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COLLEGE OF ENGINEERING & TECHNOLOGY

DEPARTMENT OF CONSTRUCTION TECHNOLOGY AND MANAGEMENT

Construction Materials

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MIX DESIGN

- Mix design is the selection of mix ingredients and their proportions.
- The purpose of a concrete mix design is to have **economical** mix proportions for the available concreting materials which has adequate workability to be placed in its final position on site.
- **Concrete mix design** is the science of deciding relative proportions of ingredients of concrete, to achieve the desired properties in the most economical way.

ADVANTAGES OF MIX DESIGN

- The aim of Mix design is to achieve good quality concrete at site economically. Mix design has the following advantages:

1. Quality concrete meaning:

- Better strength,
- Better imperviousness and durability and
- Dense and homogeneous concrete

2. Economy

- Economy in cement consumption

- Goals:
  - Maximize strength
    = minimize water
    = control bleeding & segregation
  - Reduce Cost
    = use largest gravel possible for the job
    = minimize paste requirement
  - Provide good durability
    = use well graded aggregates
    = maximize void packing
    = reduced segregation

Information required for mix design

The following information for available materials will be useful:

- Sieve analyses of fine and coarse aggregates.
- Unit weight of coarse aggregate.
- specific gravities and absorption of aggregates.
- Specific gravity of Portland cement and other cementations materials, if used.

Example

1. A concrete mix is specified to be 1:2:4 by volume w/c ratio 0.6 by weight if the moisture content in the fine aggregate 10% and in coarse aggregate 1.5% by volume.

Find out the quantities of different material required for one bag of cement i.e. 50kg

Answer

50kg=35lit of water

w/c =0.6 w/50kg=0.6

w=30

FA=2*35=**70**

CA=4*35=**140**

Moisture content in CA=1.5%*140=2.1

Moisture content in FA=10%*70=7

Net water required =30-(2.1+7)=**20.9**

1. A concrete mix is specified to be 1:2:4 by volume w/c ratio 0.6% by weight if the moisture content in the fine aggregate 10% and water absolution coarse aggregate 1.5% by volume.

Find out the quantities of different material required for one bag of cement i.e. 50kg

the step is the same to the above but

Total water absorb in fine and coarse

−7+2.1−9.1

Exercise

Estimate the amount of ingredients need & their proportion in order to cast a continuous beam using C-30 concrete the dimension of beam 50cm*40cm and length 30,

- ✓ take westage 5% & shrinkage 20%
- ✓ Water cement ratio(W/C) 0.5
- ✓ Aggregate size 20mm with medium slump

EBCs 2

Total agg=215kg

Fine agg=30-40%

Volume of finished concrete=0.127m3

Answer

The amount of fine agg=35%*215kg=75.26kg

Coarse agg=215- FA

=215-75.26=139.75kg

Volume of concrete to be cast =0.5*0.4*30m=6m3

Total volume = 5%+20%=25%

=25%*6+6=7.5

FA= 0.127m3=75.26kg

7.5m3 = x

X=**4444.5kg**

CA= 0.127=139.75

7.5 =y

Y= **8253kg**

For cement 50kg=0.127

z =7.5 **z=2953kg**

Ingredients proportion	weight in kg
Cement **1**	**2953**
Fine aggregate 1.51=**2**	**4444.5**
Coarse aggregate 2.79**=3**	**8253**

There for the mix ratio is 1:2:3

w/c=w/50kg/ proportion = 0.5

Water =4.16

Construction material breakdown

- Assumed concrete mix ratio =1:2:4
- Concrete volume =xm3
- Shrinkage =30%
- Wastage =5%
- Unit weight of cement=1400kg/m3
- Unit weight of sand= 1840kg/m3
- Unit weight of coarse aggregate =2250 kg/m3

Cement=1/7*xm3*1400kg/m3*1.3*1.05

sand=2/7*xm3*1840kg/m3*1.3*1.05

Cement=4/7*xm3*2250kg/m3*1.3*1.05

Quiz 2.5%

- Assumed concrete mix ratio =1:2:3
- Concrete volume =1m3
- Shrinkage =30%
- Wastage =5%
- Unit weight of cement=1400kg/m3
- Unit weight of sand= 1840kg/m3
- Unit weight of coarse aggregate =2250 kg/m3

Find the quantities of the mixing ingredients??

