DESIGN OF M100 GRADE CONCRETE (ACI METHOD)

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ABSTRACT
Concrete is a product obtained by hardening the mixture of cement, sand, gravel and water in predetermined proportions. These days concrete is being used for wide varieties of purposes to make it suitable in different conditions. In these conditions ordinary concrete may fail to exhibit the required quality performance or durability. In such cases, Admixtures are used to modify the properties of ordinary concrete so as to make it more suitable for any situation.

Keywords: High strength concrete, Silica fume, Rheobuild, Mineral admixture and Chemical admixture

INTRODUCTION
"Concrete is a product obtained by hardening of the mixture of cement, sand, gravel and water in predetermined operations". Concrete is one of the most widely used construction materials throughout the world. Many desirable properties such as high compressive strength, excellent durability and fire resistance contributed toward its wide range of applicability (Parrot, 1969). The most advantageous and unique feature of concrete is that it can be produced using locally available ingredients as aggregates. Therefore, in countries where steel is not readily available, as in Bangladesh, concrete is the most used construction material. These days concrete is being used for wide varieties of purposes to make it suitable in different conditions. In these conditions ordinary concrete may fail to exhibit the required quality performance or durability. In such cases, Admixtures are used to modify the properties of ordinary concrete so as to make it more suitable for any situation (Gupta et al., 1884).

High Strength Concrete: In recent years, the terminology "High-Performance Concrete" has been introduced into the construction industry. The American Concrete Institute (ACI) defines high-performance concrete as concrete meeting special combinations of performance and uniformity requirements that cannot always be achieved routinely when using conventional constituents and normal mixing, placing and curing practices. The specification of high-strength concrete generally results in a true performance specification in which the performance is specified for the intended application, and the performance can be measured using a well-accepted standard test procedure.

Admixtures: Admixture is defined as a material, other than cement, water and aggregates which is used as an ingredient of concrete and is added to the batch immediately before or during mixing. Additive is material, which is added at the time of grinding cement clinker at the cement factory. It will be slightly difficult to predict the effect and the results of using admixtures because, many a time the change in the brand of cement, aggregate grading mix proportions and richness of mix after the properties of concrete. Sometimes many admixtures affect more than one property of concrete. Some times more than one admixture is used in the same mix. The effect of more than one admixture is difficult to predict. Therefore, one must be cautious in the selection of admixtures and in predicting the effect of the same in concrete. As per the report the ACI committee-212, admixtures have been classified into 16 groups according to the type of materials constituting the admixtures or characteristic affect of the use. There are many types of admixtures used, namely

1. Plasticizers
2. Super Plasticizers
3. Retarders and retarding plasticizers
4. Accelerators and accelerating plasticizers
5. Air entraining admixtures
6. Pozzolanic or mineral admixtures
7. Damp-proofing and waterproofing admixtures
8. Gas forming admixtures
9. Air-detraining admixtures
10. Alkali aggregate expansion inhibiting admixtures
11. Workability admixtures
12. Grouting admixtures
13. Corrosion inhibiting admixtures
14. Bonding admixtures
15. Fungicidal, germicidal, insecticidal admixtures
16. Coloring admixtures

For high-strength concretes, a combination of mineral and chemical admixtures is nearly always essential to ensure achievement of the required strength.

Mineral Admixtures: Mineral admixtures make mixtures more economical, reduce permeability, increase strength and influence other concrete properties. Mineral admixtures affect the nature of the hardened concrete through hydraulic or pozzolanic activity. Pozzolans are cementitious materials and include natural pozzolans (such as the volcanic ash used in Roman concrete), fly ash and silica fume. They can be used with Portland cement, or blended cement either individually or in combination.

