UNIT III

PROPORTIONING OF CONCRETE MIX

SYLLABUS

Principles of Mix Proportioning - Properties of concrete related to Mix Design - Physical properties of materials required for Mix Design - Design Mix and Nominal Mix - BIS Method of Mix Design - Mix Design Examples

3.1 PRINCIPLES OF MIX PROPORTIONING

1. The environmental exposure condition for the structure
2. The grade of concrete, their characteristic strength's and standard deviations
3. The type of cement
4. The types and sizes of aggregates and their sources of supply
5. The nominal maximum sizes of aggregates
6. Maximum and minimum cement content in kg/m^3
7. Water cement ratio
8. The degree of workability of concrete based on placing conditions
9. Air content inclusive of entrained air
10. The maximum/minimum density of concrete
11. The maximum/minimum temperature of fresh concrete
12. Type of water available for mixing and curing
13. The source of water and the impurities present in it.

THE ENVIRONMENTAL EXPOSURE CONDITION FOR THE STRUCTURE

(as per IS456:2000)

Table 3 Environmental Exposure Conditions

(*Clauses* 8.2.2.1 *and* 35.3.2)

Sl No. (1)	Environment (2)	Exposure Conditions (3)
i)	Mild	Concrete surfaces protected against weather or aggressive conditions, except those situated in coastal area.
ii)	Moderate	Concrete surfaces sheltered from severe rain or freezing whilst wet
		Concrete exposed to condensation and rain
		Concrete continuously under water
		Concrete in contact or buried under non-aggressive soil/ground water
		Concrete surfaces sheltered from saturated salt air in coastal area
iii)	Severe	Concrete surfaces exposed to severe rain, alternate wetting and drying or occasional freezing whilst wet or severe condensation.
		Concrete completely immersed in sea water
		Concrete exposed to coastal environment
iv)	Very severe	Concrete surfaces exposed to sea water spray, corrosive fumes or severe freezing conditions whilst wet
		Concrete in contact with or buried under aggressive sub-soil/ground water
v)	Extreme	Surface of members in tidal zone
		Members in direct contact with liquid/ solid aggressive chemicals

THE GRADE OF CONCRETE, THEIR CHARACTERISTIC STRENGTH AND STANDARD DEVIATIONS (as per IS456:2000)

Table 2 Grades of Concrete

(*Clause* 6.1, 9.2.2, 15.1.1 *and* 36.1)

Group	Grade Designation	Specified Characteristic Compressive Strength of 150 mm Cube at 28 Days in N/mm²
(1)	(2)	(3)
Ordinary Concrete	M 10	10
	M 15	15
	M 20	20
Standard Concrete	M 25	25
	M 30	30
	M 35	35
	M 40	40
	M 45	45
	M 50	50
	M 55	55
High Strength Concrete	M 60	60
	M 65	65
	M 70	70
	M 75	75
	M 80	80

NOTES

1 In the designation of concrete mix M refers to the mix and the number to the specified compressive strength of 150 mm size cube at 28 days, expressed in N/mm².

2 For concrete of compressive strength greater than M 55, design parameters given in the standard may not be applicable and the values may be obtained from specialized literatures and experimental results.

Table 8 Assumed Standard Deviation
(*Clause* 9.2.4.2 and *Table* 11)

Grade of Concrete	Assumed Standard Deviation N/mm²
M 10, M 15	3.5
M 20, M 25	4.0
M 30, M 35, M 40, M 45, M 50	5.0

NOTE—The above values correspond to the site control having proper storage of cement; weigh batching of all materials; controlled addition of water; regular checking of all materials, aggregate gradings and moisture content; and periodical checking of workability and strength. Where there is deviation from the above the values given in the above table shall be increased by 1N/mm².

3.1.1 Objectives of Mix Design

- The purpose of concrete mix design is to ensure the most optimum proportions of the constituent materials to fulfil the requirement of the structure being built. Mix design should ensure following objectives.
- To achieve the designed/ desired workability in the plastic stage
- To achieve the desired minimum strength in the hardened stage
- To achieve the desired durability in the given environment conditions
- To produce concrete as economically as possible.

3.2 PROPERTIES OF CONCRETE RELATED TO MIX DESIGN

The mix design of concrete is the process of deciding what type of raw material and how much of each raw material needs to be selected to make concrete that can meet prerequisites such as strength, durability, and workability.

The required properties of hardened concrete are specified by the designer of the structure and the properties of fresh concrete are governed by the type of construction and by the techniques of placing and transporting. These two sets of requirements are the main factors that determine the composition of the mix, also taking account of the construction experience on site. Mix design can, therefore, be defined as the processes of selecting suitable ingredients and determining their relative quantities, with the purpose of producing an economical concrete that has certain minimum properties, notably workability, strength, and durability.

It should be pointed out that the mix design of concrete is frequently done by trial and error. Hence, mix design of concrete is an art, not a science. This means that the mix design of concrete in the strict sense is not possible: the materials used vary in a number of respects and their properties cannot be assessed truly quantitatively, so that we are really making no more than an intelligent guess at the optimum combinations of the ingredients onthe basis of relationships established in the earlier sections.

It is not surprising, therefore, that to obtain a satisfactory mix, we must check the estimated proportions of the mix by making trial mixes and, if necessary, make appropriate adjustments to the proportions until a satisfactory mix has been obtained (Neville and Brooks, 1994).

Workability

As discussed earlier, the workability of concrete consists of two aspects, flowability and cohesiveness. Two factors have to be taken into consideration when determining the workability. One is the geometry of the member to be cast, including size of cross section and the amount and spacing of reinforcement. The other is the compaction method, including the equipment for compacting and duration of consolidation.

It is clear that when the cross section of the member to be cast is narrow and complicated in shape, the concrete must have a high fluidity so that full compaction can be achieved. The same applies when the member is heavily reinforced with steel bars that make placing and compaction difficult. Moreover, it is important to choose proper compacting equipment, such as a plate-type vibrator or a sticker-type vibrator, and a compaction duration to ensure that concrete can be fully compacted during the entire progress of construction.

After choosing the workability, the water content of the mix (mass of water per unit volume of concrete) can be estimated by considering the workability requirement. Well-shaped coarse aggregates and, although the water requirement is influenced by the texture and shape of the aggregate.

Water content is regarded as the most important factor influencing the workability of concrete. After adding water to a concrete mix, the water is absorbed on the surface of the particles of the cement and aggregates. Additional water fills the spaces among the particles and “lubricates” the particles by a water film. Decreasing the water content will result in a low fluidity. If the water content is too small, the concrete will become too dry to mix and place. Increasing the amount of water will increase the amount of water for lubrication and hence improve the fluidity andmake it easy to be compacted. However, too much water will reduce cohesiveness. This not only leads to segregation and bleeding, but also reduces the concrete strength. The water content in a concrete is determined by *w /c* or *w /b* and cement or binder content.

Cement content influences the workability of concrete in two ways. First, for given *w /c* ratio, the larger the cement content, the higher the total water amount in the concrete; hence, the consistency of concrete will be enhanced. Second, cement paste itself plays the roles of coating, filling, and lubrication for aggregate particles. In normal concrete, a considerably low cement content tends to produce a harsh mixture, with poor consistency and, subsequently, poor finish-ability.

Durability

Severe exposure conditions require a stringent control of the *w /c* ratio because it is the fundamental factor determining the permeability and diffusivity of the cement paste and, to a large extent, of the resulting concrete. In addition, adequate cover to embedded reinforcing steel is essential. However, the *w /c* ratio can be assessed indirectly through the workability of the mix, the cement content, and strength. If the *w /c* ratio is determined due to durability requirements, the cement content can be reduced by the use of a larger-size aggregate.

It must be remembered that air entrainment is essential under conditions of freezing and thawing or exposure to deicing salts, although entrained air does not protect concrete containing coarse aggregate that undergoes disruptive volume changes when frozen in a saturated condition.

3.3 FACTORS AFFECTING THE MIX DESIGN

- Cost
- Specifications
- Grade of Concrete
- Type of cement
- Maximum nominal size of aggregate
- Grading of combined aggregate
- Maximum water / cement ratio
- Workability
- Durability
- Compressive strength

Cost

The cost of concrete is made up of

- **Material Cost**
- **Equipment Cost**
- **Labour Cost**

The variation in the cost of materials arises from the fact that cement is several times costlier than aggregates. So it is natural in mix design to aim at as lean a mix as possible. Therefore, all possible steps should be taken to reduce the cement content of a concrete mixtures without sacrificing the desirable properties of concrete such as strength and durability.

Specifications

The following point may be kept in mind while designing concrete mixes

- Minimum Compressive Strength required
- Minimum water/ cement ratio
- Maximum cement content to avoid shrinkage cracks
- Maximum aggregate / cement ratio
- Maximum density of concrete in case of gravity dams
- Environmental Exposure Conditions
- Degree of Workability

Grade of Concrete

- The grade of concrete gives characteristic compressive strength of concrete. It is one of the important factor influencing the mix design
- The grade M 20 denotes characteristic compressive strength f_{ck} of 20 N/mm^2. Depending upon the degree of control available at site, the concrete mix is to be designed for a target mean compressive strength (f_{ck}) applying suitable standard deviation.

Designation	Mix Proportion	Characteristic Compressive Strength in N/mm^2	Group (as per IS : 456 - 2000)
M5	1 : 5 : 10	5	Lean Mix
M7.5	1 : 4 : 8	7.5	
M10	1 : 3 : 6	10	Ordinary Concrete
M15	1 : 2 : 4	15	
M20	1 : 1½ : 3	20	
M25	1 : 1 : 2	25	Standard Concrete
M30	Designed	30	
M35		35	
M40		40	
M45		45	
M50		50	
M55		55	
M60		60	High Strength Concrete

Type of Cement

- The rate of development of strength of concrete is influenced by the type of cement.

- The higher the strength of cement used in concrete, lesser will be the cement content. The use of 43 grade and 53 grade of cement, gives saving in cement consumption as much as 15 % and 25 % respectively, as compared to 33 grade of cement. For concrete of grade M_{25} it is advisable to use 43 and 53 grade of cement.

Maximum Nominal Size of Aggregates

- The maximum size of C.Ais determined by sieve analysis. It is designated by the sieve size higher than larger size on which 15 %or more of the aggregate is retained. The maximum nominal size of C.A. should not be more than one-fourth of minimum thickness of the member.

- For heavily reinforced concrete members as in the case of ribs of main beams, the nominal maximum size of the aggregate should usually be restricted to sum less than the minimum clear distance between the main bars or 5 mm less the minimum cover to the reinforcement, whoever issmaller?

- The workability of concrete increases with an increase in the maximum size of aggregate. But the smaller size of aggregates provide larger surface area for bonding with the mortar matrix which gives higher strength.

Grading of Combined Aggregates

- The relative proportions of the fine and coarse aggregate in a concrete mix is one of the important factors affecting the strength of concrete.
- For dense concrete, it is essential that the fine and coarse aggregate be well graded. In the case when the aggregate available from natural sources do not confirm to the specified grading, the proportioning of two or more aggregate become essential

Maximum Water / Cement Ratio

Abram's water / Cement ratio states that for any given condition of test, the strength of a workability concrete mix is dependent only on water / cement ratio. The lower the water / Cement ratio, the greater is the compressive strength.

Workability

Workability of fresh concrete determines the case with which a concrete mixture can be mixed, transported, placed, compacted and finished without harmful segregation and bleeding.

Durability

- Durability require low water/Cement ratio. It is usually achieved not by increasing the cement content, but by lowering the water demand at a given cement content.
- Water demand can be lowered by through control of the aggregate grading and by using water reducing admixtures

3.4 PHYSICAL PROPERTIES OF MATERIALS REQUIRED TO MIX DESIGN

Based on IS: 456 – 2000 and IS: 1343 – 1980, the factors required for the design of concrete mix are as follows.

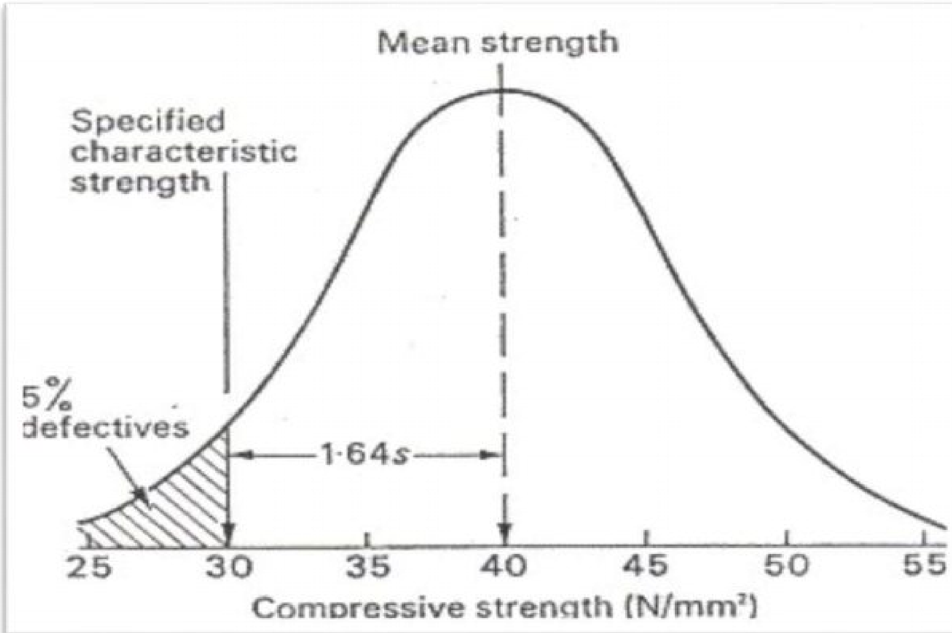
- Grade of Concrete
- Maximum Water – Cement Ratio
- Type of Cement
- Grading of combined Aggregate
- Maximum nominal size of the Aggregate
- Workability
- Durability
- Quality Control etc.

Grade of Concrete

The grade of concrete is an important factor influencing the mix design and it gives the characteristic compressive strength of the concrete.

The compressive strength of the concrete is the most important concrete property, which influences other describable properties of the hardened concrete. The average compressive strength required at 28 days. Determines the nominal water – cement ratio of the mix.

Higher grade (strength) concrete is used for the structures, which resist high compressive loads. Such as bridges and high rise structures. It has been used in components such as columns, shear walls and foundations.



Compressive strength (vs.) Characteristic compressive strength

Maximum Water – Cement Ratio

Maximum water cement ratio decides the workability and it is decides by the cement – aggregate ratio, which affects the strength. Mix design is entirely based on strength and hence w / c ratio is one of the parameter in the mix design.

Type of Cement

The rate of development of compressive strength of the concrete varies with type of the cement, and choices of the type of cement depends on the strength and other requirements. The higher the strength of the cement used in concrete, lesser will be the cement content.

Grading of Aggregate

For dense concrete, the proportions of fine and coarse aggregate should be well graded. The relative proportions of the fine and coarse aggregate in a mix is an important factor affecting the strength.

Aggregate grading influences the mix proportions for a specified workability and water – cement ratio. The relative proportions between coarse and fine aggregate in concrete mix influence concrete strength. Well graded fine and coarse aggregate produce a dense concrete because of the achievement of ultimate packing density. If available aggregate, which obtained from natural source, does not confirm to the specified grading, the proportioning of two or more aggregate become essential. Additionally, for specific workability and water to cement ratio, type of aggregate affects aggregate to cement ratio.

Aggregate Grading Types

Maximum Nominal Size of the Aggregate

The maximum nominal size of the aggregate should be as large as possible (within its specified limit). However it should not be more than ¼ of the minimum thickness of the structural member. The maximum size of the coarse aggregate is determined by sieve analysis, it is designated by the sieve size higher than the largest size on which 15 percent of the aggregate is retained.

Maximum aggregate size is determined and controlled by spacing of reinforcement. Aggregate size is inversely proportional to cement requirement for water – cement ratio. This is because workability is directly proportional to size of aggregate. However, the compressive strength tends to increase with the decrease in size of aggregate. Smaller sized aggregates provide greater surface area for bonding with mortar mix that give higher strength. IS 456:2000 and IS 1343:1980 recommends that the nominal size of the aggregate should be as large as possible.

Workability

Workability affects the quality and cost of the concrete. Concrete mixes that are possible to segregate and bleed are more expensive to finish and it will yield less durability.

Workability depends on the size and shape of the section to be concreted, the amount and spacing of reinforcement, and concrete transportation, placement, and compaction technique. In addition to this, high workability concrete is required for the narrow and complicated section with numerous corners or inaccessible amount of effort. Generally, slump test values are used to evaluate concrete workability.

Durability

Durability of the structural member is also an important factor that decides the mix design.

Physical Properties of materials required for mix design

Durability is the ability of concrete to withstand harmful environment conditions, and high strength concrete is generally more durable than low strength concrete. In the situations when the high strength is not necessary but the condition s of exposure are such that high durability is vital, the durability requirement will determine the utilized water – cement ratio.

Quality Control at Site

The degree of control could be evaluated by the variations in the properties of the mix ingredients, in addition to lack of control of accuracy in batching, mixing, placing, curing, and testing. The factor controlling this difference (variations) is termed as quality control.

3.5 TYPES OF MIXES

Compressive Strength Grading and Classes

Grade of Concrete is the classification of concrete according to its compressive strength.

Indian Standards:

There are different grades of concrete are given as M10, M15, M20, M25, M30, M35 and M40.

The letter **"M"** denotes Mix design with proportion of materials like Cement: Fine Aggregate:Coarse Aggregate.

Nominal Grades

Grade of Concrete	Mix Ratio	Compressive Strength in N/mm2 or MPa	Compressive Strength in Psi
M5	1 : 5 : 10	5 MPa	725 psi
M7.5	1 : 4 : 8	7.5 MPa	1087 psi
M10	1 : 3 : 6	10 MPa	1450 psi
M15	1 : 2 : 4	15 MPa	2175 psi
M20	1 : 1.5 : 3	20 MPa	2900 psi

2. Standard Grades

M25	1 : 1 : 2	25 MPa	3625 psi
M30	Design Mix	30 MPa	4350 psi
M35	Design Mix	35 MPa	5075 psi
M40	Design Mix	40 MPa	5800 psi
M45	Design Mix	45 MPa	6525 psi

3. High Strength Grades

M50	Design Mix	50 MPa	7250 psi
M55	Design Mix	55 MPa	7975 psi
M60	Design Mix	60 MPa	8700 psi
M65	Design Mix	65 MPa	9425 psi
M70	Design Mix	70 MPa	10150 psi
M80	Design Mix	80 MPa	11600 psi
M90	Design Mix	90 MPa	13050 psi
M100	Design Mix	100 MPa	14500 psi
M150	Design Mix	150 MPa	21750 psi
M200	Design Mix	200 MPa	29000 psi

M10 = 10N/mm^2 compressive strength after 28 days.

M15 = 15N/mm^2 compressive strength after 28 days.

M20 = 20N/mm^2 compressive strength after 28 days.

1. NOMINAL MIX

Mixes of fixed proportions, IS: 456-2000 permits nominal mixes for concretes of strength M20 or lower

Advantages of Nominal mix

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

2. DESIGN MIX

Designed on the basis of requirements of the concrete in fresh and hardened states. Design mix is permitted by IS 10262-1982 and IS 456:2000 for concrete of strength greater than M25 is design mix.

Advantages of Design mix

a. Properties of all materials are used.

b. Cement content is low and hence the mix design is economical.

TRIAL MIXES

Prepared to verify whether the Design Mix would perform as per the assumptions. If appreciable variation exists, the available alternatives are:

1. Directly employ the trial mix proportions at the site

2. Modify the trial mix proportions on the basis of intuition and employ the revised proportions at the site

3. Prepare further trial mixes incorporating changes in the proportions based on the feedback generated from the previous mix.

3.6 REQUIREMENTS OF CONCRETE MIX DESIGN AS PER BIS

- **Grade designation**: It gives characteristic compressive strength of concrete. The target mean strength of concrete is fixed by adding a suitable margin to the characteristic strength depending upon the quality control to be envisaged.

- **Type of cement**: The type and grade of cement mainly influences the rate of development of compressive strength of concrete.

- **Maximum nominal size of aggregate**: The maximum nominal size of the aggregate to be used in concrete is governed by the size of the section to be concreted and spacing of the reinforcement.

- **Maximum water-cement ratio**: The maximum water cement ratio to be used for a particular work is governed by the desired strength and limited by the durability requirements.

- **Minimum cement content**: The minimum cement content to be used is governed by the respective environmental exposure conditions.

- **Workability**: The desired workability for a particular job depends upon the shape and size of section to be concreted, denseness of reinforcement, and method of transportation, placing and compaction of concrete.

- **Exposure conditions**: The anticipated environmental exposure conditions in which the structure is intended to serve during its service span defines the durability requirements.

- **Type and properties of aggregate**: It influences the workability and strength of concrete. The relative proportions of coarse and fine aggregate are determined from the characteristics of the aggregates such as grading, shape, size and surface texture.

- **Method of transporting and placing**: It influences workability of the mix.

- **Use of admixtures**: Admixtures are used to enhance and modify one or more properties of concrete in fresh as well as hardened state.

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

3.7 BIS METHOD OF MIX DESIGN

- The BIS recommended mix design procedure is covered in IS 10262-82.
- In line with IS 456-2000, the first revision IS 10262-2009 was published, to accommodate some of the following changes:
- Increase in strength of cement
- Express workability in terms of slump, rather than the compacting factor
- Extend the W/C ratio v/s compressive strength graph

Based on IS 10262:1982

Procedure:

1. Target mean strength for mix design:

$$f_{ck}^* = f_{ck} + tS$$

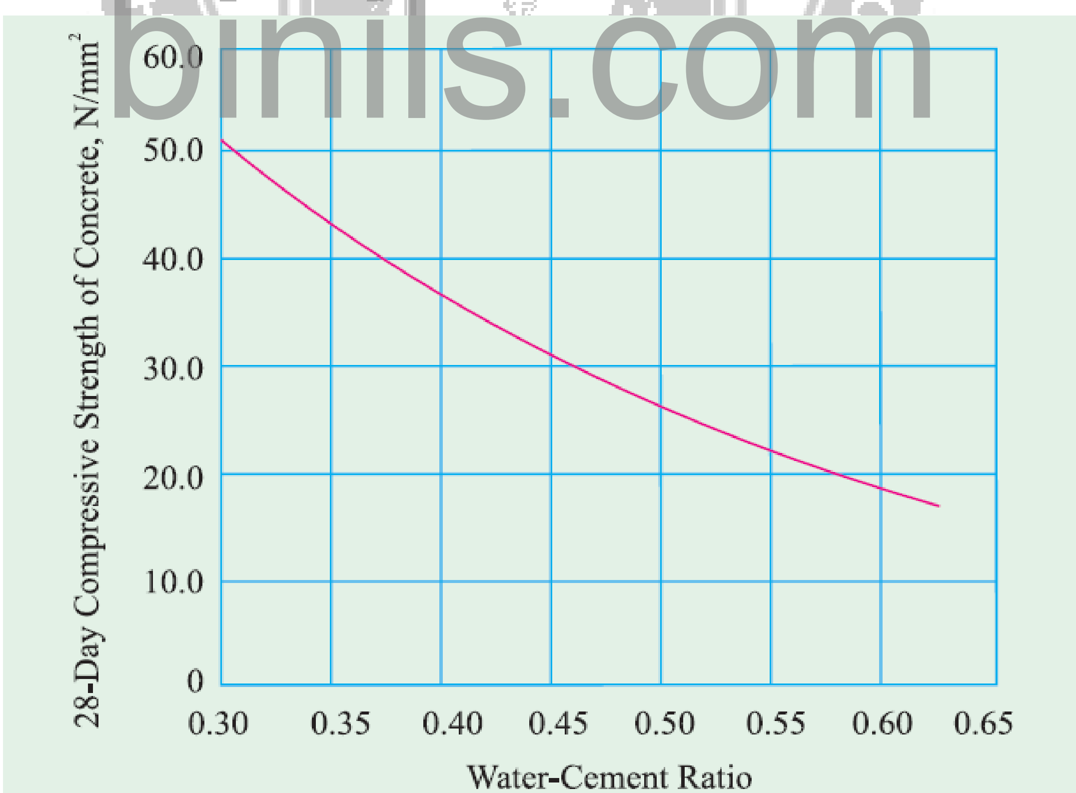
Where f_{ck} = characteristic compressive strength at 28 days S= standard deviation
t = a statistical value depending on the risk factor.

Note: The above values correspond to the site control having proper storage of cement, weigh batching of all materials, controlled addition of water; regular checking of all materials, aggregate gradings and moisture content; and periodical checking of workability and strength. Where there is deviation from the above, the values given in the above table shall be increased by 1 N/mm^2

Table 11.21. Values of Tolerance Factor (t) (Risk Factor)

Tolerance level. No of Samples	1 in 10	1 in 15	1 in 20	1 in 40	1 in 100
10	1.37	1.65	1.81	2.23	2.76
20	1.32	1.58	1.72	2.09	2.53
30	1.31	1.54	1.70	2.04	2.46
Infinite	1.28	1.50	1.64	1.96	2.33

2. Selection of Water / Cement ratio



3. Estimation of Entrapped Air

Table 11.23. 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

4. Selection of Water Content and Fine to Total Aggregate ratio

Table 11.24. Approximate Sand and Water Contents Per Cubic Metre of Concrete W/C = 0.60, Workability = 0.80 C.F. (Slump 30 mm approximately) (Applicable for concrete upto grade M 35)

Maximum Size of Aggregate (mm)	Water Content including Surface Water, Per Cubic Metre of Concrete (kg)	Sand as per cent of Total Aggregate by Absolute volume
10	200	40
20	186	35
40	165	30

Table 11.25. Approximate Sand and Water Contents Per Cubic Metre of Concrete W/C = 0.35, Workability = 0.80 C.F. (Applicable for above grade M 35)

Maximum Size of Aggregate	Water Content including Surface Water Per Cubic Metre of Concrete (kg)	Sand as per cent of Total Aggregate by Absolute Volume
10	200	28
20	180	25

Table 11.26. Adjustment of Values in Water Content and Sand Percentage for Other Conditions

Change in Conditions Stipulated for Tables	Adjustment Required in Water Content	Adjustment Required in % Sand in Total Aggregate
For sand conforming to grading Zone I, Zone III or Zone IV of Table 4, IS: 383–1979	0	+ 1.5% for Zone I – 1.5 % for Zone III – 3% for Zone IV
Increase or decrease in the value of compacting factor by 0.1	± 3%	0
Each 0.05 increase or decrease in water-cement ratio	0	± 1%
For rounded aggregate	– 15 kg	– 7%

5. Calculation of Cement Content:

Cement by mass = Water content/Water cement ratio

To be checked against the minimum cement content for the requirement of durability and the greater of the two values to be adopted.

6. Calculation of aggregate content:

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

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

7. Actual quantities required for mix

Adjust the mix for deviations from assumed conditions

8. Check the calculated mix proportions

3.8 MIX DESIGN EXAMPLES

Example: 1

Grade M20

(a) Design stipulations

(i) Characteristic compressive strength required in the field at 28days - 20MPa

(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%

Design Procedure

1. Target mean strength of concrete

$$f_{ck}^* = f_{ck} + kS$$

f_{ck}=20, k=1.64 ,S=4

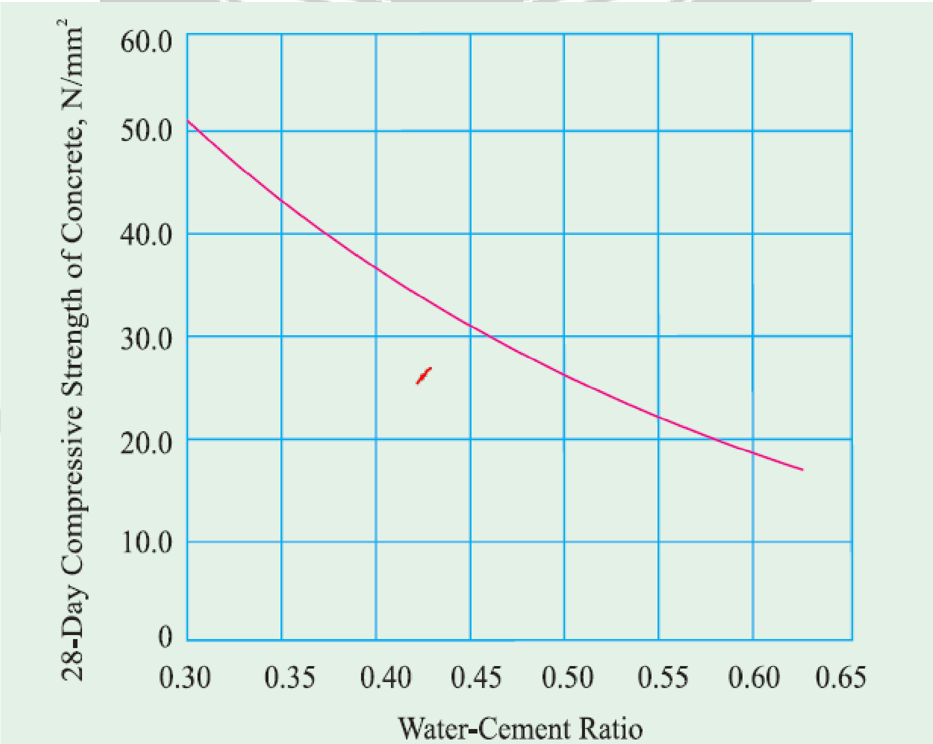
f_{ck}*=26.6MPa

*f_{ck}** = *Target mean strength*
f_{ck} = *Characteristic strength*
k = *Tolerance factor*
S = *Standard deviation*

