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Concrete Mix Design as Per IS Method of Mix Design

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Abstract: ***Concrete mix design may be defines as the art of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength & durability as economically as possible. Considering objectives of mix design desired workability in the plastic stage, desired minimum strength in the hardened stage, desired durability in the given environment conditions & basic considerations like cost, specification, workability is to be studied while designing mix design. Grade of concrete & its Characteristics compressive strength of 150 mm cube at 28 days, N/mm2 is very important criteria to be considered. Factors affecting choice of mix design is being studied for better mix design.***

Keywords: Grade of Concrete, Cost, Specification, Workability, Compressive Strengh,W/C Ratio, Target average compressive strength, ISMethod of Mix Design.

1. Introduction

The concrete mix produced under quality control keeping in view the strength, durability, and workability is called the design Mix.Others factors like compaction equipment's available, curing method adopted, type of cement, quality of fine and coarse aggregate etc. have to be kept in mind before arriving at the mix proportion.The design mix or controlled mix is being used more and more in variety of important structures, because of better strength, reduced variability, leaner mixed with consequent economy, as well as greater assurance of the resultant quality.

2. Objectives of Mix Design

The purpose of concrete mix design is to ensure the most optimum proportions of the constituent materials to fulfill the requirement of the structure being built. Mix design should ensure following objectives.

1) To achieve the designed/ desired workability in the plastic stage.
2) To achieve the desired minimum strength in the hardened stage.
3) To achieve the desired durability in the given environment conditions.
4) To produce concrete as economically as possible.

3. Basic Considerations

a) 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.

b) 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

c) Workability:-The following points related to workability shall be kept in mind while designing concrete mixes.
- The consistency of concrete should no more than that necessary for placing, compacting and finishing.
- For concrete mixes required high consistency at the time of placing, the use of water-reducing and set-retarding admixtures should be used rather than the addition of more water
- Wherever possible, the cohesiveness and finishibility of concrete should be improved by increasing sand/ aggregate ratio than by increasing the proportion of the fine particles in the sand.

d) Strength and durability:-Strength and durability require lower w/c ratio. It is usually achieved not by increasing the cement content, but by lowering the water at given cement content. Water demand can by lowered by throughout control of the aggregate grading and by using water reducing admixtures.

Group	Grade designation	Characteristics compressive strength of 150 mm cube at 28 days, N/mm2
Ordinary Concrete	M10	10
	M15	15
	M20	20
Standard Concrete	M25	25
	M30	30
	M35	35
	M40	40
	M45	45
	M50	50
	M55	55
High Strength Concrete	M60	60
	M65	65
	M70	70
	M75	75
	M80	80

e) Factors influencing Choice of Mix Design
According to IS 456:2000 and IS 1343:1980 the important influencing the design of concrete mix are as per following:-

- Grade of Concrete
- Type of Cement
- Maximum nominal Size of Aggregate
- Grading of Combined aggregate
- Maximum Water/ Cement Ratio
- Workability
- Durability
- Quality Control.

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.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.The maximum size of C.A is 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.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.

Characteristic Compressive Strength & Group as per IS-456-2000

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	1:1.5:3	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

4. IS Method of Mix Design

The Bureau of Indian Standards, recommended a set of procedure for design of concrete mix. The procedure is based on the research work carried out at national laboratories. Data for Mix Design is as per following:-

1) Characteristic Compressive strength only a few specified proportions of test results are expected to fall of concrete at 28 days (fck)
2) Degree of workability desired
3) Limitation on water/Cement Ratio with the minimum cement to ensure adequate durability
4) Type and maximum size of aggregate to be used
5) Standard deviations of compressive strength of concrete

5. Steps of IS Method of Mix Design

Step 1: Target Strength for Mix Design
The target average compressive strength (fck) of concrete at 28 days is given by
$F_{ck}= f_{ck} + t.s$
Where,

- F_{ck}= target average compressive strength at 28 days
- F_{ck}= characteristics compressive strength at 28 days
- s= Standard deviation
- t= a stastical value, depending upon the accepted proportion of low results and the number of tests.

According to Is 456: 2000 and IS 1343:1980 te characteristic strength is defined as the value below which not more than 5 percent of results are expected to fall. In such cases the above equation reduced to
$F_{ck}= f_{ck} + 1.65\ s$

The value of standard deviation is obtained from the table

TABLE 1 SUGGESTED VALUES OF STANDARD DEVIATION

Grade of Concrete	Standard Deviation for Different Degree of Control in N/mm 2		
	Very Good	Good	Fair
(1)	(2)	(3)	(4)
M 10	2·0	2·3	3·3
M 15	2·5	3·5	4·5
M 20	3·6	4·6	5·6
M 25	4·3	5·3	6·3
M 30	5·0	6·0	7·0
M 35	5·3	6·3	7·3
M 40	5·6	6·6	7·6
M 45	6·0	7·0	8·0
M 50	6·4	7·4	8·4
M 55	6·7	7·7	8·7
M 60	6·8	7·8	8·8

NOTE — Appendix A provides guidance regarding the different degrees of quality control to be expected, depending upon the infrastructure and practices adopted at the construction site.