Chemical Admixtures: Chemical admixtures reduce the cost of construction, modify properties of hardened concrete and are used to improve the
quality of concrete during mixing, transporting, placement and curing. They fall into the following categories:

a. Air entrainers
b. Water reducers
c. Set retarders
d. Set accelerators
e. Super plasticizers
f. Specialty admixtures: which include corrosion inhibitors, shrinkage control, alkali-silica reactivity inhibitors, and coloring

**ACI method of concrete mix proportion:** ACI suggests concrete mix design processes for both air-entrained and non-air-entrained concrete. Both the methods are based on the following principles:

1. The workability of the mix depends on the water content and the maximum size of aggregates.
2. The water-cement ratio (w/c ratio) is solely dependent upon the design strength with a restriction from the durability point of view. The w/c ratio is inversely proportional to the design strength.
3. The bulk volume of coarse aggregate per unit volume of concrete depends on the maximum size of the coarse aggregate and the grading of the fine aggregate, expressed as the fineness modulus.

The design starts with the selection of water content for a given maximum size of coarse aggregate and workability required for the type of work, with workability being expressed by slump. Cement content is then found out simply from this water content and the w/c ratio, determined earlier on the basis of the design strength. The volume of coarse aggregate is then determined and fine aggregate content is found out by subtracting the volume (or weight) of other ingredients from the total volume (or weight) of concrete. The weight basis is a trial and error approach while the volume basis is more direct and gives a more accurate result.

**Design Procedure:** The ACI Standard 211.1 is a "Recommended Practice for Selecting Proportions for Concrete". The procedure is as follows:

**Trial strength**

\[ f_{ck} = f_{ck} \text{ Trial Mix Strength} \]

\[ f_{ck} = f_{ck} \text{ Specified Compressive Characteristic Strength} = 100 \text{ N/mm}^2 \]

\[ S = \text{Standard deviation (from ACI 211.4)} = 10 \]

**Trial Mix Strength:**

1. \[ f_{ck} = f_{ck} + 1.34S = 100 + 1.34 \times 10 = 113.4 \text{ N/mm}^2 \]

Or

2. \[ f_{ck} = 0.9f_{ck} + 2.33 \times S = 0.9 \times 100 + 2.33 \times 10 = 113.3 \text{ N/mm}^2 \]

Larger Value out of these two is taken as \[ f_{ck} \]

Therefore, the Value of \[ f_{ck} = 113.4 \text{ N/mm}^2 \]

**Step-1 Choice of slump**

The value of slump height is taken from the Table A 1.5.3.1 of ACI 211.1 based on the type of work. Slump Height is considered as 50 mm.

**Step-2 Choice of maximum size of aggregate**

The ACI method is based on the principle that the Maximum size of aggregate should be the largest available so long it is consistent with the dimensions of the structure.

When high strength concrete is desired, best results may be obtained with reduced maximum sizes of aggregate as they produce higher strengths at a given w/c ratio. The max. size of Coarse aggregate is considered as 20 mm.

**Step-3 Estimation of mixing water and air content**

From the Table A 1.5.3.3 of ACI 211.1, the quantity of water required (for 50 mm Slump and 20 mm aggregates) = 168 kg/m³

**Step-4 Selection of water/cement ratio**

Let the water/cement ratio = 0.25

**Step-5 Calculation of cement content**

Water/cement ratio = 0.25 & Water content = 168 kg/m³ & Specific gravity = 3.15

\[ \Rightarrow \text{Cement content} = 168 / 0.25 = 672 \text{ kg} \]

**Step-6 Estimation of coarse aggregate content**

From the Table A1.5.3.6 of ACI 211.1 (20 mm aggregate and Fineness Modulus of Fine Aggregate as 2.54), the Volume of coarse aggregate per unit volume of concrete = 0.646

