UNIT III

PROPORTIONING OF CONCRETE MIX

1. Give the types of concrete mixes.

- Nominal Mixes
- Standard mixes
- Designed Mixes

2. Define Nominal Mixes and its advantages.

Nominal mix is permitted by IS456:2000 for concrete of strength lower than M25 In the past the specifications for concrete prescribed the proportions of cement, fine and coarse aggregates. These mixes of fixed cement-aggregate ratio which ensures adequate strength are termed nominal mixes. These offer simplicity and under normal circumstances, have a margin of strength above that specified. However, due to the variability of mix ingredients the nominal concrete for a given workability varies widely in strength.

3. Define Standard mixes.

The nominal mixes of fixed cement-aggregate ratio (by volume) vary widely in strength and may result in under- or over-rich mixes. For this reason, the minimum compressive strength has been included in many specifications. These mixes are termed standard mixes.

IS 456-2000 has designated the concrete mixes into a number of grades as M10, M15, M20, M25, M30, M35 and M40. In this designation the letter M refers to the mix and the number to the specified 28 day cube strength of mix in N/mm2. The mixes of grades M10, M15, M20 and M25 correspond approximately to the mix proportions (1:3:6), (1:2:4), (1:1.5:3) and (1:1:2) respectively.

4. What is Designed Mixes?

Design mix is permitted by IS 10262-1982 and IS456:2000for concrete of strength Greater than M25 is design mix.

5. What are the Factors affecting the choice of mix proportions ?

The various factors affecting the mix design are:

- Compressive strength
- Workability
- Durability
- Maximum nominal size of aggregate
- Grading and type of aggregate
- Quality Control

6. What are the Requirements of concrete mix design as per BIS?

The minimum compressive strength required from structural consideration

- The adequate workability necessary for full compaction with the compacting equipment available.
- Maximum water-cement ratio and/or maximum cement content to give adequate durability for the particular site conditions
- Maximum cement content to avoid shrinkage cracking due to temperature cycle in mass concrete

7. Define concrete mix design.

Concrete mix design is defined as the appropriate selection and proportioning of constituents to produce a concrete with pre-defined characteristics in the fresh and hardened states.

8. Define Concrete Durability.

Durability of concrete is the ability of concrete to withstand the harmful effects of environment to which it will be subjected to, during its service life, without undergoing into deterioration beyond acceptable limits.

9. What is proportioning of concrete mix

Proportioning of concrete mix is the art of obtaining a suitable ratio of the various ingredients of concrete with the required properties at the lowest cost.

10. What is the principle of mix proportioning.

a. Environmental exposure conditions
b. Grades of concrete
c. Type of cement
d. Type and size of aggregates
e. Nominal maximum size of aggregates
f. Maximum and minimum cement content
g. Maximum free water cement ratio by weight
h. Degree of workability
i. Air entrained agent
j. Types of admixtures used if any
k. Maximum/ minimum density of concrete
l. Maximum/ minimum temperature of fresh concrete
m. Type of curing and mixing
n. Source of water

11. Mention the properties related to mix design.

a. Durability
b. Workability
c. Strength
d. High strength concrete

12. Describe the physical properties of materials required to mix design

a. Cement
b. Aggregate
c. Water
d. Admixture

13. List out the advantages of Design mix

a. Properties of all materials are used.
b. Cement content is low and hence the mix design is economical.

14. List out the disadvantages of nominal mix

a. Nominal mix does not say which type of sand, cement, aggregate to be used.
b. High cement is required which leads to high cost.

15. What is ACI and the data used for ACI

American concrete institute was revised to include the use of entrained air.

a. Fineness modulus
b. Unit weight of dry rodded coarse aggregate
c. Specific gravity of cement, coarse and fine aggregate
d. Absorption characteristic of coarse and fine aggregate

PART B

ACI method

1.Design a concrete mix for 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 (TypeI) 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.

(a) Assuming 5 per cent of results are allowed to fall below specified design strength

The mean strength, $f_m = f_{min} + ks$
$= 30 + 1.64 \times 4$
$= 36.56$
say 36.5 MPa

(b) Since OPC is used, from table 11.5, the estimated w/c ratio is 0.47.

This w/c ratio from strength point of view is to be checked against maximum w/c ratio given for special exposure condition given in Table 11.6 and minimum of the two is to be adopted.

From exposure condition Table11.6, the maximum w/c ratio is 0.50

Therefore, adopt w/c ratio of 0.47

(c) From Table 11.8, for a slump of 50 mm, 20 mm maximum size of aggregate, for non-air-entrained concrete, the mixing water content is 185 kg/m^3 of concrete. Also the approximate entrapped air content is 2 per cent.

The required cement content $= \frac{185}{0.47}$
$= 394$ kg/m^3

(d) From Table 11.4, for 20 mm coarse aggregate, for fineness modulus of 2.80, the dry rodded bulk volume of C.A. is 0.62 per unit volume of concrete.

(e) Therefore the weight of C.A. $= 0.62 \times 1600$
$= 992$ kg/m^3

(f) From Table 11.9, the first estimate of density of fresh concrete for 20 mm maximum size of aggregate and for non-air-entrained concrete = 2355 kg/m^3

(g) The weight of all the known ingredient of concrete

weight of water = 185 kg/m^3

weight of cement = 394 $kg.m^3$

weight of C.A. = 992 kg/m^3

weight of F.A. = 2355 – (185 + 394 + 992)

= 784 kg/m^3

(h) Alternatively the weight of F.A. can also be found out by absolute volume method which is more accurate, as follows.

Tabulate the absolute volume of all the known ingredients

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

Therefore absolute volume of F.A.

$= (1000 - 697) \times 10^3$

$= 303 \times 10^3$

Weight of FA = 303 x 2.65

= 803 kg/m^3

Adopt F.A. = 803 kg/m^3.

(i) Estimated quantities of materials per cubic meter of concrete are

Cement = 394 kg

F.A = 803 kg

C.A = 992 kg

Water = 185 kg

Density of fresh concrete 2374 kg/m^3 as against 2355 read from Table 11.9

(j) Proportions

C	:	FA	:	C.A	:	water
394	:	803	:	992	:	185
1	:	2.04	:	2.52	:	0.47

Weight of materials for one bag mix in kg = 50 : 102 : 126 : 23.5

The above quantities is on the basis that both F.A and C.A are in saturated and surface dry condition (SSD conditions).

(k) The proportions are required to be adjusted for the field conditions. FA has surface moisture of 2 per cent

 Total free surface moisture in FA = $\frac{2}{100} \times 803 = 16.06$ kg/m^3

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

say 819 kg/m^3

C.A absorbs 1% water

 Quantity of water absorbed by —= 9.92 kg/m^3

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

= 982.08 kg/m^3

say 982.0 kg/m^3

With regard to water, 16.06 kg of water is contributed by F.A and 9.92 kg of water is absorbed by C.A.

Therefore 16.06 – 9.92 = 6.14 kg of extra water is contributed by aggregates. This quantity of water is deducted from Total water i.e., $185.00 - 6.14 = 178.86$ kg/m^3

say 179 kg/m^3

(l) Quantities of materials to be used in field duly corrected for free surface moisture in

F.A and absorption characteristic of C.A

Cement = 394 kg/m^3

F.A. = 819 kg/m^3

C.A. = 982 kg/m^3

Water = 179 kg/m^3

Field density of fresh concrete = 2374 kg/m^3

2.Illustrative Example of Concrete Mix Design (Grade M 20)

(a) Design stipulations

(i)	Characteristic compressive strength required in the field at 28 days.	20 MPa
(ii)	Maximum size of aggregate	20 mm (angular)
(iii)	Degree of workability	0.90 compacting factor
(iv)	Degree of quality control	Good
(v)	Type of Exposure	Mild

(b) Test data for Materials

(i)	Specific gravity of cement	3.15
(ii)	Compressive strength of cement at 7 days	Satisfies the requirement of IS: 269–1989
(iii)	1. Specific gravity of coarse aggregates	2.60
	2. Specific gravity of fine aggregates	2.60
(iv)	Water absorption:	
	1. Coarse aggregate	0.50%

2. Fine aggregate 1.0%

(v) Free (surface) moisture:

1. Coarse aggregate Nil

2. Fine aggregate 2.0%

(vi) Sieve analysis is shown below:

1. Coarse aggregate

Sieve size (mm)	Analysis of Coarse aggregate fractions (% passing)		Percentage of different Fractions			Remark
	I	II	I 60%	II 40%	Combined 100%	
20	100	100	60	40	10	Conforming
10	0	71.20	0	28.5	28.5	to Table 2, IS: 383—
4.75		9.40	–	3.7	3.7	1970
2.36	–	–	–	–	–	

2. Fine aggregate

Sieve sizes	Fine aggregate (% passing)	Remarks
4.75 mm	100	
2.36 mm	100	Conforming to grading
1.18 mm	93	Zone III of Table 4
600 micron	60	IS: 385–1970
300 micron	12	
150 micron	2	

(c) Target mean strength of concrete

The target mean strength for specified characteristic cube strength is

$$20 + 1.65 \times 4 = 26.6 \text{ MPa}$$

(refer Table 11.21 and Table 11.22 for values of t and s)

(d) Selection of water-cement ratio

From Fig. 11.10 the water-cement ratio required for the target mean strength of 26.6 MPa is 0.50. This is lower than the maximum value of 0.55 prescribed for ‗Mild' exposure.