Mix Design Methods

- Some of the prevalent concrete mix design methods are:
  - ***DOE***: Department of Environment Mix design practice (British),
  - ***ACI***: American Concrete Institute Mix Design Method,
  - ***DIN*** Mix design Method (German)
  - ***IS***: Indian Standard Mix Design Method

ACI MIX DESIGN PROCESS

Procedure

Step-1: Choice of slump

- If slump is not specified, a value appropriate for the work can be selected from Table-1

Types of construction	Slump, mm	
	Maximum*	Minimum
Reinforced foundation walls and footings	75	25
Plain footings, caissons, and substructure walls	75	25
Beams and reinforced walls	100	25
Building columns	100	25
Pavements and slabs	75	25
Mass concrete	75	25

Table-1: Recommended slumps for various types of construction

ACI MIX DESIGN PROCESS

Procedure

Step-2: Choice of maximum size of aggregate

- Large nominal maximum sizes of well graded aggregates have less voids than smaller sizes.
- Hence, concretes with the larger-sized aggregates require less mortar per unit volume of concrete.
- Generally, the nominal maximum size of aggregate should be the largest that is economically available and consistent with dimensions of the structure.

ACI MIX DESIGN PROCESS

Procedure

Step-3: Estimation of mixing water and air content

- The quantity of water per unit volume of concrete required to produce a given slump is dependent on:
  - the nominal maximum size,
  - particle shape, and
  - grading of the aggregates;
  - the concrete temperature;
  - the amount of entrained air; and
  - use of chemical admixtures.
- Table-2 provides estimates of required mixing water for concrete made with various maximum sizes of aggregate, with and without air entrainment.

ACI MIX DESIGN PROCESS

Procedure

Step-3: Estimation of mixing water and air content

Slump, mm	Water, Kg/m³ of concrete for indicated nominal maximum sizes of aggregate							
	9.5*	12.5*	19*	25*	37.5*	50†*	75†‡	150†‡
Non-air-entrained concrete								
25 to 50	207	199	190	179	166	154	130	113
75 to 100	228	216	205	193	181	169	145	124
150 to 175	243	228	216	202	190	178	160	—
Approximate amount of entrapped air in non-air-entrained concrete, percent	3	2.5	2	1.5	1	0.5	0.3	0.2
Air-entrained concrete								
25 to 50	181	175	168	160	150	142	122	107
75 to 100	202	193	184	175	165	157	133	119
150 to 175	216	205	197	184	174	166	154	—
Recommended average§total air content, percent for level of exposure:								
Mild exposure	4.5	4.0	3.5	3.0	2.5	2.0	1.5**††	1.0**††
Moderate exposure	6.0	5.5	5.0	4.5	4.5	4.0	3.5**††	3.0**††
Extreme exposure‡‡	7.5	7.0	6.0	6.0	5.5	5.0	4.5**††	4.0**††

ACI MIX DESIGN PROCESS

Procedure

Step-4: Selection of water-cement or water-cementitious materials ratio

- Approximate and relatively conservative values for concrete containing Type I Portland cement can be taken from Table-3a.

Table-3a: Relationships between water-cement ratio and

Compressive strength at 28 days, MPa*	Water-cement ratio, by mass	
	Non-air-entrained concrete	Air-entrained concrete
40	0.42	—
35	0.47	0.39
30	0.54	0.45
25	0.61	0.52
20	0.69	0.60
15	0.79	0.70

ACI MIX DESIGN PROCESS

Procedure

Step-4: Selection of water-cement or water-cementitious materials ratio

- For severe conditions of exposure, the *w/c* or *w/(c + p)* ratio should be kept low even though strength requirements may be met with a higher value. Table-3b gives limiting values.

Table-3b: Maximum permissible water-cement ratios for con

Type of structure	Structure wet continuously or frequently and exposed to freezing and thawing†	Structure exposed to sea water or sulfates
Thin sections (railings, curbs, sills, ledges, ornamental work) and sections with less than 5 mm cover over stee	0.45	0.40‡
All other structures	0.50	0.45‡

ACI MIX DESIGN PROCESS

Procedure

Step-5: Calculation of cement content

- The amount of cement per unit volume of concrete is fixed by the determinations made in Steps 3 and 4 above.
- The required cement is equal to the estimated mixing-water content (Step 3) divided by the water-cement ratio (Step 4).
- If, however, the specification includes a separate minimum limit on cement in addition to requirements for strength and durability, the mixture must be based on whichever criterion leads to the larger amount of cement.

ACI MIX DESIGN PROCESS

Procedure

Step-6: Estimation of coarse aggregate content

- Appropriate values for this aggregate volume are given in Table-4.

Tab volume of c

Nominal maximum size of aggregate, mm	Volume of dry-rodded coarse aggregate* per unit volume of concrete for different fineness moduli† of fine aggregate			
	2.40	2.60	2.80	3.00
9.5	0.50	0.48	0.46	0.44
12.5	0.59	0.57	0.55	0.53
19	0.66	0.64	0.62	0.60
25	0.71	0.69	0.67	0.65
37.5	0.75	0.73	0.71	0.69
50	0.78	0.76	0.74	0.72
75	0.82	0.80	0.78	0.76
150	0.87	0.85	0.83	0.81

ACI MIX DESIGN PROCESS

Procedure

Step-7: Estimation of fine aggregate content

- At completion of Step 6, all ingredients of the concrete have been estimated except the fine aggregate. Its quantity is determined by difference. Either of two procedures may be employed:
  - the weight method or
  - the absolute volume method.

The weight method

- If the weight of the concrete per unit volume is assumed or can be estimated from experience, the required weight of fine aggregate is simply the difference between the weight of fresh concrete and the total weight of the other ingredients.
- First estimate of weight of fresh concrete can be determined from Table- 5.

ACI MIX DESIGN PROCESS

Procedure

Step-7: Estimation of fine aggregate content

The weight method

Table-5: First estimate of weight of fresh concrete

Nominal maximum size of aggregate, mm	First estimate of concrete unit mass, kg/m^{3*}	
	Non-air-entrained concrete	Air-entrained concrete
9.5	2280	2200
12.5	2310	2230
19	2345	2275
25	2380	2290
37.5	2410	2350
50	2445	2345
75	2490	2405
150	2530	2435

ACI MIX DESIGN PROCESS

Procedure

Step-7: Estimation of fine aggregate content

The weight method

- If a theoretically exact calculation of fresh concrete weight per m^3 is desired, the following formula can be use

$$U_M = 10G_a(100 - A) + C_M(1 - G_a/G_c) - W_M(G_a - 1)$$

where

U_M = unit mass of fresh concrete, **kg/m³**

G_a = weighted average specific gravity of combined fine and coarse aggregate, bulk, SSD

G_c = specific gravity of cement (generally 3.15)

A = air content, percent

W_M = mixing water requirement, **kg/m³**

C_M = cement requirement, **kg/m³**

ACI MIX DESIGN PROCESS

Procedure

Step-8: Adjustment for moisture aggregate

- The aggregate quantities actually to be weighed out for the concrete must allow for moisture in the aggregates.
- Generally, the aggregates will be moist and their dry weights should be increased by the percentage of water they contain, both absorbed and surface.
- The mixing water added to the batch must be reduced by an amount equal to the free moisture contributed by the aggregate -- i.e., total moisture minus absorption.

ACI MIX DESIGN PROCESS

Procedure

Step-9: Trial batch adjustments

- The calculated mixture proportions should be checked by means of trial batches prepared and tested in accordance with ASTM C 192

ACI MIX DESIGN PROCESS

Example-1

Concrete is required for a portion of a structure that will be below ground level in a location where it will not be exposed to severe weathering or sulfate attack. Structural considerations require it to have an average ***28-day compressive strength of 25 Mpa*** . It is determined that under the conditions of placement to be employed, a ***slump of 75-100 mm*** should be used. and the ***coarse aggregate*** has a ***nominal maximum size of 37.5 mm*** and ***dry-rodded mass of 1600 kg/m³***.

- Other properties of the ingredients are: ***cement*** -Type I with specific gravity of 3.15; ***coarse aggregate*** - bulk specific gravity 2.68 and absorption 0.5 percent; ***fine aggregate*** - bulk specific gravity 2.64, absorption 0.7 percent, and fineness modulus 2.8.
- Calculate the weights of all materials that you would use for the first trial mix on a concrete mix.

ACI MIX DESIGN PROCESS

Example-1

Solution

- ***Step 1:*** The slump is required to be 75 to 100 mm.
- ***Step 2***: The aggregate to be used has a nominal maximum size of 37.5 mm.
- ***Step 3***: The concrete will be non-airentrained since the structure is not exposed to severe weathering.
  - From ***Table-2***, the estimated mixing water for a slump of 75 to 100 mm in non-air-entrained concrete made with 37.5 mm aggregate is found to be ***181 kg/m³***.
- ***Step 4:***The water-cement ratio for non-airentrained concrete with a strength of 24 MPa is found from ***Table-3a*** to be ***0.62***.

- ***Step-5***: From the information developed in Steps 3 and 4, the required cement content is found to be

ACI MIX DESIGN PROCESS

Example-1

Solution

- ***Step 6***: The quantity of coarse aggregate is estimated from ***Table-4***. For a fine aggregate having a fineness modulus of 2.8 and a 37.5 mm nominal maximum size of coarse aggregate, the table indicates that 0.71 m^3 of coarse aggregate, on a dry-rodded basis, may be used in each cubic meter of concrete.
  - The required dry mass is, therefore, 0.71 x 1600 = ***1136 kg***.
- ***Step 7***: The required fine aggregate may be determined on the basis of either mass or absolute volume as shown below:

ACI MIX DESIGN PROCESS

Example-1

Solution

- ***Step 7***: ***Mass basis***
  - From Table-5, the mass of a cubic meter of non-air-entrained concrete made with aggregate having a nominal maximum size of 37.5 mm is estimated to be ***2410***

Water (net mixing)	181 kg
Cement	292 kg
Coarse aggregate	1136 kg
Total	1609 kg

:

  - The mass of fine aggregate is therefore estimated to be

$$2410 - 1609 = 801\text{Kg}$$

ACI MIX DESIGN PROCESS

Example-1

Solution

- ***Step 7***: ***Absolute volume basis***
  - With the quantities of cement, water, and coarse aggregate established, and the approximate ***entrapped air content*** of ***1 percent*** determined from Table-2 , the sand content can be calculated as follows:

$$\text{Volume of water} = \frac{181}{1000} = 0.181\ \text{m}^3$$

$$\text{Solid volume of cement} = \frac{292}{3.15 \times 1000} = 0.093\ \text{m}^3$$

$$\text{Solid volume of coarse aggregate} = \frac{1136}{2.68 \times 1000} = 0.424\ \text{m}^3$$

ACI MIX DESIGN PROCESS

Example-1

Solution

- ***Step 7*: *Absolute volume basis***

Volume of entrapped air	=	0.01 x 1.000	0.010 m^3
Total solid volume of ingredients except fine aggregate			0.708 m^3
Solid volume of fine aggregate required	=	1.000 - 0.705	0.292 m^3
Required weight of dry fiie aggregate	=	0.292 x 2.64 x 1000	771 kg

ACI MIX DESIGN PROCESS

Example-1

Solution

- ***Step 7***:
  - Batch masses per cubic meter of concrete calculated on the two bases are compared below:

	Based on estimated concrete mass, kg	Based on absolute volume of ingredients, kg
Water (net mixing)	181	181
Cement	292	292
Coarse aggregate (dry)	1136	1136
Sand (dry)	801	771

ACI MIX DESIGN PROCESS

Example-1

Solution

- ***Step 8***: Tests indicate total moisture of 2 percent in the coarse aggregate and 6 percent in the fine aggregate. If the trial batch proportions based on assumed concrete mass are used, the adjusted agg

Coarse aggregate (wet) = 1136(1.02) = 1159 kg

Fine aggregates (wet) = 801(1.06) = 849kg

  - Absorbed water does not become part of the mixing water and must be excluded from the adjustment in added water. Thus, surface water contributed by the ***coarse aggregate amounts to 2 - 0.5*** 181 - 1136(0.015) - 801(0.053) = 122 kg ***- 0.7 = 5.3%***. The estimated requirement for added water, therefore, becomes

ACI MIX DESIGN PROCESS

Example-1

Solution

- ***Step 8***:
  - The estimated batch masses for a cubic meter of concrete are

Water (to be added)	122 kg
Cement	292 kg
Coarse aggregate (wet)	1159 kg
Fine aggregate (wet)	849 kg
Total	2422 kg

- ***Step 9***: For the laboratory trial batch, it is found convenient to scale the masses down to produce 0.02 m^3 of concrete.

ACI MIX DESIGN PROCESS

Exercise-1

- Calculate the weights of all materials that you would use for the first trial mix on a concrete mix required to achieve Characteristic compressive strength of 25 N/mm^2 at 28 days (cubic strength). The following information on material properties and plant performance is available to you.

Cement type, specific gravity respectively	**O.P.C, 3.15**
Max. Aggregate size, rodded bulk density of aggregate	**19 mm, 1600kg/m^3**
Rel. Density (S.G) of combined aggregate (SSD)	**2.75**
Required Slump	**25 to 50mm**
Maximum Cement Content	**500 Kg/m^3**
Max free water/cement ratio	**0.5**
Fineness modulus	**2.97**
Air content	**1%**
Free moisture content of sand and coarse aggregate respectively	**8%, 1%**
Bulk specific gravity of coarse and fine aggregate	**2.7, 2.6**

- ***Step 1:*** The slump is required to be 25mm.
- ***Step 2***: The aggregate to be used has a nominal maximum size of 19mm.
- ***Step 3***: The concrete will be airentrained since the structure is for trail mix
- From ***Table-2***, the estimated mixing water for a slump of 25mm in air-entrained concrete made with 19mm aggregate is found to be ***168kg/m³***.
- ***Step 4:***The water-cement ratio for airentrained concrete with a strength of 25MPa is found from ***Table-3a*** to be ***0.52***.
- ***Step-5***: From the information developed in Steps 3 and 4, the required cement content is found to be 168/0.52 = ***323.08 kg/m³***.

- ***Step 6***: The quantity of coarse aggregate is estimated from ***Table-4***. For a fine aggregate having a fineness modulus of 2.8 and a 37.5 mm nominal maximum size of coarse aggregate, the table indicates that 0.71 m^3 of coarse aggregate, on a dry-rodded basis, may be used in each cubic meter of concrete.
  - The required dry mass is, therefore, 0.71 x 1600 = ***1136 kg***.
- ***Step 7***: The required fine aggregate may be determined on the basis of either mass or absolute volume as shown below:

THANK YOU!