Table 11.22. Assumed standard Deviation as per IS 456 of 2000

Grade of Concrete	Assumed standard Deviation N/mm^2
M 10	
M 15	3.5
M 20	
M 25	4.00
M 30	
M 35	
M 40	5.00
M 45	
M 50	

2. Selection of Water / Cement Ratio



Durability Criteria: Mild Exposure Conditions

Table 9.18. Minimum Cement Content, Maximum W/C Ratio and Minimum Grade of Concrete for Different Exposures with Normal Weight Aggregates of 20 mm Nominal Maximum size. IS 456 : 2000

Sl. No.	Exposure	Plain Concrete			Reinforced Concrete		
		Minimum cement contents kg/m³	Maximum Free W/C ratio	Minimum Grade of concrete	Minimum Cement Content kg/m³	Maximum Free W/C ratio	Minimum Grade of Concrete
1.	Mild	220	0.60	–	300	0.55	M 20
2.	Moderate	240	0.60	M 15	300	0.50	M 25
3.	Severe	250	0.50	M 20	320	0.45	M 30
4.	Very Severe	260	0.45	M 20	340	0.45	M 35
5.	Extreme	280	0.40	M 25	360	0.40	M 40

Notes: (1) Cement content prescribed in this table is irrespective of the grade of cement and it is inclusive of all supplementary cementitious materials. The additions of all supplementary cementitious materials may be taken into account in the concrete composition with respect to the cement content and W/C ratio if the suitability is established and as long as the maximum amounts taken into account do not exceed the limit prescribed in relevant codes.

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

W/C ratio from strength considerations =0.50

W/C ratio from durability considerations = 0.55

Adopt the lower value

3. Selection of water and sand content

Table 11.24. Approximate Sand and Water Contents Per Cubic Metre of Concrete W/C = 0.60, Workability = 0.80 C.F. (Slump 30 mm approximately) (Applicable for concrete upto grade M 35)

Maximum Size of Aggregate (mm)	Water Content including Surface Water, Per Cubic Metre of Concrete (kg)	Sand as per cent of Total Aggregate by Absolute volume
10	200	40
20	186	35
40	165	30

Adjustments in Water and Sand Contents

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

4. Determination of cement content

Water-cement ratio=0.50 water=191.6 kg/m^3

Cement =191.6/0.50 =383kg/m^3

Is this satisfactory for 'mild' exposure condition?

5. Determination of coarse and fine aggregate contents

Specified max. Size of aggregate = 20mm
Corresponding entrapped air =2%

f_a=546kg/m^3 ,

C_a=1188kg/m^3

Final Mix Proportions

Water	Cement	FA	CA
191.6	383	546	1188
0.50	1	1.425	3.10

Example: 2

Mix Design for Grade M30

Step 01: Data to be collected

- Grade Designation = M 30
- Type of cement = O.P.C- 43 grade
- Fine Aggregate = Zone-II
- Sp. Gravity Cement = 3.15
- Fine Aggregate = 2.61
- Coarse Aggregate (20mm) = 2.65
- Coarse Aggregate (10mm) = 2.66

Step 02: Target Mean Strength

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 Target mean strength for mix design

Table 11.22. Assumed standard Deviation as per IS 456 of 2000

Grade of Concrete	Assumed standard Deviation N/mm^2
M 10	
M 15	3.5
M 20	
M 25	4.00
M 30	
M 35	
M 40	5.00
M 45	
M 50	

$f_{ck}^{*}=f_{ck}+kS$

$f_{ck}=30+1.65 \, x \, 5.0$

$f_{ck}=38.25 \, MPa$

$f_{ck}*$ = *Target mean strength*
f_{ck} = *Characteristic strength*
k = *Tolerance factor*
S = *Standard deviation*

Step 03: Water/cement ratio

Selection of Water / Content Ratio consider from the specified table (Table-5) of IS: 456 for desired exposure condition as preliminary w/c ratio that has to be further checked for limiting value ensuring durability.

Sl. No.	Exposure	Plain Concrete			Reinforced Concrete		
		Minimum cement contents kg/m^3	Maximum Free W/C ratio	Minimum Grade of concrete	Minimum Cement Content kg/m^3	Maximum Free W/C ratio	Minimum Grade of Concrete
1.	Mild	220	0.60	–	300	0.55	M 20
2.	Moderate	240	0.60	M 15	300	0.50	M 25
3.	Severe	250	0.50	M 20	320	0.45	M 30
4.	Very Severe	260	0.45	M 20	340	0.45	M 35
5.	Extreme	280	0.40	M 25	360	0.40	M 40

Step 04: Calculation of Water Content

IS: 10262-2009 allows use of water reducers/ super plasticizers and also specifies the alteration in water content accordingly.