(refer Table 9.18) adopt W/C ratio of 0.50.

(e) Selection of water and sand content

From Table 11.24, for 20 mm maximum size aggregate, sand conforming to grading Zone II, water content per cubic metre of concrete = 186 kg and sand content as percentage of total aggregate by absolute volume = 35 per cent.

For change in value in water-cement ratio, compacting factor, for sand belonging to Zone III, following adjustment is required.

Change in Condition (See Table 11.26)	*Per cent adjustment required Water content*	*Sand in total aggregate*
For decrease in water-cement ratio by (0.60–0.50) that is 0.10.	*0*	*– 2.0*
For increase in compacting factor (0.9–0.8), that is 0.10	*+ 3*	*0*
For sand conforming to Zone III of Table 4, IS: 383–1970	*0*	*– 1.5*
Total	*+ 3*	*– 3.5*

Therefore, required sand content as percentage of total aggregate by absolute volume

$$= 35 - 3.5 = 31.5\%$$

Required water content $= 186 + 5.58 = 191.6 \text{ 1/m}^3$

(*f*) Determination of cement content

Water-cement ratio = 0.50

water = 191.6 litre

$$\text{cement} = \frac{191.6}{0\ 50} = 383 \text{ kg/m}^3$$

This cement content is adequate for ‗mild' exposure condition.

(*g*) Determination of coarse and fine aggregate contents

From Table 11.23, for the specified maximum size of aggregate of 20 mm, the amount of entrapped air in the wet concrete is 2 per cent. Taking this into account and applying equations. 1 and 2 given on page 494.

$$0.98 = 191.6 + \frac{383}{3.15} + \frac{1}{0.315} \times \frac{f_a}{2.6} \frac{1}{1000}$$

$f_a = 546 \text{ kg/m}^3$, and

$$C_a = \frac{1 - 0.315}{0.315} \times 546 = \frac{2\ .6}{2\ 6}$$

$f_a = 546 \text{ kg/m}^3$, and

$C_a = 1188 \text{ kg/m}^3$.

The mix proportion then becomes:

Water		Cement		Fine aggregate		Coarse Aggregate
191.6		383 kg		546 kg		1188 kg
0.50	:	1	:	1.425	:	3.10

(*h*) Actual quantities required for the mix per bag of cement

The mix is 0.50 : 1 : 1.425 : 3.10. For 50 kg of cement, the quantity of materials are worked out as below:

(i) Cement = 50 kg

(ii) Sand = 71.0 kg

(iii) Coarse aggregate = 155 kg | Fraction I = 60% = 93 kg | Fraction II = 40% = 62 kg |

(iv) Water

1. for w/c ratio of 0.50, quantity = 25 litres of water.

2. Extra quantity of water to be added for absorption in case of CA, at 0.5 percent mass.

   = 0.77 litres

3. Quantity of water to be deducted for moisture present in sand, at 2 per cent by mass.

   = 1.42 litres

4. Actual quantity of water required to be added

   = 25.0 + 0.77 – 1.42

   = 24.35 litres.

(i) Actual quantity of sand required after = 71.0 + 1.42

allowing for mass of free moisture = 72.42 kgs.

(j) Actual quantity of CA required

1. Fraction I = 93 – 0.46 = 92.54 kg
2. Fraction II = 62 – 0.31 = 61.69 kg

Therefore, the actual quantities of different constituents required for one bag mix are

Water	:	24.35 kg
Cement	:	50.00 kg
Sand	:	72.42 kg
CA Fraction I	:	92.54 kg
Fraction II	:	61.69 kg

3.Explain the concept of mix design and Mention the method of proportioning?

Concept of Mix Design

It will be worthwhile to recall at this stage the relationships between aggregate and paste which are the two essential ingredients of concrete. Workability of the mass is provided by the lubricating effect of the paste and is influenced by the amount and dilution of paste.

The strength of concrete is limited by the strength of paste, since mineral aggregates with rare exceptions, are far stronger than the paste compound. Essentially the permeability of concrete is governed by the quality and continuity of the paste, since little water flows through aggregate either under pressure or by capillarity.

Further, the predominant contribution to drying shrinkage of concretes is that of paste.Since the properties of concrete are governed to a considerable extent by the quality of paste, it is helpful to consider more closely the structure of the paste. The fresh paste is a suspension, not a solution of cement in water. The more dilute the paste, the greater the spacing between cement particles, and thus the weaker will be the ultimate paste structure. The other conditions being equal, for workable mixes, the strength of concrete varies as an inverse function of the water/cement ratio.

