Lecture 06

ACI Method of Mix Design – Problem; LW Concrete Mix, High Strength Concrete

ACI 211.1-91: Steps for the Design of Normal Concrete Mixes

Step 1: Choice of slump

- Determine slump from Table 6.3.1 for vibratory compaction
- For other compaction, increase by 1 inch

Step 2: Choice of maximum size of aggregate

- Largest size economically available and consistent with dimension of structure
- For higher strength, lower maximum sizes are used
- Structural limits for maximum size:
    - Max. size $1/5^{th}$ of narrowest dimension between sides of forms
      $1/3^{rd}$ of the depth of the slab
      $3/4^{th}$ of the minimum clear spacing between bars

Step 3: Estimating mixing water and air content

- For a given slump, max. size of agg., Approx. mixing water and air content is obtained from Table 6.3.3 which are for
    - Use at 68 -77°F,
    - Angular and well graded aggregate

- Round aggs. Need 30 lb less water for non-air entrained and 25 lb less water for air entrained concrete

Step 4: Selection of w/c or w/ (c+p) ratio

- For OPC, relatively conservative w/c ratio can be taken from Table 6.3.4(a)
- Strength values in 6.3.4(a) are based on 6"x12"cylinders moist cured for 28 days and tested as per ASTM C31, for OPC, AND ¾" -1" max. size
- Values are for 2% air for non-airentrained and 6% air for airentrained concrete
- Avg. strength values exceed specific strength by a margin (ACI 214 and ACI 318)

    Increase in strengths when records of test data are not available are, (ACI 318)
    1000 psi for less than 3000 psi concrete
    1200 psi for 3000 – 5000 psi concrete, and
    1400 psi for more than 5000 psi concrete

- For severe exposure Table 6.3.4(b) may be used

Step 5: Calculation of cement content

Required cement content = estimated mixing water (Table 6.3.3) / w/c ratio (Table 6.3.4(a)

Step 6: Estimation of coarse aggregate content

- For max. agg. size and F.M. of fine agg., coarse aggregate (O-D basis, rodded) is determined from Table 6.3.6 per unit volume of concrete
- Volume from Table 6.3.6 is converted to weight by O-D, rodded unit weight of C.A.
- For workable pumping concrete, values in Table 6.3.6 may be increased by 10%
- For less workable concrete (pavement) the values of Table 6.3.6 may be decreased by 10%

Step 7: Estimation of fine aggregate content

- Fine aggregate weight = Wt. of fresh concrete – Wt. of (CA + Cement + Water)
- Wt. of fresh concrete is taken from experience or (as a first estimate) from Table 6.3.7.1
- Exact unit wt. of fresh concrete, U = 16.85Ga(100-A) + C(1-Ga/Gc) – W(Ga-1) -- sheet
- Values in Table 6.3.7.1 are adjusted in trial batches

Step 8: Adjustment for aggregate moisture

- Moisture in aggregate
- Mixing water should be reduced for surface water of saturated aggregate
- For dry aggregate, moisture required for absorption should be added with required mixing water or preconditioning (SSD) is required

Step 9: Trial batch adjustments

- Trial batches are to be prepared as per ASTM C192
- Only sufficient water is to be added for required slump
- Calculate new batch weights starting with step , modifying the volume of coarse aggregate from Table 6.3.6, if necessary, to provide proper workability

Example: Page 14 – sheet supplied

Mix Design Problem:

A concrete mix is to be designed for the rehabilitation works of loading/unloading jetty of Chittagong food silo. The properties of the ingredients are as follows:

Cement: Ordinary Portland Type I, satisfies all the requirements of ASTM C109, ASTM C187, ASTM C191 & ASTM C204.

Fine Aggregate:

Grading requirement satisfies the specified fine aggregate grading.
Fine aggregate is Sylhet sand with F.M = 2.46
Unit weight of F.A. (ASTM C29) = 91.5 lb/cft
Voids in F.A. = 44.0 percent
Specific Gravity (O-D basis) = 2.65
Absorption (ASTM C128) = 1.0 percent
Clay Lump & Friable particles (ASTM C142) = 0.0 percent
Organic impurities (ASTM C40) = Present
Mica content = 1.30 percent
Materials finer than 75 micron (ASTM C117) = 0.6 percent
Sand equivalent value (ASTM D2419) = 94

Coarse aggregate:

Two types of coarse aggregate (1" max. size and ¾" max. size) are available. These aggregates are combined in 2:1 ratio to obtain the specified grading.
Los Angeles Abrasion value: 1" size = 29 (Grading B)
¾" size = 33 "
Unit weight = 98 lb/cft (combined in 2:1 ratio)
Absorption of combined C.A = 0.8 percent
Voids in combined C.A = 41.0 percent
Specific gravity of combined C.A.(O-D basis) = 2.68

Mix Design Requirements:

- The designer has the freedom to select the mixing of two types of coarse aggregate
- Specified compressive strength at 28 days = 28 MPa
- Required average compressive strength = 35 MPa
- Minimum cement content = 390 kg/m3
- Maximum water cement ratio = 0.45
- Mix design batches shall be in weight basis
- Minimum volume of fine aggregate = 40 percent of total aggregate volume
- Maximum slump = 75 mm

Field Adjustments: Field conditions are unknown

Laboratory Trial Mix:

Coarse and Fine aggregates were sent to BUET laboratory in sealed gunny bags. Moisture contents were found to be 0.5 percent for both types of aggregate. Find the amounts of ingredients for casting nine 4 inch diameter cylinders.

Solution:

The mix was designed as per ACI 211.1-91 as follows:

- Step 1:
- Step 2:
- Step 3:
- Step 4:
- Step 5:
- Step 6:
- Step 7:
- Step 8:
- Step 9:

The result of the mix design is as follows: