APPENDIX- A

Mix Design Procedure of M20 Concrete (Reference Mix)

Characteristic Compressive Strength = 20N/mm²
Maximum size of aggregate = 20mm (Angular)
Degree of workability = 0.9 Compaction factor
Degree of workability = good
Type of exposure = Mild

1. The target strength is determined using the following relation.

\[ F_t = F_{ck} + (t \times s) \]

\( F_t \) = Target mean strength at 28 days.

\( F_{ck} \) = Characteristic compressive strength at 28 days.

\( t \) = A statistical value depending upon the results and number of tests.

\( s \) = standard deviation shown from IS: 10262-1982[8]

Assuming not more than 5% results are expected to fall below the characteristics compressive strength. In which case the value of ‘t’ is 1.65. Standard deviation for M20 grade concrete is 4.6.

\[ F_t = 20 + 1.65 \times 4.6 \]

2. From Figure 2 of IS: 10262-1982[8] the water cement ratio required for the target mean strength of 27.59N/mm² is 0.5.

3. From Figure 2 of IS: 10262-1982[8] for the maximum size of aggregate the air content (entrapped air) is 2%.
4. From Figure 2 of IS: 10262-1982[8] for concrete grade up to M35 and 20mm maximum size of aggregate and natural sand conforming to zone-II, the water content and percentage of sand in total aggregate by absolute volume are 186 Kg/m³ and 35% respectively.

For change in value of water – cement ratio and compaction factor, the following adjustments are required according to IS: 10262-1982[8] in water content and percentage of sand in total aggregate.

<table>
<thead>
<tr>
<th>Change in condition</th>
<th>Adjustment required in</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water content</td>
</tr>
<tr>
<td>For increase in Compaction factor by 0.9 - 0.8 = 0.1</td>
<td>+ 3%</td>
</tr>
<tr>
<td>For decrease in water – cement ratio by 0.6-0.5 = 0.1</td>
<td>--------</td>
</tr>
<tr>
<td>Total</td>
<td>+ 3%</td>
</tr>
</tbody>
</table>

Therefore required sand content as percentage of total aggregate by absolute volume

\[ = 35\% - 2\% \]

\[ = 33\% \]

Required water content = 186 + 186 x3/100

\[ = 191.58 \text{ Kg/m}^3 \]

5. Water –Cement ratio = 0.5

Required Cement content = 191.58/0.5 = 383.2 Kg/m³

This cement content is adequate for mild exposure.

6. The required quantities of fine and coarse aggregates are calculated from the following relation

\[ V = \left[ W + \frac{C}{S_c} + 1/P \frac{F_a}{S_{fa}} \right] \times 1/1000 \] and
\[ C_a = 1 - \frac{P}{P} \times F_{fa} \times S_{ca}/S_{fa} \]

Where

\[ V = \text{Absolute volume of fresh concrete, which is equal to gross volume (m}^3\text{) minus the volume of entrapped air.} \]
\[ W = \text{Mass of water Kg/m}^3\text{ of concrete,} \]
\[ C = \text{Mass of cement Kg/m}^3\text{ of concrete,} \]
\[ S_c = \text{Specific gravity of cement,} \]
\[ P = \text{Ratio of fine to total aggregate by absolute volume,} \]
\[ F_{fa}, C_{ca} = \text{Total masses of fine and coarse aggregate, Kg/m}^3\text{ of concrete,} \]
\[ S_{fa}, S_{ca} = \text{Specific gravities of saturated surface dry fine and coarse aggregate.} \]

\[ 0.98 = [191.6 + 383.2 + 1/0.33 \times F_{fa}/2.68] \times 1/1000 \]

\[ F_{fa} = 727.0 \text{ Kg/m}^3 \]

\[ C_a = 1 - 0.33/0.33 \times 586.54 \times 2.75/2.68 \]
\[ = 1103.0 \text{ Kg/m}^3 \]

The total quantities of ingredients for M20 grade concrete are as follows

Water – Cement = 0.5
Cement content = 383.0 Kg/m³
Fine aggregate = 727.0 Kg/m³
Coarse aggregate = 1103.0 Kg/m³
Water content = 191.6 Kg/m³

Mix proportion is  Cement: Fine aggregate: Coarse aggregate: Water

1: 1.5 : 3.3 : 0.5
APPENDIX – B

A Sample Calculation of Weight Extraction from Chromosome for Workability of High Performance Concrete Problem:

Configuration of GA / ANN model for workability is 4-10-2

Number of weights to be determined = (4x10) + (10x2) = 60

Gene length (d) = 5

Chromosome length or string length = 60x5 = 300

Population size = 300 chromosomes each made up of 60 Genes

A sample chromosome made up of 60 genes is shown below

<table>
<thead>
<tr>
<th>Gene 0</th>
<th>Gene 1</th>
<th>-----</th>
<th>-----</th>
<th>-----</th>
<th>Gene 59</th>
</tr>
</thead>
<tbody>
<tr>
<td>78643</td>
<td>43210</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>34694</td>
</tr>
</tbody>
</table>

To determine the fitness values for each of the chromosomes, we extract weights from each of chromosomes

Let $x_1, x_2, \ldots, x_d, \ldots, x_l$ represents a chromosome and $x_{kd+1}, x_{kd+2}, \ldots, x_{(k+l)d}$ represent the $k^{th}$ gene ($k \geq 0$) in the chromosome. The actual weight $w_k$ is given by

$$w_k = \begin{cases} 
\frac{x_{kd+2} 10^d + x_{kd+3} 10^{d-3} + \ldots x_{(k+l)d}}{10^d}, & \text{if } 5 \leq x_{kd+1} \leq 9 \\
\frac{10^d}{x_{kd+2} 10^d + x_{kd+3} 10^{d-3} + \ldots x_{(k+l)d}} - \frac{10^d}{10^d}, & \text{if } 0 \leq x_{kd+1} \leq 5 
\end{cases}$$

For the sample chromosome shown above we have the weights extracted from the 60 genes as
Gene 0: 78643, we have $k=0$, $d=5$ and $x_{kd+1}$ which is $x_1$ where 

$$5 \leq x_1 = 7 \leq 9$$

$$= + \frac{8 \times 10^3 + 6 \times 10^2 + 3 \times 10^1 + 5}{10^3}$$

$$= +8.643$$

Gene 1: 43210, we have $k=1$, $d=5$ and $x_{kd+1}$ which is $x_6$, is such that 

$$0 \leq x_6 = 4 \leq 5$$

$$= - \frac{3 \times 10^3 + 6 \times 10^2 + 8 \times 10^1 + 7}{10^3}$$

$$= -3.210$$

The weights from all other genes are calculated in similar fashion are tabulated below

<table>
<thead>
<tr>
<th>Gene No</th>
<th>Gene Code</th>
<th>Weight Extracted</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.</td>
<td>78643</td>
<td>+8.643</td>
</tr>
<tr>
<td>1.</td>
<td>43210</td>
<td>-3.210</td>
</tr>
<tr>
<td>2.</td>
<td>54787</td>
<td>+4.787</td>
</tr>
<tr>
<td>3.</td>
<td>97341</td>
<td>+7.341</td>
</tr>
<tr>
<td>4.</td>
<td>12357</td>
<td>-0.357</td>
</tr>
<tr>
<td>5.</td>
<td>43598</td>
<td>-3.598</td>
</tr>
<tr>
<td>6.</td>
<td>86641</td>
<td>+6.641</td>
</tr>
<tr>
<td>7.</td>
<td>92358</td>
<td>-2.358</td>
</tr>
<tr>
<td>8.</td>
<td>32105</td>
<td>+0.105</td>
</tr>
<tr>
<td>9.</td>
<td>96542</td>
<td>+6.542</td>
</tr>
<tr>
<td>10.</td>
<td>23685</td>
<td>-3.685</td>
</tr>
<tr>
<td>11.</td>
<td>43232</td>
<td>-3.232</td>
</tr>
<tr>
<td>12.</td>
<td>56487</td>
<td>+6.487</td>
</tr>
<tr>
<td>13.</td>
<td>32114</td>
<td>-2.114</td>
</tr>
<tr>
<td>14.</td>
<td>36234</td>
<td>-6.234</td>
</tr>
<tr>
<td>15.</td>
<td>97641</td>
<td>+7.641</td>
</tr>
<tr>
<td>16.</td>
<td>64325</td>
<td>+4.325</td>
</tr>
<tr>
<td>17.</td>
<td>12364</td>
<td>+3.64</td>
</tr>
<tr>
<td>18.</td>
<td>71457</td>
<td>+1.457</td>
</tr>
<tr>
<td>19.</td>
<td>14320</td>
<td>-4.320</td>
</tr>
<tr>
<td>20.</td>
<td>57658</td>
<td>+7.658</td>
</tr>
<tr>
<td>21.</td>
<td>94301</td>
<td>+4.301</td>
</tr>
<tr>
<td>22.</td>
<td>72621</td>
<td>+2.621</td>
</tr>
<tr>
<td>23.</td>
<td>22987</td>
<td>-2.987</td>
</tr>
<tr>
<td>24.</td>
<td>14894</td>
<td>-4.894</td>
</tr>
</tbody>
</table>
Similar procedure was adopted for weight extraction of other GA/ANN model.