Since the quantity of water required also depends upon the amount of paste, it is important that as little paste as possible should be used and hence the importance of grading.

Variables in Proportioning With the given materials, the four variable factors to be considered in connection with specifying a concrete mix are:

(a) Water-Cement ratio

(b) Cement content or cement-aggregate ratio

(c) Gradation of the aggregates

(d) Consistency.

In general all four of these inter-related variables cannot be chosen or manipulated arbitrarily. Usually two or three factors are specified, and the others are adjusted to give minimum workability and economy.

Water/cement ratio expresses the dilution of the paste-cement content varies directly with the amount of paste. Gradation of aggregate is controlled by varying the amount of given fine and coarse aggregate. Consistency is established by practical requirements of placing. In brief, the effort in proportioning is to use a minimum amount of paste (and therefore cement) that will lubricate the mass while fresh and after hardening will bind the aggregate particles together and fill the space between them.

Any excess of paste involves greater cost, greater drying shrinkage, greater susceptibility to percolation of water and therefore attack by aggressive waters and weathering action. This is achieved by minimizing the voids by good gradation.

Various Methods of Proportioning

(a) Arbitrary proportion

(b) Fineness modulus method

(c) Maximum density method

(d) Surface area method

(e) Indian Road Congress, IRC 44 method

(f) High strength concrete mix design

(g) Mix design based on flexural strength

(h) Road note No. 4 (Grading Curve method)

(i) ACI Committee 211 method

(j) DOE method

(k) Mix design for pumpable concrete

(l) Indian standard Recommended method IS 10262-82

Out of the above methods, some of them are not very widely used these days because of some difficulties or drawbacks in the procedures for arriving at the satisfactory proportions.

The ACI Committee 211 method, the DOE method and Indian standard recommended methods are commonly used.

4. Explain the design procedure of ACI method of mix design?

The ACI Committee mix design method assume certain basic facts which have been substantiated by field experiments or large works. They are:

(a) The method makes use of the established fact, that over a considerable range of practical proportions, fresh concrete of given slump and containing a reasonably well graded aggregate of given maximum size will have practically a constant total water content regardless of variations in water/cement ratio and cement content, which are necessarily interrelated.

(b) It makes use of the relation that the optimum dry rodded volume of coarse aggregate per unit volume of concrete depends on its maximum size and the fineness modulus of the fine aggregate as indicated in Table 11.4 regardless of shape of particles. The effect of angularity is reflected in the void content, thus angular coarse aggregates require more mortar than rounded coarse aggregate.

(c) Irrespective of the methods of compaction, even after complete compaction is done, a definite percentage of air remains which is inversely proportional to the maximum size of the aggregate.

The following is the procedure of mix design in this method:

(a) Data to be collected :

(i) Fineness modulus of selected F.A.

(ii) Unit weight of dry rodded coarse aggregate.

(iii) Sp. gravity of coarse and fine aggregates in SSD condition

(iv) Absorption characteristics of both coarse and fine aggregates.

(v) Specific gravity of cement.

(b) From the minimum strength specified, estimate the average design strength either by using standard deviation or by using coefficient of variation.

(c) Find the water/cement ratio from the strength point of view. Find also the water/cement ratio from durability point of view. Adopt lower value out of strength consideration and durability consideration.

(d) Decide maximum size of aggregate to be used. Generally for RCC work 20 mm and prestressed concrete 10 mm size are used.

(e) Decide workability in terms of slump for the type of job in hand.

(f) The total water in kg/m^3 of concrete is read from table 11.8 entering the table with the selected slump and selected maximum size of aggregate. Table 11.8 also gives the approximate amount of accidentally entrapped air in non-air-entrained concrete.

(g) Cement content is computed by dividing the total water content by the water/cement ratio.

(h) the bulk volume of dry rodded coarse aggregate per unit volume of concrete is selected, for the particular maximum size of coarse aggregate and fineness modulus of fine aggregate.

(j) The weight of C.A. per cubic meter of concrete is calculated by multiplying the bulk volume with bulk density.

(k) The solid volume of coarse aggregate in one cubic meter of concrete is calculated by knowing the specific gravity of C.A.

(l) Similarly the solid volume of cement, water and volume of air is calculated in one cubic meter of concrete.

(m) The solid volume of sand is computed by subtracting from the total volume of concrete the solid volume of cement, coarse aggregate, water and entrapped air.

