UNIT III

1. **Explain the design procedure of BIS method concrete design (MAY 2019)(May 2018)**

Various Methods of Proportioning

- Arbitrary proportion
- Indian Road Congress,
- IRC 44 method
- High strength concrete mix design
- Mix design based on flexural strength
- Road note No. 4 (Grading Curve method)
- ACI Committee 211 method
- DOE method
- Mix design for pumpable concrete
- Indian standard Recommended method IS 10262-82

Procedure for Concrete Mix Design – IS456:2000

Step1. Determine the mean target strength ft from the specified characteristic compressive strength at 28-day fck and the level of quality control.

ft = fck + 1.65 S

Where, S is the standard deviation obtained from the Table of approximate contents given after the design mix.

Step 2.Obtain the water cement ratio for the desired mean target using the empirical relationship between compressive strength and water cement ratio so chosen is checked against the limiting water cement ratio. The water cement ratio so chosen is checked against the limiting water cement ratio for the requirements of durability given in table and adopts the lower of the two values.

Step 3.Estimate the amount of entrapped air for maximum nominal size of the aggregate from the table.

Step 4. Select the water content, for the required workability and maximum size of aggregates (for aggregates in saturated surface dry condition) from table.

Step 5. Determine the percentage of fine aggregate in total aggregate by absolute volume from table for the concrete using crushed coarse aggregate.

Step 6.Adjust the values of water content and percentage of sand as provided in the table for any difference in workability, water cement ratio, grading of fine aggregate and for rounded aggregate the values are given in table.

Step 7.Calculate the cement content form the water-cement ratio and the final water content as arrived after adjustment. Check the cement against the minimum cement content from the requirements of the durability, and greater of the two values is adopted.

Step 8.From the quantities of water and cement per unit volume of concrete and the percentage of sand already determined in steps 6 and 7 above, calculate the content of coarse and fine aggregates per unit volume of concrete from the following relations:

Where, V = absolute volume of concrete = gross volume (1m3) minus the volume of
entrapped air

Sc = specific gravity of cement

W = Mass of water per cubic metre of concrete, kg

C = mass of cement per cubic metre of concrete, kg

p = ratio of fine aggregate to total aggregate by absolute volume

fa, Ca = total masses of fine and coarse aggregates, per cubic metre of concrete,respectively, kg, and Sfa, Sca = specific gravities of saturated surface dry fine and coarse aggregates, respectively

Step 9. Determine the concrete mix proportions for the first trial mix.

Step 10. Prepare the concrete using the calculated proportions and cast three cubes of 150 mm size and test them wet after 28-days moist curing and check for the strength.

Step 11. Prepare trial mixes with suitable adjustments till the final mix proportions are arrived at.

2. Explain the factors that influence the choice of mix design and requirements of concrete design (MAY 2016)(NOV 2019)

Factors to be considered for mix design

· The grade designation giving the characteristic strength requirement of concrete.

· The type of cement influences the rate of development of compressive strength of concrete.

· Maximum nominal size of aggregates to be used in concrete may be as large as possible within the limits prescribed by IS 456:2000.

· The cement content is to be limited from shrinkage, cracking and creep.

· The workability of concrete for satisfactory placing and compaction is related to the size and shape of section, quantity and spacing of reinforcement and technique used for transportation, placing and compaction.

Requirements of concrete mix design should be known before calculations for concrete mix. Mix design is done in the laboratory and samples from each mix designed is tested for confirmation of result. But before the mix design process is started, the information about available materials, strength of concrete required, workability, site conditions etc. are required to be known.

1. Characteristic strength of concrete required: Characteristic strength is the strength of concrete below which not more than 5% of test results of samples are expected to fall. This can also be called as the grade of concrete required for mix design. For example, for M30 grade concrete, the required concrete compressive strength is 30 N/mm^2 and characteristic strength is also the same.

2. Workability requirement of concrete: The workability of concrete is commonly measured by slump test. The slump value or workability requirement of concrete is based on the type of concrete construction

For example, reinforced concrete construction with high percentage of steel reinforcement, it will be difficult to compact the concrete with vibrators or other equipment. In this case, the workability of concrete should be such that the concrete flows to each and every part of the member. For concrete member, where it is easy to compact the concrete, low workability concrete can also be used.