Step 2: Selection of Water –Cement Ratio

Since different cements and aggregates of different maximum sizes, grading, surface texture shape and other characteristics may produce concrete of different compressive strength for the same free water cement ratio, the relationship between strength and free water cement ratio should preferable be established for the material actually to be used. In the absence of such data, the preliminary free water-cement ratio corresponding to the target strength at 28 days may be selected from the relationship shown below.

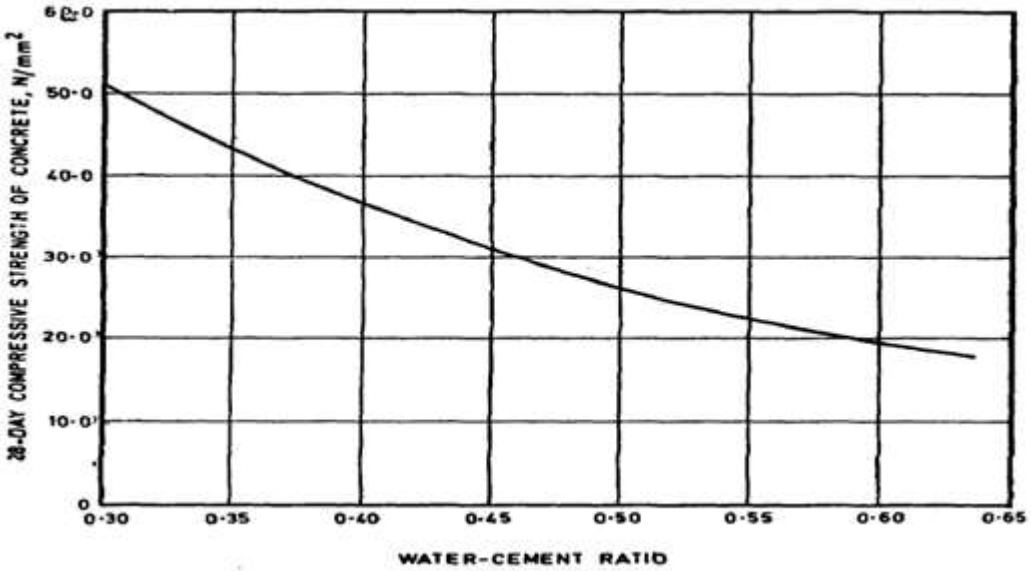
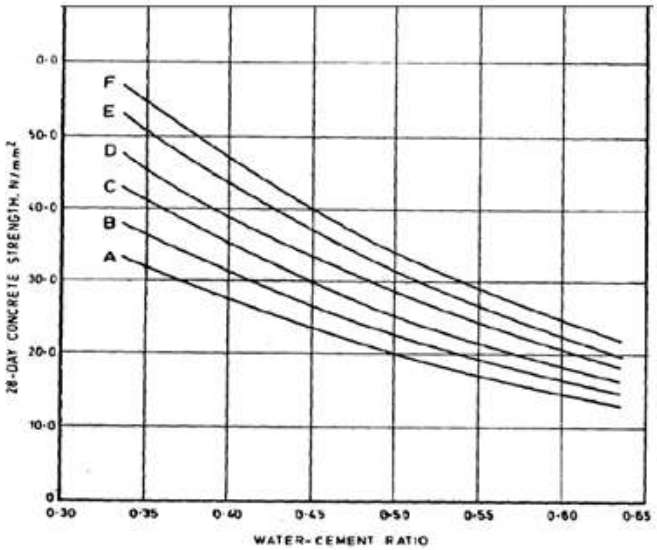


Figure 1: Relationship between W/C ratio & compressive strength of concrete

Alternatively, the preliminary free water cement ratio by mass corresponding to the average strength may be selected from the relationship shown below using the curve corresponding to the 28 days cement strength to be used for the purpose. However, this will need 28 days for testing of cement.

As Per IS: 4031-1968 (Methods of physical analysis of hydraulic cements)



28 Day Strength of Cement, Tested according to IS 4031-1968.
A=31.9 to 36.8 N/mm^2 (325-375 kg/cm^2), B=36.8 to 41.7 N/mm^2 (375-425 kg/cm^2)
C=41.7 to 46.6 N/mm^2 (425-475 kg/cm^2), D=46.6 to 51.5 N/mm^2 (475-525 kg/cm^2)
E=51.5 to 56.4 N/mm^2 (525-575 kg/cm^2), F=56.4 to 61.3 N/mm^2 (575-625 kg/cm^2)

The free water-cement ratio thus selected should be checked against limiting water-cement ratio for the requirements of durability as per table 2 and the lower of the two values should be adopted.

