UNIT-III

PROPORTIONING OF CONCRETE MIX

1. 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.

2. 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
3. Mention the properties related to mix design
   a. Durability
   b. Workability
   c. Strength
   d. High strength concrete
4. Describe the physical properties of materials required to mix design
   a. Cement
   b. Aggregate
   c. Water
   d. Admixtures
5. Define Nominal mix
   Nominal mix is permitted by IS456:2000 for concrete of strength lower than M_{25}
6. Define Design mix
   Design mix is permitted by IS 10262-1982 and IS456:2000 for concrete of strength Greater than M_{25} is design mix.
7. 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.
8. 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.

9. What is ACI
   American concrete institute was revised to include the use of entrained air.
10. What are the data used for ACI
    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

1. Explain the factors that influence the choice of mix design.

Compressive strength

It is one of the most important properties of concrete and influences many other describable properties of the hardened concrete. The mean compressive strength required at a specific age, usually 28 days, determines the nominal water-cement ratio of the mix. The other factor affecting the strength of concrete at a given age and cured at a prescribed temperature is the degree of compaction. According to Abraham‟s law the strength of fully compacted concrete is inversely proportional to the water-cement ratio.

Workability

The degree of workability required depends on three factors. These are the size of the section to be concreted, the amount of reinforcement, and the method of compaction to be used. For the narrow and complicated section with numerous corners or inaccessible parts, the concrete must have a high workability so that full compaction can be achieved with a reasonable amount of effort. This also applies to the embedded steel sections. The desired workability depends on the compacting equipment available at the site.

Durability

The durability of concrete is its resistance to the aggressive environmental conditions. High strength concrete is generally more durable than low strength concrete. In the situations when the high strength is not necessary but the conditions of exposure are such that high durability is vital, the durability requirement will determine the water-cement ratio to be used.

Maximum nominal size of aggregate

In general, larger the maximum size of aggregate, smaller is the cement requirement for a particular water-cement ratio, because the workability of concrete increases with increase in maximum size of the aggregate. However, the compressive strength tends to increase with the decrease in size of aggregate. IS 456:2000 and IS 1343:1980 recommend that the nominal size of the aggregate should be as large as possible.

Grading and type of aggregate

The grading of aggregate influences the mix proportions for a specified workability and watercement ratio. Coarser the grading leaner will be mix which can be used. Very lean mix is not desirable since it does not contain enough finer material to make the concrete cohesive. The type of aggregate influences strongly the aggregate-cement ratio for the desired workability and stipulated water cement ratio. An important feature of a satisfactory aggregate is the uniformity of the grading which can be achieved by mixing different size fractions.

Quality Control

The degree of control can be estimated statistically by the variations in test results. The variation in strength results from the variations in the properties of the mix ingredients and lack of control of accuracy in batching, mixing, placing, curing and testing. The lower the difference between the mean and minimum strengths of the mix lower will be the cement-content required. The factor controlling this difference is termed as quality control.

2.Explain in detail about the statistical quality control and acceptance criteria of concrete.

Statistical Quality Control of Concrete

Concrete like most other construction processes, have certain amount of variability both in materials as well as in constructional methods. This results in variation of strength from batchto batch and also within the batch. It becomes very difficult to assess the strength of the final product. It is not possible to have a large number of destructive tests for evaluating the strength of the end products and as such we have to resort to sample tests. It will be very costly to have very rigid criteria to reject the structure on the basis of a single or a few standard samples. The basis of acceptance of a sample is that a reasonable control of concrete work can be provided, by ensuring that the probability of test result falling below the design
strength is not more than a specified tolerance level.The aim of quality control is to limit the variability as much as practicable. Statistical quality control method provides a scientific approach to the concrete designer to understand the realistic variability of the materials so as to lay down design specifications with proper tolerance to cater for unavoidable variations. The acceptance criteria are based on statistical evaluation of the test result of samples taken at random during execution. By devising a proper sampling
plan it is possible to ensure a certain quality at a specified risk. Thus the method provides a scientific basis of acceptance which is not only realistic but also restrictive as required by the design requirements for the concrete construction. The quality of concrete will be of immense value for large contracts where the specifications insist on certain minimum requirements. The efforts put in will be more than repaid by the resulting savings in the overall concreting operations. The compressive strength test cubes from random sampling of a mix, exhibit variations, which are inherent in the various operations involved in the making and testing of concrete. If a number of cube test results are plotted on histogram, the results are found so follow a bell shaped curve known as “Normal Distribution Curve”. The results are said to follow a normal distribution curve if they are equally spaced about the mean value and if the largest number of the cubes have a strength closer to the mean value, and very few number of results with much greater or less value than the mean value. However, some divergence from the smooth curve can be expected, particularly if the number of results available is relatively small. The arithmetic mean or the average value of the number of test result gives no indication of the extent of variation of strength. However, this can be ascertained by relating the individual strength to the mean strength and determining the variation from the mean with the help of the properties of the normal distribution curve.