It is also known that with increase in workability of concrete, the strength of concrete reduces. Thus, based on type of structure or structural member, the workability requirement of concrete should be assumed and considered in the mix design. For pumped concrete, it is essential to have high workability to transfer concrete to greater heights with ease. This case also should be considered in the mix design

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3. **How to modify concrete mix design with fly ash and super plasticizers?(MAY 2018)**

A mix is to be designed for characteristic strength of 50 N/mm^2 at 28 days having target strength of 62 N/mm^2 at 28 days. 30% of fly ash is to be included by weight of cementitious material. Maximum w/c ratio or w/c + f.a. ratio = 0.4, minimum cement concrete or cement + f.a. content = 400 kg/m^3. Slump 50$\pm$10 mm.

Cement : OPC, 53 grade, specific gravity = 3.15

Fine aggregate : From river of Zone II Sp.gr. = 2.6

Coarse aggregate : Crushed 20 mm graded, Sp. Gr. = 2.6

Fly ash : As per I.S.: 3812, Sp. Gr = 2.25

Superplasticizer : Liquid Sp.gr. 1.15, dosage 1% b.w.c. for required

Workability

Water content reduction for fly ash concrete : 5%

Increase in cementitious material : 12%

Designed plain concrete of above strength and workability:

Water (free) = 170 kg/m^3
OP Cement = 430 kg/m^3
Fine aggregate = 707 kg/m^3
Coarse aggregate = 1060 kg/m^3
Superplasticizer = 4.300 kg/m^3= 3739 ml/m^3

Total = Sum of all of the above = 2371 kg/m^3 (air = 1%)

Total cementitious	wt. (kg/m^3)	vol (m^3)
Material = 1.12 x 430 = 482		
OP Cement = 482 x 0.70 = 337	337 / 3150	= 0.1070
Fly ash= 482 x 0.30 = 145	145 / 2250	= 0.0644
Water (free) = 170 x 0.95 = 162	162 / 1000	= 0.1620
Superplasticizer= 482 x 0.01 = 4.82*	4.82 / 1150	= 0.0042
Air = 1%		= 0.0100
Total = 0.3476		
Aggregates=	1-0.3476	= 0.6524
Coarse aggregate(SSD) unaltered=1060	1060 / 2600	= 0.4077
Fine aggregate = 0.2447×2600= 636	0.6524-0.4077	= 0.2447
Total	= 2345	= 1

Materials	Plain Concrete	Fly ash Concrete
Water (free)	170	162
OP Cement	430	337
Fly ash	—	145
Fine aggregate	707	636
Coarse aggregate	1060	1060

Superplasticizer	4.300	4.820
	2371	2345

Saving in cement 430-337 = 93 kg/m^3

It may be noticed that, for the fly ash concrete the total cementitious material is greater but the OP cement content is smaller, the fine aggregate content is reduced but the coarse aggregate content is deliberately the same, the water is reduced and the density is reduced because of the lower density of fly ash compared with cement.

Note that it should not be assumed that ggbfs concrete or other fly ash concretes would require the same adjustment. The factors can differ appreciably between materials, source and quantities and will be influenced by the proportion of ggbfs or fly ash, the cement content and other factors. The method, however will be applicable and can be used for any situation, provided the factors are known.

4. (a) Design a concrete mix design for M40 grade of concrete using IS method with the following data (May 2017)(May 2016)(NOV 2019)

(a) Type of cement: OPC 43 grade
(b) Type of mineral admixture: Fly ash conforming to IS: 3812 (Part-l)
(c) Maximum nominal size of Aggregate: 20 mm
(d) Minimum cement content: 320 kg/ m3
(e) Maximum water-cement ratio: 0.45
(f) Workability: 100 mm slump
(g) Exposure condition: Severe (For RCC)
(h) Method of placing concrete: Pumping
(I) Degree of supervision: Good
(j) Type of aggregate: Crushed angular aggregate
(k)Maximum cement content: 450 kg/m3
(1) Chemical admixture type: Super plasticizer
(m) Specific gravity of cement: 3.15
Specific gravity of C.A.: 2.74
Specific gravity of F.A.: 2-74
Specific gravity of Fly ash: 2.20
(n) Water absorption
Coarse aggregate: 0.5%
Find aggregate: Nil
(0) Free surface moisture
Coarse aggregate: Nil

Find aggregate 1.5%
Grading of C.A. conforming Table-2 of IS: 383
Grading of EA. Conforming to grading Z one-Io f Table-4o f IS: 383

SOLUTION:

Step-l: Target mean strength
fck_= 40 N/mm2
fck'=fck + 1.65 From Table 6.4 for
M40 concrete,
= 40+ 1.65x 5 standard deviatio
S = 5 N/mm2
= 48.25 N/mm2

Step-2: Selection of w/c ratio

From Table-5 of IS: 456-2000 Table 6.5
Maximum free w/c ratio = 0.45
Based on experience of the mix design w/c, ratio is taken as 0.40.
Adopt smaller of the two values,
w/c = 0.40

Step-3 : Selection of water content

Maximum water content. From Table-6.6 for nominal maximum size of aggregate 20 mm
= 186 litre.
This is for 50 mm slump.
Increase 3% water for every 25 mm slump over and above 50 mm slump.
We have slump value of 100 mm, hence increase water content by 6%.
Estimated water content for 100 mm slump
=186+6/100×186
= 197 litre
As super plasticizer is used the water content can be reduced up to 20% and above.
Assume 25% reduction in water content due to super plasticizer,
Actual water to be used = 197 x 0.75 = 148 litre.

Step-4 : Calculation of cement + fly ash content

w/c ratio = 0.40
Water used = 148 litre
Cement + fly ash content, w/c = 0.40
C = 148/0.40 = 370 kg/m3

As per IS: 456_2000. Table_5. Minimum cement content for severe exposure condition

370 kg/m3 > 320 kg/m3 hence O.K.

Since fly ash is not as active as that of cement. It is usual to increase the cementites materially some percentage.
In this example an increase of 10% is considered.
Cementitious material (Cement + y ash) content = 370 x 1.10 = 407 kg/m3

Water content = 148 litre

w/c ratio = 148/407 = 0.364

Let us the percentage of fly ash as 30%
Fly ash content = 407 x 0.30 = 122.0 kg/m3
Cement content = 407 – 122 = 285 kg/m3
Therefore. saving of cement while using y ash: 370 – 285 = 85 kg/m3

Step-5 : Coarse aggregate and flnd aggregate content

From Table-6.8. volume of coarse aggregate corresponding to 20 mm maximum size of Aggregate and fine aggregate (Zone-I) for water cement ratio 0.50 = 0.60. In the present case w/c = 0.40. i.e. less by 0.10. As the w/c ratio is reduced it is desirable to increase the CA. content to decrease F.A. content.

For every decrease of w/c ratio by 0.05, the CA. volume may be increased by 1.0% (Le. 0.01).
As the w/c ratio is less by 0.10, the CA. volume is increased by 0.02.
Corrected proportion of volume of CA. = 0.60 + 0.02 = 0.62

For pumpable concrete, C.A. volume can be reduced by 10%.
Final volume of CA. = 0.62 X 0.90 = 056
Volume of EA. = l – 0.56 = 0.44

Step-6: Calculation of Mix Proportions

(1) Volume of concrete = 1 m3

(2) Volume of cement mass of cement = mass of cement/specific gravity of cement x 1/100
= 285/3.15 x 1/100 = 0.090 m3

3) Mass of fly ash = mass of fly / specific gravity of fly ash x 1/100 = 122x 1/100= 0.055 m3

4) Volume of water = mass of water / specific gravity of water x 1/100= 148/1 x 1/100
= 0.148 m3

(5) Volume of chemical admixture (supper plasticizer) @ 2.0% by mass of cementitious
= mass of chemical admixture / specific gravity of chemical admixture x 1/100
= 8.14/1.145 x 1/100 = 0.0071 m3

Absolute volume of all the materials except total aggregates
= 0.09 + 0055 + 0.148 + 0.0071 = 0.3 m3
Absolute volume of total aggregate:- 1 – 0.31 = 0.7 m3

Mass of CA. = V. x Volume of CA. x Sp.gravity of CA. x 1000
= 0.7 x 0.56 x 2.74 x 1000 = 1074 kg

Mass of EA. = V. x Volume of FA. x Sp. Gravity of EA. x 1000
= 0.7 x 0.44 x 2.74 x 1000 = 844 kg

Step-7 : Mix Proportions for Trial No. l :

Cement : 285 kg/m3
Fly ash : 122kg
Water : 148 litre
Fine aggregate : 844 kg/m3
Coarse aggregate : 1074 kg/m3
Chemical admixture : 8.14 kglm3
Wet densityof concrete= 2481 ltglm3
w/c ratio= 148/407 = 0.364

We may use 40% 0f 10 mm sizeand60% of 20 mm size of aggregate.
Quantity of mm size aggregate =ga%tex1074= 429.k6g /m3
Quantiotyf20mmsizeaggreg=at£ex1074 = 644.4k g/m3

Step_8: Site corrections for water absorption and surface moisture

Quantity of F.A. = 844 kg

Absorption = Nil

Surface moisture = 1.5%

Quantity of surface moisture = 1.5/100×844 = 12.66 kg

Mass of FA. In field condition = 844 + 12.66 = 856.66 kg/m3

Absorption of C.A= 0.5/100×844=5.37g

Mass of CA. in field condition = 1074-5.37 = 1068.63 kg/m3

As regards to water, 12.66 kg of water is contributed by F.A. and 5.37kg of water is Absorbed by CA.

Therefore, 12.66-5.37 = 7.29 kg of extra water is contributed .This quantity of water Is to be deducted from total water.

Net quantity of water required= 148-7.29 = 140.71 kg/m3

Step-9: Mix Proportions (by mass):

Water Cement+ Fly ash F.A. CA.
140.71 lit. 285kg+ 122= 407kg 856.66 kg 1068.6k3g
0.345 1 2.105 2.625

Final quantities of materials:

Cement: 285 kg/m3.
Fly ash: 122 kg/m3
Water; 140.71 kg/m3
Fine aggregate 856.66 kg/m3
Coarse aggregate 1068.63 kg/m3
Chemical admixture =8.14 kg/m3
Wet density of concrete= 2481 kg/m3
13.(b) Design a concrete mix design for M40 grade of concrete using IS method with the following data (MAY 2017)(NOV 2018)(MAY 2016)(NOV 2019)

(a) Characteristic compressive strength required in the field at 28 days grade designation — M 30

(b) Type of Cement : OPC 53 Grade confirming to IS 12269

(b) Maximum Nominal size of aggregate — 20 mm

(c) Shape of CA — Angular

(d) Workabiltiy required at site — 100 mm (slump)

(e) Type of exposure the structure will be subjected to (as defined in IS: 456) — Moderate

(h) Method of concrete placing: pump able concrete

(ii) Test data of material

The following materials are to be tested in the laboratory and results are to be ascertained for the design mix

(a) Cement Used : OPC 53 Grade Confirming to IS 12269

(b) Specific Gravity of Cement : 3.15

(c) Chemical admixture : Super plasticizer confirming to IS 9103

(d) Specific gravity

Specific gravity of Fine Aggregate (sand) : 2.70

Specific gravity of Coarse Aggregate : 2.80

(e) Water Absorption

Coarse Aggregate : 0.4%

Fine Aggregate : 1.0%

(f) Free (surface) moisture

Coarse Aggregate : Nil

Fine Aggregate : Nil

Aggregate are assumed to be in saturated surface dry condition usually while preparing design mix.

(g) Seive Analysis

Fine aggregates : Confirming to Zone I of Table 4 IS – 383

Step by Step Procedure for Concrete Mix Design of M30 Grade Concrete

Step 1 — Determining the Target Strength for Mix Proportioning

F'ck = fck + 1.65 x S

Where,

F'ck = Target average compressive strength at 28 days

Fck = Characteristic compressive strength at 28 days

S = Assumed standard deviation in N/mm2 = 5 (as per table -1 of IS 10262- 2009)

= 30 + 1.65 x 5.0 = 38.25 N/mm2

Note : Under control conditions if Target average compressive strength is achieved then at field the probability of getting compressive strength of 30 MPa is very high

Table 1 Assumed Standard Deviation
(*Clauses* 3.2.1.2, A-3 *and* B-3)

Sl No. (1)	Grade of Concrete (2)	Assumed Standard Deviation N/mm² (3)
i)	M 10	3.5
ii)	M 15	
iii)	M 20	4.0
iv)	M 25	
v)	M 30	5.0
vi)	M 35	
vii)	M 40	
viii)	M 45	
ix)	M 50	
x)	M 55	

Step 2 — Selection of water-cement ratio:-

From Table 5 of IS 456, Maximum water-cement ratio = 0.50

Note : Do not start with w/c ratio above 0.50,even though the other desired results like Strength, workability could be achieved.

Table 5 Minimum Cement Content, Maximum Water-Cement Ratio and Minimum Grade of Concrete for Different Exposures with Normal Weight Aggregates of 20 mm Nominal Maximum Size

(*Clauses* 6.1.2, 8.2.4.1 *and* 9.1.2)

Sl No.	Exposure	Plain Concrete			Reinforced Concrete		
		Minimum Cement Content kg/m³	Maximum Free Water-Cement Ratio	Minimum Grade of Concrete	Minimum Cement Content kg/m³	Maximum Free Water-Cement Ratio	Minimum Grade of Concrete
1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Mild	220	0.60	–	300	0.55	M 20
iii)	Moderate	240	0.60	M 15	300	0.50	M 25
iii)	Severe	250	0.50	M 20	320	0.45	M 30
iv)	Very severe	260	0.45	M 20	340	0.45	M 35
v)	Extreme	280	0.40	M 25	360	0.40	M 40

NOTES

1 Cement content prescribed in this table is irrespective of the grades of cement and it is inclusive of additions mentioned in **5.2**. The additions such as fly ash or ground granulated blast furnace slag may be taken into account in the concrete composition with respect to the cement content and water-cement ratio if the suitability is established and as long as the maximum amounts taken into account do not exceed the limit of pozzolona and slag specified in IS 1489 (Part 1) and IS 455 respectively.

2 Minimum grade for plain concrete under mild exposure condition is not specified.

Step 3 — Selection of Water Content

Maximum water content for 20 mm aggregate = 186 Kg (for 25 to 50 slump)

Table 2 Maximum Water Content per Cubic Metre of Concrete for Nominal Maximum Size of Aggregate

(*Clauses* 4.2, A-5 *and* B-5)

Sl No.	Nominal Maximum Size of Aggregate mm	Maximum Water Content [1] kg
(1)	(2)	(3)
i)	10	208
ii)	20	186
iii)	40	165

NOTE — These quantities of mixing water are for use in computing cementitious material contents for trial batches.

[1] Water}content corresponding to saturated surface dry aggregate.

We are targeting a slump of 100mm, we need to increase water content by 3% for every 25mm above 50 mm i.e. increase 6% for 100mm slump

i.e. Estimated water content for 100 Slump = 186+(6/100) X 186 = 197 litre

Water content = 197 liters

Step 4 – Calculation of Cement Content

Water-Cement Ratio = 0.50
Water content from Step – 3 i.e. 197 liters

Cement Content = Water content / "w-c ratio" = (197/0.50) = 394 kgs

From Table 5 of IS 456,

Minimum cement Content for moderate exposure condition = 300 kg/m3

394 kg/m3 > 300 kg/m3, hence, OK.

As per clause 8.2.4.2 of IS: 456

Maximum cement content = 450 kg/m3, hence ok too.

Step 5: Proportion of Volume of Coarse Aggregate and Fine aggregate Content

From Table 3 of IS 10262- 2009, Volume of coarse aggregate corresponding to 20 mm size and fine aggregate (Zone I) = 0.60

Table 3 Volume of Coarse Aggregate per Unit Volume of Total Aggregate for Different Zones of Fine Aggregate

(*Clauses* 4.4, A-7 *and* B-7)

Sl No.	Nominal Maximum Size of Aggregate	Volume of Coarse Aggregate[1] per Unit Volume of Total Aggregate for Different Zones of Fine Aggregate			
	mm	Zone IV	Zone III	Zone II	Zone I
(1)	(2)	(3)	(4)	(5)	(6)
i)	10	0.50	0.48	0.46	0.44
ii)	20	0.66	0.64	0.62	0.60
iii)	40	0.75	0.73	0.71	0.69

[1] Volumes are based on aggregates in saturated surface dry condition.