Bulk Density of Coarse aggregate = 1710 kg/m³

Per 1m³ of Concrete, the Volume of C.A = 672 kg

The quantity of C.A = 1710 "0.646 = 1104.66 kg

**Step-7 Estimation of Fine Aggregate Content**

**Volume based calculation**

Volume of water = 168/1000 = 0.168 m³

Volume of Cement = 672/(3.15*1000) = 0.213 m³

Volume of Coarse aggregate = 1104.66 / (2.68*1000) = 0.412 m³

Volume of entrapped air = 0.05 m³

Volume of Fine aggregate = 1 - 0.168 - 0.213 - 0.412 - 0.05 = 0.157 m³

Fine Aggregate Content = 0.157x2.64x1000 = 414.48 kg

**Step-8 Adjustments for Aggregate Moisture**

Aggregate quantities actually to be weighed out for the concrete must allow for moisture in the aggregates. Usually the air-dry condition for the CA is close enough for use in laboratory, but the FA is often 2% or 3% above or below SSD. This means that a correction must be made before a laboratory batch of concrete is made.

**Step-9 Trial Batch Adjustments**

The ACI method is written on the basis that a trial batch of concrete will be prepared in the laboratory, and adjusted to give the desired slump, freedom from segregation, finishability, unit weight, air content and strength.

**M100 Mix Design Procedure:**
**Design Stipulations:** Grade of concrete : M100
Size of aggregate : 20 mm & 12.5mm
Degree of workability : 0.90 (compaction factor)
Degree of quality control : good
Type of exposure : moderate
Grade of cement : 53 grade ordinary Portland cement

**Test Data for Materials**
Specific gravity of cement : 3.15
Specific gravity of fine aggregate : 2.64
Specific gravity of coarse aggregate : 2.89
Water absorption of fine aggregate : 1%
Water absorption of coarse aggregate : 0.6%
Bulk Density of coarse aggregate : 1710 kg/m³
Aggregate Impact value : 8.2% (Exceptionally Strong)

**Sieve Analysis** (Table 1)
Fine aggregate: Sand zone II according to IS: 383-1970
Coarse aggregate: Confirming to IS: 383-1970

**RESULTS:**
**Determination of Compressive Strength**
By conducting the workability slump test, it is found that the amount of Rheobuild required for getting the slump height 50 mm = 1.5% (total weight) (Fig 1).

In recent years, the terminology "High-Performance Concrete" has been introduced into the construction industry. Most high-performance concretes produced today contain materials in addition to portland cement to achieve the compressive strength or durability performance. These materials include fly ash, silica fume, ground-granulated blast furnace slag etc. are used separately or in combination. At the same time, chemical admixtures such as high-range water-reducers are needed to ensure that the concrete is easy to transport, place and finish. For high-strength concretes, a combination of mineral and chemical admixtures is nearly always essential to ensure achievement of the required strength. In the present work, Silica Fume as the air entraining admixture and Rheobuild 1100 as the water reducing admixture have been used for obtaining the required strength. The Preliminary experiments have been done on Cement, Fine aggregate and Coarse aggregate. The Mix Proportion for M100 grade concrete is derived as 1 : 0.617 : 1.644 by following the design procedure given by ACI Method. By maintaining the w/c ratio as 0.25, the 28 day strength of concrete has been obtained as 153.46 N/mm² at 6% silica fume and 1.5% of Rheobuild.

**CONCLUSIONS**
The mix exhibited a slump of 50 mm with Chemical admixture, Rheobuild, of 1.5% by weight of cement. By maintaining the w/c ratio as 0.25, the 28 day strength of the concrete is achieved as 150.9 N/mm² at 6% of silica fume and 1.5% of Rheobuild. The strength of the concrete may still be increased by reducing the w/c ratio & increasing the percentage of silica fume.

**REFERENCES**

**Table 1:** Mix Proportion of M100 Grade Concrete

<table>
<thead>
<tr>
<th>Cement</th>
<th>Fine Aggregate</th>
<th>Coarse Aggregate</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>672 kg</td>
<td>414.48 kg</td>
<td>1104.66 kg</td>
<td>168 kg</td>
</tr>
<tr>
<td>1</td>
<td>0.617</td>
<td>1.644</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Water / Cement ratio = 0.25

**Fig 1:** The graph shows the variation of 28 days compressive strength of concrete with the variation of % of Silica Fume.