Concrete Mix Design

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DEFINITION

Mix design is the combination of art and science of determining the relative proportions of the ingredients of concrete to achieve the desired properties in the most economical way

METHODS

1. American Concrete Institute Committee 211 method
2. Bureau of Indian Standards Recommended method IS 10262-82
3. Road note No. 4 (Grading Curve) method
4. Department Of Environment (DOE - British) method
5. Trial and Adjustment Method
6. Fineness modulus method
7. Maximum density method
8. Indian Road Congress, IRC 44 method

PRINCIPLES

1. Environmental exposure for the structure
2. Characteristic strength and standard deviation of concrete
3. Type of cement
4. Maximum size of aggregate
5. w/c ratio
6. Degree of workability
7. Air content
8. Density of concrete

PROBLEM

Design a concrete mix for the construction of an elevated water tank. The specified design strength of concrete (characteristic strength) is 30 MPa at 28 days measured on standard cylinders. Standard deviation can be taken as 4 MPa. The specific gravity of FA and C.A. are 2.65 and 2.7 respectively. The dry rodded bulk density of C.A. is 1600 kg/m3, and fineness modulus of FA is 2.80. Ordinary Portland cement (Type I) will be used. A slump of 50 mm is necessary. C.A. is found to be absorptive to the extent of 1% and free surface moisture in sand is found to be 2 per cent. Assume any other essential data.

PROBLEM

1 Mean Cylinder Compressive Strength

Assuming 5 per cent of results are allowed to fall below specified design strength,

The mean strength,

$$f_m = f_{ck} + ks$$

$$= 30 + 1.64 \times 4$$

$$= 36.5 \text{ MPa}$$

2 Water/cement ratio

- **Strength criteria**
- **Durability criteria**

PROBLEM

Strength Criteria

Table 11.5. Relation between water/cement ratio and average compressive strength of concrete, according to ACI 211.1-91

Average compressive strength at 28 days	Effective water/cement ratio (by mass)	
MPa	Non-air entrained concrete	Air-entrained concrete
45	0.38	–
40	0.43	–
36.5 → 35	0.48 → 0.47	0.40
30	0.55	0.46
25	0.62	0.53
20	0.70	0.61
15	0.80	0.71

PROBLEM

Durability Criteria

Table 11.6. Requirements of ACI 318-89 for W/C ratio and Strength for Special Exposure Conditions

	Exposure Condition	*Maximum W/C ratio, normal density aggregate concrete*	*Minimum design strength, low density aggregate concrete MPa*
I.	Concrete Intended to be Watertight		
	(a) Exposed to fresh water	0.5	25
	(b) exposed to brackish or sea water	0.45	30
II	Concrete exposed to freezing and thawing in a moist condition:		
	(a) kerbs, gutters, gaurd rails or thin sections	0.45	30
	(b) other elements	0.50	25
	(c) in presense of de-icing chemicals	0.45	30
III.	For corrosion protection of reinforced concrete exposed to de-icing salts, brackish water, sea water or spray from these sources	0.40	33

PROBLEM

3 Mixing Water Content

Slump = 50 mm
Maximum size of aggregate = 20 mm
Concrete is non air-entrained

PROBLEM

Workability or Air content	Water Content, Kg/m³ of concrete for indicated maximum aggregate size							
	10 mm	12.5 mm	20mm	25 mm	40 mm	50 mm	70 mm	150 mm
	Non-air-entrained concrete							
Slump								
30–50 mm	205	200	185	180	160	155	145	125
80–100 mm	225	215	200	195	175	170	160	140
150–180 mm	240	230	210	205	185	180	170	-
Approximate entrapped air content per cent	3	2.5	2	1.5	1	0.5	0.3	0.2
	Air-entrained Concrete							
Slump								
30–50 mm	180	175	165	160	145	140	135	120
80–100 mm	200	190	180	175	160	155	150	135
150–180 mm	215	205	190	185	170	165	160	-
Recommended average total air content percent								
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

PROBLEM

The mixing water content is 185 kg/m³ of concrete

The approximate entrapped air content is 2%.

The required cement content =185/0.47

= 394 kg/m³

4 Bulk Volume of C.A.

Maximum size of C.A = 20mm

Fineness Modulus of F.A. = 2.80

Find the dry rodded bulk volume of C.A.

PROBLEM

Maximum Size of Aggregate	Bulk volume of dry rodded coarse aggregate per unit volume of concrete for fineness modulus of sand of			
F.M.	2.40	2.60	2.80	3.00
10	0.50	0.48	0.46	0.44
12.5	0.59	0.57	0.55	0.53
20	0.66	0.64	0.62	0.60
25	0.71	0.69	0.67	0.65
40	0.75	0.73	0.71	0.69
50	0.78	0.76	0.74	0.72
70	0.82	0.80	0.78	0.76
150	0.87	0.85	0.83	0.81

The dry rodded bulk volume of C.A. = 0.62 per unit volume of concrete

The weight of C.A. = 0.62 x 1600

= 992 kg/m³

PROBLEM

Item number	Ingredients	Weight kg/m^3	Absolute volume cm^3
1.	Cement	394	$\frac{394}{3.15} \times 10^3 = 125 \times 10^3$
2.	Water	185	$\frac{185}{1} \times 10^3 = 185 \times 10^3$
3.	Coarse Aggregate	992	$\frac{992}{2.7} \times 10^3 = 367 \times 10^3$
4.	Air		$\frac{2}{100} \times 10^6 = 20 \times 10^3$

Total absolute volume = 697×10^3 cm^3

Absolute volume of F.A. = $(1000 - 697) \times 10^3$

= 303×10^3

Weight of FA = 303×2.65

= 803 kg/m^3

PROBLEM-Estimated quantity per cubic meter

Cement = 394 kg

F.A = 803 kg

C.A = 992 kg

Water = 185 kg

PROBLEM-Field Adjustment

FA has surface moisture of 2%

Total free surface moisture in FA = (2/100 x 803)

= 16.06 kg/m^3

Weight of F.A in field condition = 803 + 16.06 = 819.06 kg/m^3

PROBLEM-Field Adjustment

C.A absorbs 1% water

Quantity of water absorbed by C.A. = (1/100 x 992) = 9.92 kg/m³

Weight of C.A in field condition = 992 – 9.92

= 982 kg/m³

Change in Water Content

Water contributed by F.A	**= 16.06 kg**
Water absorbed by C.A.	**= 9.92 kg**
Extra water contributed by aggs.	**= 16.06 – 9.92 = 6.14 kg**
Total water content	**= 185.00 – 6.14**
	= 179 kg/m³

PROBLEM-Final Quantity

Quantities of materials to be used in field, corrected for free surface moisture in F.A and absorption characteristic of C.A

Cement	**= 394 kg/m³**
F.A.	**= 819 kg/m³**
C.A.	**= 982 kg/m³**
Water	**= 179 kg/m³**

Field density of fresh concrete = 2374 kg/m³

PROBLEM-Check

Maximum size of aggregate mm	First estimate of density (unit weight) of fresh concrete	
	Non-air-entrained kg/m³	Air-entrained kg/m³
10	2285	2190
12.5	2315	2235
20	2355	2280
25	2375	2315
40	2420	2355
50	2445	2375
70	2465	2400
150	2505	2435

Calculated 2374 > Table 2355

SLUMP & Air Content are to be checked by apparatus