(n) Wight of fine aggregate is calculated by multiplying the solid volume of fine aggregate by specific gravity of F.A.

5.. Explain in detail about the method of concrete mix design.

Indian Standard Recommended Method of Concrete Mix Design (IS 10262 – 1982)

The Bureau of Indian Standards, recommended a set of procedure for design of concrete mix mainly based on the work done in national laboratories. The mix design procedures are covered in IS 10262–82. The methods given can be applied for both medium strength and high strength concrete.

Before we proceed with describing this method step by step, the following short comings in this method are pointed out. Some of them have arisen in view of the revision of IS 456– 2000. The procedures of concrete mix design needs revision and at this point of time (2000 AD) a committee has been formed to look into the matter of Mix Design.

(i) The strength of cement as available in the country today has greatly improved since 1982. The 28-day strength of A, B, C, D, E, F, category of cement is to be reviewed.

(ii) The graph connecting, different strength of cements and W/C is to be re-established.

(iii) The graph connecting 28-day compressive strength of concrete and W/C ratio is to be extended up to 80 MPa, if this graph is to cater for high strength concrete.

(iv) As per the revision of IS 456–2000, the degree of workability is expressed in terms of slump instead of compacting factor. This results in change of values in estimating approximate sand and water contents for normal concrete up to 35 MPa and high strength concrete above 35 MPa.

(v) In view of the above and other changes made in the revision of IS 456–2000, the mix design procedure as recommended in IS 10262–82 is required to be modified to the extent considered necessary and examples of mix design is worked out However, in the absence of revision of Indian Standard on method of Mix Design, the existing method i.e., IS 10262 of 1982 is described below step by step. Wherever it is possible, the new information given in IS 456 of 2000 have been incorporated and the procedure is modified to that extent.

(a) Target mean strength for mix design: The target mean compressive (fck) strength at 28 days is given by

$$\bar{f}_{ck} = f_{ck} + tS$$

where fck = characteristic compressive strength at 28 days.

S is the standard deviation. The value of the standard deviation has to be worked out from the trials conducted in the laboratory or field. As soon as enough test results become available, standard deviation should be worked out and the mix design is modified accordingly.

t = a statistical value depending on expected proportion of low results (risk factor).

According to IS: 456–2000 and IS: 1343–‘80, the characteristic strength is defined as that value below which not more than 5 per cent results are expected to fall, in which case the above equation reduces to

$$\bar{f}_{ck} = f_{ck} + 1.65\ S$$

(b) Selection of Water/Cement ratio

Various parameters like types of cement, aggregate, maximum size of aggregate, surface texture of aggregate etc. are influencing the strength of concrete, when water/cement ratio remain constant, hence it is desirable to establish a relation between concrete strength and free water cement ratio with materials and condition to be used actually at site.

(c) Estimation of Entrapped Air.

The air content is estimated from Table for the normal maximum size of aggregate used.

Maximum Size of Aggregate (mm)	Entrapped Air, as % of Volume of Concrete
10	3.0
20	2.0
40	1.0

(d) Selection of Water Content and Fine to Total Aggregate ratio

(a) Crushed (Angular) coarse aggregate, conforming to IS: 383—'70.

(b) Fine aggregate consisting of natural sand conforming to grading zone II of Table of IS: 383—'70.

(c) Workability corresponds to compacting factor of 0.80 (Slump 30 mm approximately)

(e) Calculation of Cement Content. The cement content per unit volume of concrete may be calculated from free water-cement ratio and the quantity of water per unit volume of concrete (cement by mass = Water content/Water cement ratio).

(f) Calculation of aggregate content. Aggregate content can be determined from the following equations:

$$V = \left[W + \frac{C}{S_e} + \frac{1}{P}\frac{f_a}{S_{fa}}\right]\frac{1}{1000}$$

$$C_a = \frac{1-P}{P} \times f_a \times \frac{S_{ca}}{S_{fa}}$$

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

Sc = Specific gravity of cement

P = Ratio of FA to total aggregate by absolute volume

fa, Ca = Total masses of FA and CA (kg) per m3 of concrete respectively and

Sfa, Sca = Specific gravities of saturated, surface dry fine aggregate and coarse aggregate respectively.

(g) Actual quantities required for mix. It may be mentioned that above mix proportion has been arrived at on the assumption that aggregates are saturated and surface dry. For any deviation from this condition i.e., when aggregate are moist or air dry or bone dry, correction has to be applied on quantity of mixing water as well to the aggregate.

(h) The calculated mix proportions shall be checked by means of trial batches. Quantities of material for each trial shall be enough for at least three 150 mm size cubes and concrete required to carry out workability test according to IS: 1199–'59.