subtracting the sum of the volumes of coarse aggregate, cement, water and air content from the unit volume of concrete.

• If the aggregates contain excessive moisture, suitable adjustments are made in the field mix proportions to account for the water in the aggregates.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristics compressive strength</td>
<td>20 N/mm²</td>
</tr>
<tr>
<td>Maximum size of aggregate</td>
<td>20 mm</td>
</tr>
<tr>
<td>Degree of workability</td>
<td>0.92 comp. Factor</td>
</tr>
<tr>
<td>Degree of quality control</td>
<td>Good</td>
</tr>
<tr>
<td>Type of exposure</td>
<td>Mild</td>
</tr>
<tr>
<td>Cement used C-43 grade specific gravity</td>
<td>3.14</td>
</tr>
<tr>
<td>Specific gravity of CA</td>
<td>2.65</td>
</tr>
<tr>
<td>Specific gravity of FA</td>
<td>2.60</td>
</tr>
<tr>
<td>Water absorption of CA</td>
<td>1.50%</td>
</tr>
<tr>
<td>Water absorption of FA</td>
<td>4.0%</td>
</tr>
<tr>
<td>Moisture content of CA</td>
<td>Nil</td>
</tr>
<tr>
<td>Moisture content of FA</td>
<td>4.00%</td>
</tr>
<tr>
<td>Dry Rodded Unit wt CA</td>
<td>1600 kg/m³</td>
</tr>
<tr>
<td>Fineness modulus of FA</td>
<td>2.61</td>
</tr>
<tr>
<td>Slump</td>
<td>75-100 mm</td>
</tr>
</tbody>
</table>
Mix design procedure

Step 1:

Mean target strength = \( 20 + 1.64 \times 4 \)

= 26.56 N/mm\(^2\)

Read the value of water cement ratio for mean target comp strength of 26.56 N/mm\(^2\) at 28 days for non-air entrained concrete from Table 31 (SP23: 1982).

Water Cement Ratio = 0.60

Step 2:

For slump 80-100 and maximum size of aggregate as 20mm.

The approximate water content and Table 32 (SP 23:1982)

Water = 200 kg/m\(^3\)

Entrapped air = 2%

Step 3:

The quality of cement per/m\(^3\) = \( \frac{200}{0.60} \) = 333.3 kg/m\(^3\)

Step 4:

From Table 33, read the volume of dry-rodded coarse aggregate per m\(^3\) of concrete for fineness modulus of 2.61 and maximum size of aggregate as 20mm.

Volume of dry-rodded coarse aggregate = 0.64 m\(^3\) and

Weight of dry-rodded coarse aggregate = 0.64\times1600 = 1024 kg
Step 5:

Now find the volume of fine aggregate

\[ V_f = 1000(1-0.02) - 333.3/3.14 - 200 - 1024/2.65 \times 1000 \]

\[ = 980 - 106.15 - 200 - 386.42 \]

\[ = 287.43 \times 10^3 \]

Weight of dry quarry rock dust  = 287.47 x 2.60

\[ = 747.32 \text{ kg/m}^3 \]

The quantity of ingredients will be

Cement  = 333.3 kg/m\(^3\)

Quarry rock dust  = 747.32 kg/m\(^3\)

CA  = 1024 kg/m\(^3\)

Water  = 200 kg/m\(^3\)

The mix proportion then becomes:

<table>
<thead>
<tr>
<th>Water</th>
<th>Cement</th>
<th>Fine aggregate</th>
<th>Coarse aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>200.00</td>
<td>333.3 kg</td>
<td>747.32 kg</td>
<td>1024.0 kg</td>
</tr>
<tr>
<td>0.60</td>
<td>1</td>
<td>2.24</td>
<td>3.07</td>
</tr>
</tbody>
</table>

A1.3 USBR METHOD

The method of concrete mix proportion outlined in USBR Manual is by and large similar to that of ACI method. The water content of air-entrained concrete and the proportions of fine and coarse aggregates are determined for a fixed workability and grading of fine aggregate. The water content and percentages of sand or coarse aggregate are adjusted for changes in the materials and mix proportions. The step-by-step procedure of mix design is:
• Table 34 (SP23: 1982) recommends maximum slumps for various types of concrete construction works from which an appropriate selection may be made.