Common Terminologies

The common terminologies that are used in the statistical quality control of concrete are explained below.

Mean strength:

This is the average strength obtained by dividing the sum of strength of all the cubes by the number of cubes.

$$\bar{x} = \frac{\Sigma x}{n}$$

where $\bar{x}$ = mean strength

Σx = sum of the strength of cubes

n = number of cubes.

variance:

This is the measure of variability or difference between any single observed data from the mean strength.

Standard deviation:

This is the root mean square deviation of all the results. This is denoted by s or s .Numerically it can be explained as,

$$\sigma = \sqrt{\frac{\Sigma (x - \bar{x})^2}{n-1}}$$

where σ = Standard deviation,

n = number of observations

x = particular value of observations

$\bar{x}$ = arithmetic mean.

Standard deviation increases with increasing variability. The characteristics of the normal distribution curve are fixed by the average value and the standard deviation. The spread of the curve along the horizontal scale is governed by the standard deviation, while the position of the curve along the vertical scale is fixed by the mean value.

Coefficient of variation:

It is an alternative method of expressing the variation of results. It is a non-dimensional measure of variation obtained by dividing the standard deviation by the arithmetic mean and is expressed as:

$$v = \frac{\Sigma}{\bar{x}} \times 100$$

where v = coefficient of variation.

3.Design of M20 concrete mix as per IS:10262-2009, Concrete mix proportioning guidelines(First revision)

A-1 Design stipulations for proportioning

i.Grade designation : M20

ii. Type of cement : OPC 43 grade confirming to IS 8112

iii. Maximum nominal size of aggregates : 20 mm

iv. Minimum cement content : 320 kg/m3

v. Maximum water cement ratio : 0.55

vi. Workability : 75 mm (slump)

vii. Exposure condition : Mild

viii. Degree of supervision : Good

ix. Type of aggregate : Crushed angular aggregate

x. Maximum cement content : 450 kg/m3

xi. Chemical admixture : Not recommended

A-2 TEST DATA FOR MATERIALS

Cement used : OPC 43 grade confirming to IS 8112

q) Specific gravity of cement : 3.15

r) Specific gravity of Coarse aggregate : 2.68 Fine aggregate : 2.65

s) Water absorption Coarse aggregate : 0.6 percent Fine aggregate : 1.0 percent

t) Free (surface) moisture Coarse aggregate : Nil (absorbed moisture full) Fine aggregate : Nil

u) Sieve analysis Coarse aggregate : Conforming to Table 2 of IS: 383

Fine aggregate : Conforming to Zone I of IS: 383

A-3 TARGET STRENGTH FOR MIX PROPORTIONING

f‟ ck = fck + 1.65 s

Where f‟ck = Target average compressive strength at 28 days,

fck = Characteristic compressive strength at 28 days,

s= Standard deviation From Table 1 standard deviation,

s = 4 N/mm2

Therefore target strength = 20 + 1.65 x 4 = 26.60 N/mm2

A-4 SELECTION OF WATER CEMENT RATIO

From Table 5 of IS:456-2000, maximum water cement ratio = 0.55 (Mild exposure)

Based on experience adopt water cement ratio as 0.50 0.5 < 0.55,

hence ok.