Note 1: In the present case water-cement ratio is 0.5.So there will be no change in coarse agreegate volume i.e. 0.60 .

Note 2: Incase the coarse aggregate is not angular one, then also volume of coarse aggregate may be required to be increased suitably based on experience.

Step 6: Estimation of Concrete Mix Calculations

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

1. Volume of concrete = 1 m3
2. Volume of cement = (Mass of cement / Specific gravity of cement) x (1/100) = (39/3.15) x (1/1000) = 0.125 m3
3. Volume of water = (Mass of water / Specific gravity of water) x (1/1000) = (197/1) x (1/1000) = 0.197 m3
4. Total Volume of Aggregates = 1- (b+c) =1- (0.125+0.197) = 0.678 m3
5. Mass of coarse aggregates = d X Volume of Coarse Aggregate X Specific Gravity of Coarse Aggregate X 1000 = 0.678 X 0.60 X 2.80 X 1000 = 1139 kgs/m3
6. Mass of fine aggregates = d X Volume of Fine Aggregate X Specific Gravity of Coarse Aggregate X 1000 = 0.678 X 0.40 X 2.70 X 1000 = 732 kgs/m3

Step-7: Concrete Mix proportions for Trial Number 1

Cement = 394 kg/m3

Water = 197 kg/m3

Fine aggregates = 732 kg/m3

Coarse aggregate = 1139 kg/m3

Water-cement ratio = 0.50

5. **Explain the ACI design method (NOV 2018)**

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 air-entrained 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* :

- Fineness modulus of selected F.A.

- Unit weight of dry rodded coarse aggregate.
- Sp. gravity of coarse and fine aggregates in SSD condition
- Absorption characteristics of both coarse and fine aggregates.
- Specific gravity of cement.
- 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 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.

6. Define concrete mix design and state the principles of concrete mix design.(NOV 2017)

Concrete Mix Design

As Per Indian Standard Code, The process of selecting suitable ingredients of**concrete** and determining their relative amounts with the objective of producing a **concrete** of the required, strength, durability, and workability as economically as possible, is termed the **concrete mix design**.

Basic Considerations: -

Design of concrete mixes involves determination of the proportions of the given constituents, namely, cement, water, coarse and fine aggregates and admixtures, if any, which wold produce concrete possessing specified properties both in the fresh and hardened states with the maximum overall economy. Workability is specified as the important property of concrete in the fresh state; for hardened state compressive strength and durability are important. The mix design is, therefore, generally carried out for a particular compressive strength of concrete with adequate workability so that fresh concrete can be properly placed and compacted, and to achieve the required durability.

The following basic assumptions are made in design of plastic concrete mixes of medium strength :

a) The compressive strength of concrete is governed by its water-cement ratio, and

b) For a given aggregate characteristics, the workability of concrete is governed by its water content.

Mix design on the basis of recommended guidelines is really a process of making an initial guess at the optimum combination of ingredients and final mix porportions is obtained only on the basis of further trial mixes.

Factors in the Choice of Mix Design: -

Both IS : 456-1978[3] as well as IS : 1343-1980[4] envisage that design of concrete mix be based on the following factors:

a) Grade designation,

b) Type of cement

c) Maximum nominal size of aggregates,

d) Minimum water-cement ratio,

e) Workability, and

f) Minimum cement content.

Outline of Mix Design Procedure :-

The various factors for determining the concrete mix proportions and the step by step procedure for concrete mix design can be schematically represented. The basic steps involved can be summarised as follows:

a) Arrive at the mean target strength from the characteristic strength specified and the level of quality control,

b) Choose the water-cement ratio for mean target strength and check for requirements of durability,

c) Arrive at the water content for the workability required,

d) Calculate cement content and check for requirements of durability,

e) Choose the relative proportion of the fine and coarse aggregates from the characteristics of coarse and fine aggregates,

f) Arrive at the concrete mix proportions for the first trial mix, and

g) Conduct trial mixes with suitable adjustments till the final mix composition is arrived at.

Most of the available mix design methods are essentially based on the above procedure.

7. **Describe the various methods of mix design. Briefly describe the IS method.(NOV 2017)**

Various Methods of Proportioning

Arbitrary proportion

Indian Road Congress,

IRC 44 method

High strength concrete mix design

Mix design based on flexural strength

Road note No. 4 (Grading Curve method)

ACI Committee 211 method

DOE method

Mix design for pumpable concrete

Indian standard Recommended method IS 10262-82

Procedure for Concrete Mix Design – IS456:2000

Step1. Determine the mean target strength ft from the specified characteristic compressive strength

at 28-day fck and the level of quality control.

ft = fck + 1.65 S

Where, S is the standard deviation obtained from the Table of approximate contents given

after the design mix.

Step 2.Obtain the water cement ratio for the desired mean target using the empirical relationship

between compressive strength and water cement ratio so chosen is checked against the limiting water cement ratio. The water cement ratio so chosen is checked against the limiting water cement ratio for the requirements of durability given in table and adopts the lower of the two values.

Step 3.Estimate the amount of entrapped air for maximum nominal size of the aggregate from the

table.

Step 4. Select the water content, for the required workability and maximum size of aggregates (for

aggregates in saturated surface dry condition) from table.

Step 5. Determine the percentage of fine aggregate in total aggregate by absolute volume from table

for the concrete using crushed coarse aggregate.

Step 6.Adjust the values of water content and percentage of sand as provided in the table for any

difference in workability, water cement ratio, grading of fine aggregate and for rounded aggregate the values are given in table.

Step 7.Calculate the cement content form the water-cement ratio and the final water content as arrived after adjustment. Check the cement against the minimum cement content from the requirements of the durability, and greater of the two values is adopted.

Step 8.From the quantities of water and cement per unit volume of concrete and the percentage of

sand already determined in steps 6 and 7 above, calculate the content of coarse and fine aggregates per unit volume of concrete from the following relations:

Where, V = absolute volume of concrete = gross volume (1m3) minus the volume of

entrapped air

Sc = specific gravity of cement

W = Mass of water per cubic metre of concrete, kg

C = mass of cement per cubic metre of concrete, kg

p = ratio of fine aggregate to total aggregate by absolute volume

fa, Ca = total masses of fine and coarse aggregates, per cubic metre of concrete,respectively, kg, and

Sfa, Sca = specific gravities of saturated surface dry fine and coarse aggregates, respectively

Step 9. Determine the concrete mix proportions for the first trial mix.

Step 10. Prepare the concrete using the calculated proportions and cast three cubes of 150 mm size and test them wet after 28-days moist curing and check for the strength.

Step 11. Prepare trial mixes with suitable adjustments till the final mix proportions are arrived at.

8. **Design a concrete mix design by IS method for the following requirements (NOV 2017)**

a) Grade designation : M25
b) Type of cement : OPC 53 Grade conforming IS 12269
c) Maximum nominal size of aggregate : 20mm
d) Minimum cement content : 300 kg/m^3 (IS 456:2000)
e) Maximum water-cement ratio : 0.50 (Table 5 of IS 456:2000)
f) Workability : 100-120mm slump
g) Exposure condition : Moderate (For Reinforced Concrete)
h) Method of concrete placing : Pumping
j) Degree of supervision : Good
k) Type of aggregate : Crushed Angular Aggregates
m) Maximum cement content : 340 kg/m^3
n) Chemical admixture type : Super Plasticizer ECMAS HP 890

TEST DATA FOR MATERIALS
a) Cement used : OPC 53 Grade conforming IS 12269

b) Specific gravity of cement : 3.15

c) Chemical admixture : Super Plasticizer conforming to IS 9103 (ECMAS HP 890)

d) Specific gravity of

1) Coarse aggregate 20mm : 2.67
2) Fine aggregate : 2.65
3) GGBS : 2.84 (JSW)

e) Water absorption:

1) Coarse aggregate : 0.5 %
2) Fine aggregate (M.sand) : 2.5 %

f) Free (surface) moisture:

1) Coarse aggregate : Nil (Absorbed Moisture also Nil)
2) Fine aggregate : Nil

g) Sieve analysis:

1) Coarse aggregate: Conforming to all in aggregates of Table 2 of IS 383
2) Fine aggregate : Conforming to Grading Zone II of Table 4 of IS 383

TARGET STRENGTH FOR MIX PROPORTIONING
f'ck =fck + 1.65 s
where
f'ck = target average compressive strength at 28 days,
fck = characteristics compressive strength at 28 days, and
s = standard deviation.