• The water-cement ratio for the target mean 28-day compressive strength is determined from Table 35 (SP23: 1982) for either air-entrained concrete or air-entrained concrete with Water-Reducing, set-controlling admixtures (WRA). The water cement ratio can then be checked against the maximum permissible value for the type of exposure and construction work specified in Table 36 (SP 23:1982) and lower of the two values should be adopted.

• Approximate air and water content and the percentage of sand and coarse aggregate per m³ of concrete are determined from Table 37 (SP 23:1982), for concrete containing natural sand with fineness modulus of 2.75 and having workability of 75 to 100 mm slump.

• Adjustment of values in water content and percentage of sand or coarse aggregate are made use Table 38 (SP 23:1982) for changes in fineness modulus of sand, slump of concrete, air-content, water content ratio and the water content of concrete mix.

• The quantity of coarse aggregate is estimated from Table 37 (SP 23:1982) or by computing the total solid and volume of fine aggregate and coarse aggregate in the concrete mix and multiplying the final percentage of sand after adjustment determine proportions of aggregate. Either method is satisfactory and gives approximately the same proportions under average conditions.
Data given

1. Mean cylinder strength = 200 kg/cm² at 28 days
2. Slump = 75 mm
3. Fineness modulus of quarry dust = 2.61
4. Coarse aggregate
   (a) Maximum size of aggregate= 20mm
   (b) Dry rodded unit weight = 1600 Kg/m³
5. Specific gravity
   (a) Cement = 3.14
   (b) Coarse aggregate = 2.65
   (c) Fine aggregate = 2.60

Use Table 36 (SP 23:1982) for adjustment of values of water content percent
fine aggregate and percent of dry-rodded coarse aggregate.

<table>
<thead>
<tr>
<th>Changes in material or mix proportions</th>
<th>Adjustment required in</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water content percent</td>
</tr>
<tr>
<td>Each 0.1 increase or decrease in fineness modulus of sand</td>
<td>-</td>
</tr>
<tr>
<td>Each 25 mm increase or decrease in slump</td>
<td>± 3</td>
</tr>
<tr>
<td>Each 1 percent decrease or increase in air content</td>
<td>±3</td>
</tr>
<tr>
<td>Each 0.05 increase or decrease in water-cement ratio</td>
<td>-</td>
</tr>
<tr>
<td>Each 1 percent increase or decrease in sand content</td>
<td>±1</td>
</tr>
</tbody>
</table>
Mix design procedure

Step 1:

Target mean compressive strength = 20 x 1.64 x 4 = 26.56 N/mm²

Read value of water-cement ratio for mean compressive strength of 26.56 N/mm²

At 28 days from Table 34 (SP 23: 1982)

Water-Cement ratio = 0.53

Step 2:

Maximum permissible Water-Cement Ratio for severe climate from Table 36 (SP 23:1982) for Class B is 0.50

Therefore, adopt water-cement ratio = 0.50

Step 3:

Read value of air content, water content, and percentage dry rodded unit weight for maximum size if aggregate is equal to 20 mm from Table 35 (SP 23:1982).

Water Content = 156 kg/m³
Air Content = 6%
Fine aggregate (FA) = 42%

Therefore,

Weight of Cement = 156/0.50 = 312 kg

Volume of FA = \([(1-0.06) 1000-312x1000/3.14-156x1000] \times 0.42\)

= 0.288 cm³

Weight of FA = 0.288x1000x2.60 = 748.8 kg

Volume of coarse aggregate = \([(1-0.06) x1000-312/1000x3.14-156x1000-288/1000]\)

= 0.397 m³
Weight of coarse aggregate = 0.397 \times 1000 \times 2.65 = 1052.0 \text{ kg}

The quantity of Ingredients will be

- Cement = 312.0 kg/m$^3$
- Quarry rock dust = 748.8 kg/m$^3$
- CA = 1052 kg/m$^3$
- Water = 156 kg/m$^3$

The mix proportion then becomes:

<table>
<thead>
<tr>
<th>Water</th>
<th>Cement</th>
<th>Fine aggregate</th>
<th>Coarse aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>156.00</td>
<td>312.0 kg</td>
<td>748.80 kg</td>
<td>1052.0 kg</td>
</tr>
<tr>
<td>0.50</td>
<td>1</td>
<td>2.40</td>
<td>3.37</td>
</tr>
</tbody>
</table>

A1.4 ROAD NOTE NO.4 METHOD

This method is mainly based on the fact that aggregate grading affects the workability and strength of concrete. It uses the standard grading curves of combined aggregates and the design tables of aggregate-cement ratios for different types of cement and size, type and grading of aggregates, prepared from comprehensive laboratory tests. The tables are based on use of total water added to air-dry aggregates. The water content is found indirectly from water-cement and aggregate-cement ratios. The step-by-step procedure to be followed (based on Rajendra Chalisgaonikar 2003) for design of the mix is:

- The average compressive strength of mix to be designed is obtained by applying the control factors to the minimum compressive strength depending on the degree of quality control given in Table 3.9 on page 36
• The water-cement ratio needed to give the necessary average compressive strength, at the desired age and for type of cement used, can be read from the standard water-cement ratio compressive strength curves shown in Fig. 3.1 on page 37.

• If the aggregate available at worksite differs from the standard grading, the coarse and fine aggregates must be combined to produce one of the standard grading.

• The proportion of cement, water, fine and coarse aggregates are determined, with aknowledge of the water-cement and aggregate-cement ratios of the mix.

• The quantities of ingredients required to produce 1m$^3$ of concrete is calculated by the absolute volume method, using specific gravities of cement and aggregates.

• The necessary adjustments are made in the ingredients depending on the moisture contents in the aggregates, if any.

Data Given

1. Type of cement = Ordinary Portland Cement (OPC)
2. Mean cylinder strength = 200 kg/cm$^2$ 28 days
3. Coarse aggregate
   (a) Type of aggregate = Angular
   (b) Maximum size of aggregate = 20 mm
4. Specific gravity
   (a) Cement = 3.14
   (b) Coarse aggregate = 2.65
   (c) Fine aggregate = 2.60
5. Type of fine aggregate = quarry rock dust
6. Degree of quality control       Good
7. Degree of workability          medium
8. Proportion of fine to total aggregate = 40%
9. Grading of aggregates          Zone II
10. Moisture content
     (a) Coarse aggregate = nil%
     (b) Fine aggregate  = nil%
11. Water absorption
     (a) Coarse aggregate = 1.5%
     (b) Fine aggregate  = 4.0%

Mix Design Procedure

Step 1:

Read value of control factor for the minimum strength from Table 3.9
Factor for minimum strength = 0.75 and
Therefore, mean design strength = 20/0.75 = 26.67 N/mm²

Step 2:

Read the value of water-cement ratio corresponding to mean compressive strength of 20 N/ mm² at 28 days for ordinary Portland cement from Figure 3.1.

Water-cement ratio = 0.62
Step 3:
Read value of aggregate-cement ratio for water-cement ratio equal to 0.62 from Table 3.12(c) on page 42 for 20 mm angular aggregate, high workability and grading zone II.
Aggregate-cement ratio = 4.88

Step 4:
The proportions of ingredients can now be calculated as:
Cement = 1 = 1.0
Fine aggregate = 0.40 x 4.88 = 1.952
Coarse aggregate = (1-0.40) x 4.88 = 2.928

Step 5:
Now weight of cement can be found out by absolute volume method.
\[ \frac{C}{3.14} + 1.952x\frac{C}{2.6} + 2.928x\frac{C}{2.65} + 0.62x\frac{C}{3} = 1000 \]
Where
“C” is the weight of cement in 1 m\(^3\) of concrete.
Thus the weight of
Cement = 355.32 = 355.32 kg
Water = 0.62x355.32 = 220.30 kg
Fine aggregate = 1.952x355.32 = 693.58 kg
Coarse aggregate = 2.928x355.32 = 1040.38 kg

The quantity of ingredients will be
Cement = 355.32 kg/m\(^3\)
FA = 693.58 kg/m\(^3\)
CA = 1040.40 kg/m\(^3\)
Water = 220.30 kg/m\(^3\)
The mix proportion then becomes:

<table>
<thead>
<tr>
<th>Water</th>
<th>Cement</th>
<th>Fine aggregate</th>
<th>Coarse aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>220.30</td>
<td>355.32kg</td>
<td>693.58 kg</td>
<td>1040.40 kg</td>
</tr>
<tr>
<td>0.62</td>
<td>1</td>
<td>1.95</td>
<td>2.93</td>
</tr>
</tbody>
</table>

A1.5 BRITISH METHOD

A new method was suggested by Teychenne (1975) et al under the auspices of Department of Environment to remove some of the deficiencies of Road Note No.4 method and was named British method. It discards the use of specific grading curves of combined aggregates, uses the relationship between water-cement ratio and compressive strength of concrete depending on the type of cement and aggregates. It replaces the mix design tables correlating water-cement ratio, aggregate-cement ratio, maximum size of aggregate, type of aggregate, and degree of workability and overall grading curves of the combined aggregates in earlier Road Note 4 method. Instead, water content required to give various levels of workability is determined for two types of aggregates, namely crushed and uncrushed.

The degree of workability viz., very low, low, medium and high have now been referred to in terms of specific values of slump and Vebe time. The method results in expressing mix proportions in terms of quantities of materials per unit volume of concrete in line with European and American practice.
Mix Design Procedure

The step-by-step procedure followed for the design of mix is as:

- Compute the target mean compressive strength.
- The target mean compressive strength is now used to find the free water-cement ratio from Fig. 43(SP23-1982) based on information given in new British method.
- The water content depending upon the type and maximum size of aggregate to give a concrete of the specified slump or Vebe time is selected from Table 38(SP23-1982)
- The cement content is calculated from the water-cement ratio and the water content of the mix.
- The total aggregate content (saturated and surface-dry) is determined by subtracting the cement and water content from the wet density of concrete, the wet density being obtained from Fig. 44 (SP23-1982) depending upon the water content and the relative density of the combined aggregate.

Data Given

1. Type of Cement Ordinary Portland Cement (OPC)
2. Mean cylinder strength = 200 kg/cm² at 28 days
3. Coarse aggregate
   (a) Type of aggregate Uncrushed
   (b) Maximum size of aggregate = 20 mm
4. Specific gravity
   (a) Cement = 3.14
   (b) Coarse aggregate = 2.65
   (c) Quarry rock dust = 2.60
5. Degree of quality control = Good
6. Degree of workability = medium
7. Results falling below minimum strength = 5%
8. Fineness modulus of quarry rock dust = 2.61
9. Moisture content
   (a) Coarse aggregate = Nil
   (b) Quarry rock dust = Nil
10. Water Absorption
    (a) Coarse aggregate = 1.50%
    (b) Quarry rock dust = 4.0%

Mix Design Procedure

Step 1:
Compute target compressive strength.

Target Compressive Strength \( F_{ck} = F_{ck} + t \times S \)

Where \( F_{ck} = 20 \text{ N/mm}^2 \), \( S = 4.60 \) from Table 3.15 and \( t = 1.64 \) from Table 1 & 2, IS 10262

\( F_{ck} = 20 + 1.64 \times 4.60 = 27.59 \text{ N/mm}^2 \)

Step 2:
From Fig. 43 (SP 23:1982) water-cement ratio required to give strength of 27.60 N/mm\(^2\) at 28 days with ordinary Portland cement and uncrushed aggregate is found to be 0.63.

Step 3:
Water content is selected from Table 38 (SP 23:1982) for maximum size of aggregate of 20 mm with high degree of workability and uncrushed type of aggregate.

Water content = 170 kg/m\(^3\)
Step 4:

Cement content = \( \frac{170}{0.63} \) = 269.80 kg/m³

Step 5:

Wet density concrete is selected from Fig.44 (SP 23:1982) for water content equal to 195 kg/m³ and relative density of aggregate as 2.7.

Wet density of concrete = 2475 kg/m³ and
Weight of total aggregate = 2474-170-269.80 = 2034.20 kg

Step 6:

From Fig. 45 (SP 23:1982) proportion of fine aggregate is determined for water-cement ratio equal to 0.63, fineness modulus 2.61, aggregate size as 20 mm and high workability.

