Concrete mix was designed according to IS: 10262 (Bureau of Indian Standards 1982). The mix was designed to have more finer fractions for aggregate and the maximum size of coarse aggregate was restricted to 8mm, so that uniform distribution and random orientation of fibre could be attained in the case of fibre reinforced concrete. No separate mix was designed for fibrous concrete. The mix was used for casting beams, columns and slabs in all the specimens.

The details of the mix design are present in the Table A 1.1. The details regarding fibre reinforced concrete and Sifcon are presented in Table A 1.2 and Table A 1.3.
Table A 1.1 Details of Mix Design

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Properties</th>
<th>Values adopted</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Required cube strength (28 days)</td>
<td>30N/mm²</td>
</tr>
<tr>
<td>2.</td>
<td>Degree of control</td>
<td>Very good</td>
</tr>
<tr>
<td>3.</td>
<td>Degree of workability</td>
<td>High</td>
</tr>
<tr>
<td>4.</td>
<td>Type of cement</td>
<td>Ordinary Portland cement (conforming to IS:383)</td>
</tr>
<tr>
<td>5.</td>
<td>Type of sand</td>
<td>Natural river sand</td>
</tr>
<tr>
<td>6.</td>
<td>Type of coarse aggregate</td>
<td>Crushed granite (angular)</td>
</tr>
<tr>
<td>7.</td>
<td>Maximum size of coarse aggregate</td>
<td>8mm</td>
</tr>
<tr>
<td>8.</td>
<td>Specific gravity of cement</td>
<td>3.15</td>
</tr>
<tr>
<td>9.</td>
<td>Specific gravity of sand</td>
<td>2.6</td>
</tr>
<tr>
<td>10.</td>
<td>Specific gravity of coarse aggregate</td>
<td>2.6</td>
</tr>
<tr>
<td>11.</td>
<td>Water/ cement ratio</td>
<td>0.5</td>
</tr>
<tr>
<td>12.</td>
<td>Aggregate / cement ratio</td>
<td>4.5</td>
</tr>
<tr>
<td>13.</td>
<td>Proportion of fine aggregate to total fraction</td>
<td>60%</td>
</tr>
<tr>
<td>14.</td>
<td>Proportion of the mix</td>
<td>1:1.3:2.2</td>
</tr>
<tr>
<td>15.</td>
<td>Cube compressive strength after 28 days</td>
<td>31.4N/mm²</td>
</tr>
<tr>
<td>16.</td>
<td>Flexural strength</td>
<td>3.66N/ mm²</td>
</tr>
</tbody>
</table>
### Table A 1.2 Details of Fibre Reinforced Concrete

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Properties</th>
<th>Values adopted</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Mix proportion</td>
<td>1:1.3:1.2.2</td>
</tr>
<tr>
<td>2.</td>
<td>Length of fibre</td>
<td>36mm</td>
</tr>
<tr>
<td>3.</td>
<td>Diameter of fibre</td>
<td>0.45mm</td>
</tr>
<tr>
<td>4.</td>
<td>Volume fraction</td>
<td>1%</td>
</tr>
<tr>
<td>5.</td>
<td>Cube compressive strength – 28 days</td>
<td>32.7N/mm²</td>
</tr>
<tr>
<td>6.</td>
<td>Flexural strength</td>
<td>5.66N/mm²</td>
</tr>
</tbody>
</table>

### Table A 1.3 Details of Sifcon

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Properties</th>
<th>Values adopted</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Mix proportion</td>
<td>1:1</td>
</tr>
<tr>
<td>2.</td>
<td>Type of cement</td>
<td>ordinary Portland cement</td>
</tr>
<tr>
<td>3.</td>
<td>Type of sand</td>
<td>Natural river sand passing through 1.18mm sieve</td>
</tr>
<tr>
<td>4.</td>
<td>Length of fibre</td>
<td>36mm</td>
</tr>
<tr>
<td>5.</td>
<td>Diameter of fibre</td>
<td>0.45mm</td>
</tr>
<tr>
<td>6.</td>
<td>Volume fraction</td>
<td>8 %</td>
</tr>
<tr>
<td>7.</td>
<td>Cube compressive strength – 28 days</td>
<td>52.7N/mm²</td>
</tr>
<tr>
<td>8.</td>
<td>Flexural strength</td>
<td>17.8N/mm²</td>
</tr>
</tbody>
</table>
APPENDIX 2

THEORETICAL PREDICTIONS

A2.1 Theoretical considerations

The stress blocks adopted for doubly reinforced plain concrete section and doubly reinforced fibrous concrete section are shown in Figure A2.1.

A2.1.1 At cracking

The cracking moment using transformed section is

\[ M_{\text{crack}} = f_t \times \frac{I}{y_{\text{bottom}}} \]

Curvature at cracking,

\[ \Phi_{\text{cracking}} = \frac{\left( \frac{f_t}{E_s} \right)}{y_{\text{bottom}}} \]

Cracking Load Capacity

Equivalent area

\[ = bd + (m-1)A_{st} + (1.5m-1)A_{sc} \]
\[ = 50 \times 75 + (9.33-1) \times 56.54 = 4955.7 \text{ mm}^2 \]

Distance of centroid

\[ = \frac{bd^2}{2} + (m-1)A_{st}x d + (1.5m-1)A_{sc}x d_c/\text{Totalarea} \]
\[ = 50 \times 75^2/2 + (9.33-1) \times 56.54 \times 67 + \]
\[ (1.5 \times 9.33-1) \times 56.54 \times 8/4955.7 \]
\[ = 35.93\text{mm} \]
\[ y_{\text{bottom}} = 75-35.93=39.07\text{mm} \]

