APPENDIX 1

EXPERIMENTAL PROCEDURES AND SPECIMENS CAST

A1.1 FRESH CONCRETE TESTS FOR MEASURING WORKABILITY

A1.1.1 Slump Test

This test is used extensively at the site of work all over the world. The mould for the slump test is a frustum of a cone having internal diameters of bottom and top as 20cms and 10cme respectively and 30cms height. The internal surface of the mould is cleaned thoroughly and oiled. The mould should be held firmly in place while filling it with concrete. It is filled with four layers, each approximately 7.5cms in thickness and each layer is tamped with twenty five strokes of the rounded end of the tamping rod. After tamping the top layer, the top surface is struck off level with a trowel. Now the mould should be lifted up vertically slowly and carefully. This will allow the unsupported concrete to subside or slump, hence the name of the test. The decrease in the height of the centre of the slumped concrete is called slump and is measured to the nearest of 5mm. the slump is the difference between the original height of concrete in the mould and the highest part of concrete in subsided position.

A1.1.2 Compacting Factor Test

This test is designed primarily to determine the workability of concrete in the laboratory where maximum size of aggregate does not exceed 38mm, however it may also be used in the field. The compacting factor can be
defined as the ratio of the actual density obtained during the test to the fully compacted concrete. The apparatus consists essentially of two hoppers, each of the shape of a frustum of a cone and one cylinder. The hoppers are hinged on a vertical frame one above the other. The hoppers have hinged doors at their bottoms. The inside surface of the hoppers are polished to reduce friction. The sample of concrete to be tested is placed gently in the upper hopper. While filling concrete in upper hopper the bottom hopper and cylinder should be covered, so that no concrete should fall into them. After filling the concrete in upper hopper, the cover from bottom hopper is removed and the hinged bottom door of upper hopper is released and the concrete is allowed to fall into the bottom hopper. Now the cover from the cylinder is removed and the bottom door of the bottom hopper is released and concrete is allowed to fall in the cylinder. The excess concrete in the cylinder is wiped clean and cylinder is weighed. The net weight of the concrete in the cylinder is called as weight of partially compacted concrete and dividing it by the volume of the cylinder, its density is determined. Now the concrete is filled in the cylinder by four layers and fully compacted and the density of the fully compacted concrete is obtained.

\[
\text{Compacting factor} = \frac{\text{Weight of partially compacted concrete}}{\text{Weight of fully compacted concrete}}
\]

The value of compacting factor varies from 0.78 to 1.

**A1.1.3 Vee – Bee Consistometer**

In this method, the consistency of concrete is determined by Vee-Bee consistometer, which determines the time required to transform by vibration a concrete specimen in the shape of a conical frustum into a cylinder. First of all slump of the concrete is determined by putting the metal cone in the sheet metal cylinder of the consistometer. The cone is filled with
concrete and lifted up and the slump is read on the graduated rod. The electric vibrator is now switched on and the concrete is allowed to spread in the cylinder. The vibration is continued until the whole concrete surface uniformly adheres to the glass disc and the time taken in this operation is noted with the help of a stop watch. The consistency of concrete is expressed in Vee-Bee seconds which are equal to time in seconds recorded.

A1.2  STRENGTH TESTS

A1.2.1  Compressive Strength Test

The compressive strength of concrete is one of the most important tests conducted on hardened concrete because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength. The compression test is carried out on cubic specimens of size 150mmx150mmx150mm as per IS: 10086-1982. After 24hours the specimens are demoulded and subjected to water curing. After 3days, 7days and 28days of curing, the specimen is subjected to compressive force in a compression testing machine according to IS 516-1959. A compression testing machine (CTM) of 2000kN capacity shown in figure 4.1 is used to measure the compressive strength of concrete cubes. The ultimate load at which the failure occurs is noted and the compressive strength is calculated by dividing the maximum load by the cross sectional area. The compressive strength value is obtained in N/mm$^2$.

A1.2.2  Split Tensile Strength

This test is an indirect tensile strength test. The method of determining the tensile strength of concrete by applying diametrically opposite compressive forces on a plane passing through the center of the cylinder is called as split tensile strength test. This test is carried out on a cylindrical specimen of 150 mm diameter and 300 mm length. The cylindrical specimen is placed horizontally between the loading surface of a
compression-testing machine and the load is applied until failure of cylinder along the vertical diameter occurs. The CTM machine of 2000kN is used to measure the split tensile strength. Figure 2 shows the testing arrangement. The specimen is loaded until failure occurs and failure load is noted. The split tensile strength in N/mm$^2$ is calculated using the following formula,

$$\frac{2p}{(\pi Ld)}$$

where ‘p’ is the ultimate load at which the cylinder fails, ‘d’ is the diameter of the cylinder ‘L’ is the length of the cylinder.