Proportion of fine aggregate = 43%
Weight of fine aggregate = 0.43x2034 = 874.62 kg and
Weight of coarse aggregate = (1-0.43) x2034 = 1159.4 kg

The quantity of ingredients will be

Cement = 269.80 kg/m³
FA = 874.62 kg/m³
CA = 1159.40 kg/m³
Water = 170.00 kg/m³

The mix proportion then becomes:

<table>
<thead>
<tr>
<th>Water</th>
<th>Cement</th>
<th>Fine aggregate</th>
<th>Coarse aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>170.00</td>
<td>269.80kg</td>
<td>874.62 kg</td>
<td>1159.40 kg</td>
</tr>
<tr>
<td>0.63</td>
<td>1</td>
<td>3.24</td>
<td>4.30</td>
</tr>
</tbody>
</table>
APPENDIX 2

COST ANALYSIS

A2.1 COST ANALYSIS OF FINE AGGREGATE

Cost of river sand = Rs 635.40/ m³

Wastage due to pebbles, shells and unwanted materials - 20% minimum

Cost of sieving  Rs 17.65/ m³

Actual cost of sand Rs 812/ m³

Cost of crusher sand Rs 370/ m³

Washing charges Rs 123/ m³

Net total Rs 423/ m³ + VAT 4%=Rs 440/ m³

Saving Rs 372/ m³

Cost of savings in fine aggregate -forty five percent per m³
A2.2 COST ANALYSIS FOR CONCRETE

Concrete 10 m³ M20 (1:1.62:3.00)
(Natural sand as fine aggregate)

Table A2.1 Cost analysis of conventional concrete

<table>
<thead>
<tr>
<th>9 m³</th>
<th>Broken stone 20 mm jelly</th>
<th>707.40</th>
<th>m³</th>
<th>6366.60</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.5m³</td>
<td>Cement mortar 1:1.62</td>
<td>3815.00</td>
<td>m³</td>
<td>17167.50</td>
</tr>
<tr>
<td>1.8nos</td>
<td>Mason II Class</td>
<td>145.00</td>
<td>Per person</td>
<td>261.00</td>
</tr>
<tr>
<td>17.7nos</td>
<td>Mazdoor I Class</td>
<td>100.00</td>
<td>Per person</td>
<td>1770.00</td>
</tr>
<tr>
<td>14.1nos</td>
<td>Mazdoor II Class</td>
<td>90.00</td>
<td>Per person</td>
<td>1269.00</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>26834.10</td>
</tr>
</tbody>
</table>

Say Rs. 2684/m³  2683.40/m³

Concrete 10 m³ M20 (1:1.50:3.00)
(Quarry rock dust as fine aggregate)

Table A2.2 Cost analysis of quarry rock dust concrete

<table>
<thead>
<tr>
<th>9 m³</th>
<th>Broken stone 20 mm jelly</th>
<th>707.40</th>
<th>m³</th>
<th>6366.60</th>
</tr>
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<tbody>
<tr>
<td>4.5m³</td>
<td>Cement mortar 1:1.50</td>
<td>3410.00</td>
<td>m³</td>
<td>15345.00</td>
</tr>
<tr>
<td>1.8nos</td>
<td>Mason II Class</td>
<td>145.00</td>
<td>Per person</td>
<td>261.00</td>
</tr>
<tr>
<td>17.7nos</td>
<td>Mazdoor I Class</td>
<td>100.00</td>
<td>Per person</td>
<td>1770.00</td>
</tr>
<tr>
<td>14.1nos</td>
<td>Mazdoor II Class</td>
<td>90.00</td>
<td>Per person</td>
<td>1269.00</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>25011.00</td>
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</table>

Say Rs. 2502/m³

Cost of saving in concrete 7 percent per m³
APPENDIX 3

QUARRY ROCK DUST WASHING PLANT

A3.1 INTRODUCTION

The objective of quarry rock dust washing plant is to remove excess fine particles and introduce artificial moisture content. The plant has integrated screening, fine recovery and water recycling system in an efficient and compact turnkey package.

Quarry rock dust is fully managed from raw feed to quality quarry dust and grit output with an easily handled final waste. Minimum fresh waste is required to advance recycling system.

The operating principles of Impeller in the water groove are to move like a circle transmitted by electric motor. It decelerates the mix and overturns it. Then the mix is cleaned and discharged.

In Figure A3.1, the quarry rock dust is to vibrate feeder regularly. The bottom portion is connected to 5mm sieves and allows the particles less than 5 mm. Figure A3.2 explains the high-pressure water and quarry rock dust mixed uniformly and is sent regularly to Impeller drive.

In Figure A3.3 the impeller drive, the bearing device is separated from water and quarry rock dust. The dust with higher density is sunken down to bottom; the screw blade pushes this upward.
Figure A3.4 explains the silt water being allowed to three stage storage-recycling tanks. In every stage, silt particles are deposited at the bottom of the tank. In the final stage, water is again recycled for washing purpose to mixing plant. (Figures A3.5 and A3.6 indicates the final product of quarry rock dust collected from impeller.)

Figure A3.1 Quarry rock dust feed in vibrating feeder

Figure A3.2 Quarry rock dust with fresh water mixing plant
Figure A3.3 Impeller drive

Figure A3.4 Silt water recycling system
A3.2 PROPERTIES OF WASHED QUARRY ROCK DUST

From Tables A3.1 and A3.2, it is observed that the washed quarry rock dust properties are very close to natural sand. After washing, more than 12% of fine particles (silt) is removed from samples. The water absorption of quarry rock dust has changed and it is has moisture content of 2%. The sieve
analysis test of washed quarry rock dust samples fall in the Zone II of IS 383:1970. (Table A3.2)

**Table A3.1 Physical properties of washed quarry rock dust**

<table>
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<tr>
<th>Property</th>
<th>Washed Quarry rock dust</th>
<th>Test Method</th>
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<tbody>
<tr>
<td>Specific gravity</td>
<td>2.60</td>
<td>IS 2386 (Part III) 1963</td>
</tr>
<tr>
<td>Bulk relative density in Kg/m³</td>
<td>1730</td>
<td>IS 2386 (Part III) 1963</td>
</tr>
<tr>
<td>Absorption in %</td>
<td>Nil</td>
<td>IS 2386 (Part III) 1963</td>
</tr>
<tr>
<td>Moisture content in %</td>
<td>2</td>
<td>IS 2386 (Part III) 1963</td>
</tr>
<tr>
<td>Fine particles less than 0.075 mm in %</td>
<td>3</td>
<td>IS 2386 (Part I) 1963</td>
</tr>
<tr>
<td>Sieve analysis</td>
<td>Zone II</td>
<td>IS 383 - 1970</td>
</tr>
</tbody>
</table>

**Table A3.2 Sieve analysis compression sample used (river sand and washed quarry rock dust)**

<table>
<thead>
<tr>
<th>IS sieve Designation</th>
<th>River sand</th>
<th>*Washed quarry rock dust (Q1)</th>
<th>% Of passing for single sized aggregates of normal sand (IS 383 – 1970)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>% Of Passing</td>
<td>Zone-I</td>
<td>Zone-II</td>
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<tr>
<td>10 mm</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>4.75 mm</td>
<td>99.24</td>
<td>97.40</td>
<td>90-100</td>
</tr>
<tr>
<td>2.36 mm</td>
<td>93.54</td>
<td>84.52</td>
<td>60-95</td>
</tr>
<tr>
<td>1.18 mm</td>
<td>48.67</td>
<td>54.67</td>
<td>30-70</td>
</tr>
<tr>
<td>600 Microns</td>
<td>20.91</td>
<td>40.91</td>
<td>15-34</td>
</tr>
<tr>
<td>300 Microns</td>
<td>04.56</td>
<td>29.33</td>
<td>5-20</td>
</tr>
<tr>
<td>150 Microns</td>
<td>00.38</td>
<td>07.38</td>
<td>0-10</td>
</tr>
<tr>
<td>75 Microns</td>
<td>0.10</td>
<td>03.00</td>
<td>-</td>
</tr>
</tbody>
</table>

* Confirms to IS 383-1970 Zone-II