Cracked moment of Inertia

\[ I_c = \frac{bd_1^3}{3} + \frac{bd_2^3}{3} + (m-1)A_{st} \times (y_{b-d_c})^2 + \]
\[ (1.5m-1)A_{sc} \times y(b-d_c)^2 \]
\[
= 50 \times 35.93^3/3 + 50 \times 39.07^3/3 + \\
(9.33-1) \times 56.54 \times 27.93^2 + \\
(1.5 \times 9.33-1) \times 56.54 \times 31.07^2 \\
= 2.8 \times 10^6 \text{mm}^4
\]

**Cracking Moment**

\[
= f_{cr} \times I_t/y_{bottom} \\
= 18 \times 2.8 \times 10^6/39.07 \\
= 1.3 \text{ kN m}
\]

**Equivalent cracking load**

\[
= (1.3)/0.3 = 4.33 \text{ kN}
\]

**Curvature at cracking**

\[
= \left(\frac{f_{cr}}{E_c}\right)/y_{bottom} \\
= (18 / (2.2 \times 10^4))/(39.07) \\
= 2.1 \times 10^{-5}
\]

### A2.1.2 Yield Load

**Depth of neutral axis**

\[
kd = \frac{(A_s \times f_y + \sigma_t \times b \times D/2-A_s' \times f_{s'})/}{(0.67 \times f_{ck} \times b(2/3)+1/2 \sigma_t \times b)}
\]

Where \(\sigma_t\) is the tensile stress in fibrous concrete section. The following equation incorporating bond efficiency factor and effect of orientation, suggested by Lankard (1972) is used for calculating \(\sigma_t\).

\[
\sigma_t = (0.41 \times 0.82 \times l/d_f) \times b \times v_f
\]

Assume \(f_{s'}\)

\[
= 0.87 f_y \\
= 361 \text{ N/mm}^2
\]

\[
kd = \frac{(56.54 \times 250 + 8.07 \times 50 \times 75/2-56.54 \times 21.75)}{(0.67 \times 52 \times 50 \times 67 + 8.1 \times 50/2)} \\
= 12.39 \text{mm}
\]

**Strain in compression**

\[
\text{steel } \varepsilon_s' = \frac{0.002 \times (12.39-8)/12.39}{7.08 \times 10^{-4}}
\]
FIG A.2.1 REINFORCED CONCRETE BEAM SECTION IN FLEXURE

FIG A.2.2 REINFORCED FIBROUS CONCRETE BEAM SECTION IN FLEXURE
Stress in compression

\[ f_s' = E_s \epsilon_s' = 2 \times 10^5 \times 7.08 \times 10^{-4} \]
\[ = 141.6 \text{ N/mm}^2 \text{ (assumed value)} \]

Substituting \( f_s' = 141.6 \text{ N/mm}^2 \), \( kd = 15.52 \text{ mm and} \)
\[ f_s' = 192 \text{ N/mm}^2 \]

Again by

substituting \( kd = 13.44 \text{ mm and} \)
\[ f_s' = 161.9 \text{ N/mm}^2 \]

Yield moment is given by

\[ (A_s' x f_s' x (d-d')) + 0.67 x f_{ck} x b x kd x (2x3) x (d-0.375kd)) - ((1/2\sigma_t x b) x (D-kd) x (0.33(D-kd)-d')) \]
\[ = 56.54 x 161.9 x 59 + (0.67 x 52 x 50 x 13.44 x 0.67) \times \]
\[ (67-0.375x 13.44) -0.5 x 8.09 x 50 x (75-13.34) x (0.33) \times \]
\[ (75-13.44-8) \]

\[ M_y = 1.35 \text{ kNm} \]

Corresponding load

at yield = 1.35/3=4.51 kN-m.

Curvature at yield = 0.002/kd =0.002/13.44=1.4 \times 10^{-4}

A2.1.3 Ultimate Load

Depth of stress block \( a = (A_s x f_y+\sigma_t x b) (D-a/0.85)-A_s' x f_s') / \)
\[ (0.67 f_{ck} x b) \]
\[ = (56.54 x 250 + 8.09 x 50(75-a/0.85) -56.54 \times 217.5) / (0.67 x 52 x 50) \]
\[ = 14.51 \text{ mm} \]

\[ c = a/0.85 = 14.51 / 0.85 = 17.07 \text{ mm} \]
Strain in compression steel $\varepsilon_s' = 0.008 \times (17.07 - 8) / 17.07 = 4.25 \times 10^{-3}$

Stress in compression steel $f_s' = E_s \times \varepsilon_s' = 2 \times 10^5 \times 4.25 \times 10^{-3} = 850 \text{ N/mm}^2 > f_y$

Compression steel is yielded. Therefore $f_s' = f_y$

$$a = (56.54 \times 250 + 78.09 \times 50 \times (75 - a/0.85)) - 56.54 \times 250 / (0.67 \times 52 \times 50) = 13.68 \text{ mm}$$
$$c = a/0.85 = 13.68 / 0.85 = 16.09 \text{ mm}$$

Ultimate moment $= + \sigma_i \times b(D-c) x (D/2+c/2-a/2) + A_s x f_y x (d-a/2) + A_s' x f_s' x (a/2-d')$
$$= 8.09 \times 50 \times (75 - 16.09) \times (37.5 + 8.05 - 6.84) + 56.54 \times 250 \times (67 - 6.84) + 56.54 \times 250 \times (6.84 - 8) = 1.76 \text{ kNm}$$

Corresponding ultimate load $= 1.76/0.3 = 5.87 \text{ kN}$