A1.2.3 Flexural Strength Test

Beams of size 100 x 100 x 500 mm were cast for determining the flexural strength of concrete. After 3days, 7days and 28days of curing, the testing is carried out in UTM of capacity 40T and the system of loading is two point loading as per IS 516-1959. The experimental setup is shown in Figure 4.3. Flexural strength is expressed as modulus of rupture and is given by,

$$f_b = \frac{3pa}{bd^2}$$

where ‘b’ is the measured width of the specimen in cm, ‘a’ is the distance between the support and point of application of load, ‘d’ is the measured depth of the specimen in cm at the point of failure, ‘l’ is the length of the span on which the specimen is supported, and ‘p’ is the maximum load in kg applied to the specimen.

A1.2.4 Bond Strength

The corrosion rate has a direct effect on the bond strength and hence, it is one of the chief factors to be considered. Cylinders of size 150mm diameter and 300 mm length with high yield strength deformed(HYSD) rods of 70cm length kept at the centre, were used for determination of bond strength. Bond strength is given by the formula $P/A$, where $P$ is the ultimate load and $A$ is the total area of the rod i.e. surface area and cross sectional area.
A1.3 MIX DESIGN FOR CONVENTIONAL CONCRETE (I.S. METHOD)

Design Stipulations

Characteristic compressive strength required in the field at 28 days-20 N/mm²
Maximum size of aggregate - 20 mm
Degree of workability - 0.90 compacting factor
Degree of quality control - Good
Type of exposure - Mild

Test Data for Materials

Cement used - Ordinary Portland cement 43 grade
Specific gravity of cement - 3.15
Specific gravity of fine aggregate (river sand) - 2.507
Specific gravity of coarse aggregate - 2.703

Water absorption

i) Coarse aggregate - 0.6%
ii) Fine aggregate - 1.2%

Fine aggregate conforming to grade Zone II

Target mean strength of concrete

Tolerance factor of 1.65
The target mean strength for specified characteristic cube strength is
\[ f_{ck} + t_s \]
\[ 20 + 4.6 \times 1.65 = 26.6 \text{ N/mm}^2 \]
Selection of water cement ratio

Water cement ratio = 0.45

Determination of cement content:

Water cement ratio = 0.45
Water content per cube meter of concrete = 172.5 l / m³
Cement = 172.5/0.45 = 383.3 kg/m³

Determination of course and fine aggregate content:

The maximum size of aggregate 20mm, the amount of entrapped air in the wet concrete is 2%. Locally available well graded granite aggregate of maximum size 20mm was used along with 12mm size aggregates and 6mm chips as coarse aggregates. Their optimal proportion for maximum density was arrived to be 70: 20: 10 respectively and adopted.

Determination of fine aggregate

\[ V = \left[ W + \left( \frac{C_{SC}}{C} \right) + \left( \frac{1}{p} \right) \times \left( \frac{f_{a}}{S_{fa}} \right) \right] \times \frac{1}{1000} \]

Determination of coarse aggregate

\[ Ca = \left[ \frac{(1-P)}{P} \right] x f_{a}x \left( \frac{S_{ca}}{S_{fa}} \right) \]

where

- \( V \) = absolute volume of fresh concrete, which is equal to gross volume (m³) minus the volume of entrapped air
- \( W \) = Mass of water (kg) per m³ of concrete
- \( C \) = Mass of cement (kg) per m³ of concrete
- \( S_{C} \) = Specific gravity of cement
\[
P = \text{Ratio of fine aggregate to total aggregate by absolute volume}
\]
\[
f_a, c_a = \text{Total mass of Ratio of fine aggregate and coarse aggregate (kg) per m}^3\text{ of concrete respectively}
\]
\[
S_{f_a}, S_{c_a} = \text{Specific gravities of saturated, surface dry fine aggregate and coarse aggregate respectively}
\]

**Determination of fine aggregate**

\[
0.98 = \left[172.5 + \frac{383.28}{3.15} + \frac{1}{0.315} \times \left(\frac{f_a}{2.507}\right)\right] \times \frac{1}{1000}
\]

\[
f_a = 581.4 \text{ kg/m}^3
\]