From Table I of IS 10262:2009, Standard Deviation, s = 4 N/mm^2. Therefore, target strength = 25 + 1.65 x 4 = 31.6 N/mm^2.

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SELECTION OF WATER•CEMENT RATIO
Adopted maximum water-cement ratio = 0.47.

From the Table 5 of IS 456 for Very severe Exposure maximum Water Cement Ratio is 0.50
0.47 < 0.50Hence ok.

SELECTION OF WATER CONTENT
From Table 2 of IS 10262:2009, maximum water content for 20 mm aggregate = 186 litre (for 25 to 50 mm slump range) Estimated water content for 100 mm slump = 186+ (6/186) = 197 litre.

(Note: If Super plasticizer is used, the water content can be reduced upto 20% and above.)

Based on trials with Super plasticizer water content reduction of 20% has been achieved, Hence the arrived water content = 197-[197 x (20/100)] = 158 litre.

CALCULATION OF CEMENT CONTENT
Adopted w/c Ratio = 0.47
Cement Content = 158/0.47 = 336 kg/m^3
From Table 5 of IS 456, Minimum cement content for 'Very severe' exposure conditions 300kg/m^3

336 kg/m^3 > 300 kg/m^3 hence ok.

PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT
From Table 3 of (IS 10262:2009) Volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone II) for water-cement ratio of 0.50 =0.62 .

In the present case water-cement ratio is 0.44. Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by

0.06. The proportion of volume of coarse aggregate is increased by 0.02 (at the rate of -/+ 0.01 for every ± 0.05 change in water-cement ratio).

Therefore, corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.47 = 0.63

NOTE – In case the coarse aggregate is not angular one, then also volume of coarse aggregate may be required to be increased suitably based on experience & Site conditions.

For pumpable concrete these values should be reduced up to 10%. Therefore, volume of coarse aggregate =0.63 x 0.9 =0.57.

Volume of fine aggregate content = 1 – 0.57= 0.43.

MIX CALCULATIONS

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

a) Volume of concrete = 1 m^3

b) Volume of cement = [Mass of cement] / {[Specific Gravity of Cement] x 1000}
= 336/{3.15 x 1000}
= 0.106 m^3

c) Volume of water = [Mass of water] / {[Specific Gravity of water] x 1000}
= 158/{1 x 1000}
= 0.158m^3

d) Volume of chemical admixture = 1.75 litres/ m^3 (By Trial and Error Method used 0.4% by the weight cement)

e) Volume of all in aggregate = [a-(b+c+d)]
= [1-(0.106+0.158+0.004)]
= 0.732 m^3

f) Mass of coarse aggregate= e x Volume of Coarse Aggregate x Specific Gravity of Fine Aggregate x 1000
= 0.732x 0.57 x 2.67 x 1000
= 1114 kg/m^3

g) Mass of fine aggregate= e x Volume of Fine Aggregate x Specific Gravity of Fine Aggregate x 1000
= 0.732 x 0.43 x 2.65 x 1000
= 834 kg/m^3

MIX PROPORTIONS

Cement = 269kg/m^3
GGBS = 67 kg/m^3 (20% By Total weight of Cement)
Water = 158 l/m^3
Fine aggregate = 834 kg/m^3
Coarse aggregate 20mm = 891 kg/m^3
12mm = 223 kg/m^3 (20% By Total weight of Coarse Aggregate)
Chemical admixture = 1.34 kg/m^3 (0.4% by the weight of cement)
Density of concrete = 2443 kg/m^3
Water-cement ratio = 0.47
Mix Proportion By weight = 1: 2.48: 3.31

9.