Further water adjustment was specified in terms of variation of compaction factor in the older version whereas the same has been remoulded in terms of slump variation (+3% for every 25mm slump over 50mm) in the revised one.

Table No. 2 Maximum Water Content per Cubic Meter of Concrete for Nominal Maximum Size of Aggregate		
Sr. No.	Nominal Maximum Size of Aggregate	Maximum Water Content kg/m^3
1	10	208
2	**20**	**189**
3	40	165

Step 05: Cement Content

From Table 5, of IS: 456 for desired exposure condition as preliminary w/c ratio 0.40 ,the mixing water content is 189 kg/m3 of concrete.

$CementContent$=1890.40

$CementContent$=475.0 $kgm3$

Which is more than 360 kg (As per Table No. 5, IS: 456) Hence o.k.

Step 06: Weight of Coarse Aggregate

□5. Calculation of Coarse Aggregate Proportion: For the desired workability, the quantity of mixing water per unit volume of concrete and the ratio of coarse aggregate to total aggregate by absolute volume are to be estimated from Table 3

Table No. 3 Volume of Coarse Aggregate per Unit Volume of Total Aggregate for Different Zones of Fine Aggregate					
Sr. No.	Nominal Size of Aggregate	Zone IV	Zone III	Zone II	Zone I
1	10	0.50	0.48	0.46	0.44
2	**20**	**0.66**	**0.64**	**0.62**	**0.60**
3	40	0.75	0.73	0.71	0.69

Step 06: Weight of Coarse Aggregate

□Find Aggregate (Sand) belongs to Zone II and maximum size of aggregate is 20 mm, the ratio of coarse aggregate to total aggregate by absolute volume are 0.62

□As per Table No. 3, IS-10262, for 20mm maximum size entrapped air is 2%

V = [W+C/Sc+1/P×Ca/Sca] ×1/1000

(1−0.02) = [189+475.0/3.15+1/0.62×Ca/2.65×1/1000

Ca=1052.0$kg/m3$

Step 07: Weight of Fine Aggregate

□Similarly Weight of Fine Aggregate is calculated as

V = [W+C/Sc+1/1−P×fa/Sfa×1/1000

(1−0.02) = [189+475.0/3.15+1/0.38×Ca2.61×1/1000

fa=634.0kgm^3

Step 08: Combination of Different Coarse Aggregate Fractions

□The coarse aggregate used shall conform to IS 383 – 1970. Coarse aggregate of different sizes may be combined in suitable proportions so as result in an overall grading conforming to Table 2 of IS 383 – 1970 for nominal maximum size of aggregate

Table 3.14. Grading Limits for Coarse Aggregate IS: 383-1970

IS Sieve Designation	Percentage passing for single-sized aggregate nominal size (by weight)						Percentage passing for Graded aggregate of nominal size (by weight)			
	63 mm	40 mm	20 mm	16 mm	12.5 mm	10 mm	40 mm	20 mm	16 mm	12.5 mm
80 mm	100	–	–	–	–	–	100	–	–	–
63 mm	85–100	100	–	–	–	–	–	–	–	–
40 mm	0–30	85–100	100	–	–	–	95–100	100	–	–
20 mm	0–5	0–20	85–100	100	–	–	30–70	95–100	100	100
16 mm	–	–	–	85–100	100	–	–	–	90–100	–
12.5 mm	–	–	–	–	85–100	100	–	–	–	90–100
10 mm	–	0–5	0–20	0–30	0–45	85–100	10–35	25–55	30–70	40–85
4.75 mm	–	–	0–5	0–5	0–10	0–20	0–5	0–10	0–10	0–10
2.36 mm	–	–	–	–	–	0–5	–	–	–	–

Step 09: Proportions

Ingredients	Cement	Fine Aggregate	Coarse Aggregate	Water	Chemical
Quantity $kgm3$	475.0	634.0	1052.0	189.0	NM
Ratio	1.00	1.33	2.21	0.40	NM
1 Bag Cement	50.0	66.5	110.5	20.0	NM

Step 10: Adjustment for Field Condition

□The proportions are required to be adjusted for the field conditions. Fine Aggregate has surface moisture of 2 %

Weight of F. A. = 634.0 + 2/100 634.0
= 643.7 kg/m3

Course Aggregate absorbs 1% water

Weight of C. A. = 1052.0 – 1/100 1052.0
= 1041.5 kg/m3

Step 10: Final Design Proportions

Ingredients	Cement	Fine Aggregate	Coarse Aggregate	Water	Chemical
Quantity $kgm3$	475.0	643.7	1041.5	189.0	NM
Ratio	**1.00**	**1.36**	**2.19**	**0.40**	NM
1 Bag Cement	50.0	68.0	109.5	20.0	NM