Table 2
Durability Criteria as per IS 456- 2000

Exposure	Plain Concrete			Reinforced Concrete		
	Min. Cement	Max w/c	Min grade	Min. Cement	Max w/c	Min grade
Mild	220 kg/m^3	0.60	--	300 kg/m^3	0.55	M 20
Moderate	240 kg/m^3	0.60	M 15	300 kg/m^3	0.50	M 25
Severe	250 kg/m^3	0.50	M 20	320 kg/m^3	0.45	M 30
V. Severe	260 kg/m^3	0.45	M 20	340 kg/m^3	0.45	M 35
Extreme	280 kg/m^3	0.40	M 25	360 kg/m^3	0.40	M 40

Step 3: Estimation of Air Content

Amount of Entrapped Air Content is taken from following table.

Table 3

Nominal Maximum Size of Aggregates	Entrapped Air, as percentage of volume of concrete
10	3%
20	2%
40	1%

Step 4: Selection of Water Content and fine to total aggregate ratio

For the desired workability the quantity of mixing water per unit volume of concrete and the ratio of fine aggregate (sand) to total aggregate by absolute volume are to be estimated from table below as applicable. Depending upon the nominal maximum size and type of aggregate.

Approximate Sand and water Content per Cubic Metre of Concrete for Grades up to M_{35} W/C = 0.6 Workability= 0.8 C.F

Table 4

Nominal Maximum size of aggregate (mm)	Water Content per cubic metre of concrete (kg)	Sand as percentage of total aggregate by absolute volume
10	208	40
20	186	35
40	165	30

Approximate Sand and Water Content per cubic metre of concrete for grades above M_{35} W/C = 0.35 Workability= 0.8 C.F.

Table 5

Nominal Maximum size of aggregate (mm)	Water Content per cubic metre of concrete (kg)	Sand as percentage of total aggregate by absolute volume
10	200	28
20	180	25

Adjustment of values in water content and sand percentage for other conditions

Table 6

Change in Condition	Adjustment Required	
	Water Content	Percentage sand in total aggregate
For sand confirming to grading Zones I , III and IV	0	+ 1.5 percent for zone I -1.5 percent for zone III -3.0 for zone IV
Increase or decrease in values of compacting factor by 0.1	± 3 %	0
Each 0.05 increase or decrease in free water cement ratio	0	± 1 %
For rounded aggregates	-15kg/m^3	-7 %

Step 5: Calculation of Cement Content
The cement content per unit volume of concrete may be calculated from the free water-cement ratio obtained in step-2, and the quantity of water per unit volume of concrete obtained in step-4.The cement content so obtained should be checked against the minimum cement content for the requirement of durability as per table 2 IS 456:2000 and the greater of the two value is adopted.

Sept 6: Calculation of Aggregate Content
With the quantities of water and cement per unit volume of concrete and the ratio of fine to total aggregate already determined, the total aggregate content per unit volume of concrete may be calculated from the following equations
V=[W+C/Sc+1/p Xfa/Sfa]X1/1000……for Fine Aggregate
V=[E+c/Sc+1/(1-p)XCa/Sca]X1/1000……for Coarse Aggregate

Where,
V= Absolute volume of fresh concrete (m^3)
W= Mass of Water (kg) per m^3 of concrete
C= Mass of Cement (Kg) per m^3 of concrete
Sc= Specific gravity of cement say 3.15
P= ratio of fine aggregate to total aggregate by absolute volume
Fa and Ca = Total masses of fine aggregate and coarse aggregate (kg) / m^3 of concrete mass respectively
Sfa, Sca= Specific gravities of saturated surface dry fine aggregate and coarse aggregate respectively
Normally Sfa= 2.6 and Sca= 2.7

6. Conclusion

Above Method of Mix Design by IS Method of Mix Design is very useful for engineer who is working with Laboratory Testing works. Above stepwise method is very simple to understand & also fruitful to Students who is doing that Degree/ Diploma in civil engineering. Concrete mix design is economically proportioning of concrete ingredients for better strength and durability based on construction site. While the nominalconcrete mix may have higher amount of cement, when it is designed mix, thecement requirement may be low for the same grade of concrete for a given site.By use of IS method of Concrete mix design Good quality concrete as per requirements,best use of Available materials & desired concrete properties. By use of Concrete mix Design by IS method of Mix Design, You will get High workability for longer periods, Lower pumping pressure, Resistance to segregation even at high workability, Extended setting with longer workability, Reduced water content for a given workability, Higher ultimate strength, Reduced permeability and improved durability, Reduced shrinkage and creep, Better resistance to aggressive atmospheric conditions, Increased ease in finishing concrete.

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