**Determination of coarse aggregate**

\[
c_a = \frac{1-0.315}{0.315} \times 581.43 \times \frac{2.703}{2.507}
\]

\[
c_a = 1297.4 \text{ kg/m}^3
\]

**Mix proportion**

<table>
<thead>
<tr>
<th>Water</th>
<th>cement</th>
<th>fine aggregate</th>
<th>coarse aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>172.5 ml</td>
<td>383.3 kg/m³</td>
<td>581.4 kg/m³</td>
<td>1297.4 kg/m³</td>
</tr>
</tbody>
</table>
| 0.45 : 1.0 : 1.517 : 3.385

**A1.4 MIX DESIGN FOR QUARRY DUST CONCRETE (I.S METHOD)**

**Design Stipulations**

- Characteristic compressive strength required in the field at 28 days - 20 N/mm²
- Maximum size of aggregate - 20 mm
- Degree of workability - 0.90 compacting factor
- Degree of quality control - Good
- Type of exposure - Mild
Test data for materials

Cement used - Ordinary Portland cement 43 grade
Specific gravity of cement - 3.15
Specific gravity of fine aggregate (quarry dust) - 2.688
Specific gravity of coarse aggregate - 2.703

Water absorption

i) Coarse aggregate - 0.6%
ii) Fine aggregate - 1.2%

Fine aggregate conforming to grade Zone II

Target mean strength of concrete

Tolerance factor of 1.65

The target mean strength for specified characteristic cube strength is \( f_{ck} + t_s \)
\[
20 + 4.6 \times 1.65 = 26.6 \text{ N/mm}^2
\]

Selection of water cement ratio

Water cement ratio = 0.45

Determination of cement content

Water cement ratio = 0.45
Water content per cube meter of concrete = 172.5 l/m³
Cement = \( 172.5/0.45 \) = 383.3 kg/m³

Determination of course and fine aggregate content

The maximum size of aggregate 20mm, the amount of entrapped air in the wet concrete is 2%. Locally available well graded granite aggregate of
maximum size 20mm was used along with 12mm size aggregates and 6mm chips as coarse aggregates. Their optimal proportion for maximum density was arrived to be 70: 20: 10 respectively and adopted.

**Determination of fine aggregate**

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

Determination of coarse aggregate

\[ C_a = \left( \frac{1-P}{P} \right) \times f_a \times \left( \frac{S_{ca}}{S_{fa}} \right) \]

where

- \( V \) = absolute volume of fresh concrete, which is equal to gross volume (m³) minus the volume of entrapped air
- \( W \) = Mass of water (kg) per m³ of concrete
- \( C \) = Mass of cement (kg) per m³ of concrete
- \( S_C \) = Specific gravity of cement
- \( P \) = Ratio of fine aggregate to total aggregate by absolute volume
- \( f_a, c_a \) = Total mass of Ratio of fine aggregate and coarse aggregate (kg) per m³ of concrete respectively
- \( S_{fa, S_{ca}} \) = Specific gravities of saturated, surface dry fine aggregate and coarse aggregate respectively

**Determination of fine aggregate**

\[ 0.98 = \left[ 172.5 + \frac{383.28}{3.15} + \frac{1}{0.315} \times f_a \times 2.688 \right] \times \frac{1}{1000} \]

\[ f_a = 576.8 \text{ kg/m}^3 \]
Determination of coarse aggregate

\[ c_a = \frac{(1-0.315)}{0.315} \times 576.8 \times \frac{2.703}{2.688} \]

\[ c_a = 1135.7 \text{ kg/m}^3 \]

Mix proportion

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</tr>
<tr>
<td>0.45 :</td>
<td>1.0          : 1.505          : 2.963</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A1.5 IMAGES OF TEST SPECIMENS

Figure A1.1 below shows the specimens cast for determining the mechanical properties of hardened company.

![Images of test specimens](image1.jpg)

Figure A1.1 Specimens cast for various strength and corrosion tests
The specimen cast were completely immersed in water and subjected curing as shown in Figure A1.2.

Figure A1.2 Curing of specimens

Figure A1.3 below shows the tested concrete specimen for corrosion resistance.

Figure A1.3 Corrosion specimens after testing
Figure A1.4 shows the concrete specimen tested for their mechanical properties.