A-5 SELECTION OF WATER CONTENT

From Table-2, maximum water content = 186 liters (for 25mm – 50mm slump range and for 20 mm aggregates)

Estimated water content for 75 mm slump = 186 + 3/100 x186 = 191.6 liters

A-6 CALCULATION OF CEMENT CONTENT

Water cement ratio = 0.50

Cement content = 191.6/0.5 = 383 kg/m3 >320 kg/m3(given)

From Table 5 of IS: 456, minimum cement content for mild exposure condition = 300 kg/m3

Hence OK

A-7 PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT

From Table 3, volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone I) for water-cement ratio of 0.50 =0.60

A-8 MIX CALCULATIONS

The mix calculations per unit volume of concrete shall be as follows

a) Volume of concrete = 1 m3

b) Volume of cement = = [383.16/3.15] x [1/1000] = 0.122 m3

c) Volume of water = [192/1] x [1/1000] = 0.192 m3

d) Volume of all in aggregates (e) =a – (b + c) = 1 – (0.122 + 0.192) = 0.686 m3

e) Volume of coarse aggregates = e x Volume of CA x specific gravity of CA = 0.686 x 0.6 x 2.68 x 1000

= 1103 kg

f) Volume of fine aggregates = e x Volume of FA x specific gravity of FA

= 0.686 x 0.4 x 2.65 x 1000 = 727 kg

A-9 MIX PROPORTIONS FOR TRIAL NUMBER

1 Cement = 383 kg/m3
Water = 191.6 kg/m3
Fine aggregate = 727 kg/m3
Coarse aggregates = 1103 kg/m3
Water cement ratio = 0.50 Yield =2404.6 kg
Aggregates are assumed to be in SSD. Otherwise corrections are to be applied while calculating the water content. Necessary corrections are also required to be made in mass of aggregates.
Trial mixes:Laboratory study.

4.Describe the procedure in adopting ACI method of concrete mix design.

American Concrete Institute Method of Mix Design

This method of proportioning was first published in 1944 by ACI committee 613. In 1954 the method was revised to include, among other modifications, the use of entrained air. In 1970, the method of mix design became the responsibility of ACI committee 211. ACI committee 211 have further updated the method (ACI–211.1) of 1991. Almost all of the major multipurpose concrete dams in India built during 1950 have been designed by using then
prevalent ACI Committee method of mix design. We shall now deal with the latest ACI Committee 211.1 of 1991 method. It has the advantages of simplicity in that it applies equally well, and with more or less identical procedure to rounded or angular aggregate, to regular or light weight aggregates and to airentrained or non-air-entrained concretes. 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 from Table 11.5. Find also the water/ cement ratio from durability point of view from Table 11.6. 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. General guidance can be taken from table 11.7.
(f) The total water in kg/m 3 kg/m3 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) From table 11.4 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 the Design Procedure for IS method of Concrete Mix Design.

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 reestablished.
(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. The Table giving adjustment of values in water content and sand percentage for other than standard conditions, requires appropriate changes and modifications.
(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 (*f*) strength at 28 days is given by
where f ck = 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—*fck* = fck + 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. In absence of such relationship, the free water/cement ratio corresponding to the target strength may be determined from the relationship .

c. Estimation of Entrapped Air

The air content is estimated from Table 11.23 for the normal maximum size of aggregate used.

Approximate Entrapped Air Content

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

The water content and percentage of sand in total aggregate by absolute volume are determined from Table for medium (below grade M 35) and high strength (above grade M 35) concrete respectively. Both Table are based on the following conditions.
(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) Water cement ratio in case of Table is 0.6 0 (by mass) whereas the same for Table is 0.35 (by mass).
For any departure from above mentioned conditions, corrections have to be applied as per table for water content and percent sand in total aggregate by absolute volume, determined .

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).
The cement content so calculated shall be checked against the minimum cement content for the requirement of drurability Table 9.18 and the greater of the two values to be adopted.

f. 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.

g. 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.
Trial mix number 1 should be checked for workability and freedom from segregation and bleeding and its finishing property. If the measured workability is different from that assumed in the calculation, a change
in the water content has to done from table 11.26 and the whole mix design has to be recalculated keeping W/C ratio constant. A minor adjustment in the aggregate quantity may be made to improve the finishing quality or freedom from segregation and bleeding. This will comprise trial mix number 2. Now water/cement ratio is changed by ± 10 per cent of preselected value and mix proportions are recalculated.
These will form trial mix numbers 3 and 4. Testing for trial mix numbers 2, 3, 4 are done simultaneously.
These tests normally provide sufficient information, including the relationship between compressive
strength and water cement ratio, from which the mix proportions for field trials may be arrived at.

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