CONCRETE MIX PROPORTIONING AS PER IS 10262-2009

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Abstract

IS 10262-2009 "Concrete Mix Proportioning- Guidelines"brought out by Bureau of Indian Standards had brought relief to many stake holders of Construction Industry specially related to concrete making. Fourth revision of IS 456 in the year 2000 was a milestone in the Code of practice for "Plain and Reinforced Concrete". There was a need to bring IS 10262 in line with IS 456 with reference to concrete making materials, minimum cement content, maximum water-cement ratio and minimum grade of concrete for various exposure conditions from durability point of view. The applicability of the Standard has been specified for ordinary and standard concrete grades (as defined in IS 456-2000)only. Modified water content and coarse aggregate content are in line with present practices of proportioning concrete mixes worldwide. This paper makes an attempt to look into major modifications in the first revision of the Standard and example of concrete mix proportioning is presented following the guidelines of the Standard.

Introduction:

Concrete Mix Proportioning is more challenging now than before. This is due to availability of a variety of mineral admixtures which can replacepartially Ordinary Portland Cement and High Range Water Reducing Admixtures which are responsible changing the rheology of concrete to suit any challenging application. In the changing scenario manufactured sand is replacing natural river sand in urban areas.

Concrete mix proportions chosen should be such that the concrete is of adequate workability for the placing conditions at site and can properly be compacted with the means available. In hardened state concrete shall have required strength, durability and surface finish.

Concrete Mix Proportioning:

Design mix concrete is preferred to nominal mix. As per IS 456-2000[1]-Code of Practice for Plain and Reinforced Concrete, as a guarantor of quality of concrete used in construction, the constructor shall carry out the mix design and the mix so designed (not the method of design) shall be approved by the employer. From the above statement, it is clear that concrete technologist can adopt any method of mix design following stipulations laid down in IS 456-2000 with respect to minimum cement content, maximum water to cement ratio and minimum grade of concrete for various exposure conditions and guidelines given in IS 10262-2009[2] "Concrete Mix Proportioning- Guidelines" (First Revision)

Major modifications in the first revision of IS 10262-2009, have been summarized as follows:

After the revision of IS 456 in the year 2000, there was a need to revise IS 10262-1982 in the light of the experience gained and this revision incorporates changes to bring it in line with IS 456-2000. As there is no real design involved in proportioning of concrete mixes, the title of the standard has been modified as 'Concrete mix proportioning – Guidelines' from the earlier title `Recommended guidelines for concrete mix design'. It may be noted that mix proportioning procedure laid in this standard is applicable for ordinary concretes such as M10, M15 and M 20 grades of concrete and standard grades of concretes from M 25 to M55. Concrete grades M60 and above falls under the category of high strength concretes which can be proportioned referring to specialist literature.

The graph of water-cement ratio versus 28-day compressive strength does not find a place in the revised version of the standard. The relationship between water-cement ratio and compressive strength of concrete needs to be established for the materials actually to be used or any established relationship, if available, shall be used. Maximum water-cement to ratio given in IS 456-2000 for various environmental exposure conditions may be used as a starting point.

Water content per cubic metre of concrete in the earlier version of the standard was a constant value for various nominal maximum size of aggregates. However, in the revised version, maximum water content per cubic metre of concrete is suggested. Another major inclusion in the revised standard is estimation of volume of coarse aggregate per unit volume of total aggregate for different zones of fine aggregate.

Assumption of air content which depends on the nominal maximum size of aggregate does not find a place in the revised version of the standard as it is not a part of IS 456-2000.

Definition:

Concrete mix design is the process of proportioning various ingredients such as cement,cementitious materials, aggregate, water and admixtures, if used, in the most optimal manner so as to produce a concrete at minimal cost having specified properties of workability and homogeneity in the green state and strength and durability in the hardened state.

Principal Factors to be considered in Concrete Mix Design

1) Workability for transporting and placing of concrete in position (pumping or any other method) and its compaction with the given compacting equipment. Workability is specified in terms of slump.
2) Characteristic strength of concrete
3) Type of cement and its strength at 28 days
4) Minimum grade of concrete, minimum cement content and maximum w/c ratio from considerations of durability of concrete for the given exposure condition.
5) Aggregate grading, shape, size and surface texture.

All ingredients are proportioned by weight per unit volume of concrete.

Objectives of Concrete Mix Design

Objective of Concrete Mix Design is to make a concrete that:

- satisfies workability requirements in terms of slump for the placing conditions
- meets the strength requirements as measured by compressive strength
- fulfils durability requirements to resist the environment in which the structure is expected to serve

- can be mixed, transported, placed and compacted as efficiently as possible
- has a satisfactory appearance where it is exposed to view
- will be as economical as possible

Process of Concrete Mix Design

The process of Concrete Mix Design essentially consists of 3 stages.

i. Correct mix proportions are arrived at based on guidelines of mix proportioning methods, past experience or published data, and information obtained on the properties of the constituent materials that are actually used in making the concrete.
ii. Small-scale trial mixes, usually in a laboratory are made and tested using the materials that will be used on site.
iii. Full-scale site trials before construction begins.

It is always advisable to design the trial mixes with those materials that will be used on the job itself so that the adjustments can be easily understood and implemented in the field.

MIX PROPORTION CALCULATIONS AS PER IS 10262-2009

IS 456:2000 has recommended that minimum grade of concrete shall not be less than M20 in reinforced concrete work. Design mix concrete is preferred to nominal mix. If design mix concrete cannot be used for any reason on the work for grades M20 or lower, nominal mixes may be used with permission of engineer-in-charge, which, however is likely to involve higher cement content. Accordingly all concrete above M20 grade for RCC work must be of design mixes.

DATA FOR MIX PROPORTIONING:

The following basic data are required for mix proportioning of a particular grade of concrete:

a) Exposure condition of the structure under consideration (for guidance see Table 3 of IS 456-2000)
b) Grade Designation:Minimum grade of concrete to be designed for the type of exposure condition of the structure under consideration (for guidance see Tables 3 and 5 of IS 456-2000). This has been reproduced in Appendix
c) Type of cement, viz., Ordinary Portland Cement (OPC), Portland Pozzolana Cement (PPC), Portland Slag Cement (PSC) etc.
d) Maximum nominal size of aggregate to be used, viz. 40 mm, 20 mm and 12.5 mm.
e) Minimum cement content (for guidance see Tables 3,4,5 and 6 of IS 456-2000)
f) Maximum water-cement ratio (for guidance see Tables 3 and 5 of IS 456-2000)
g) Degree of workability desired (for guidance see Clause 7 of IS 456-2000)
   (this has been reproduced in Appendix as Table 5)
h) Maximum temperature of concrete at the time of placing
i) Early age strength requirements, if required
j) Type of aggregate viz. Granite, Basalt, Natural River sand, Crushed Stone sand etc.
k) Maximum cement content.
l) Use of admixture, its type and condition of its use.

The step-by-step procedure of mix proportioning is as follows:

I. <u>Target Mean Compressive Strength for Mix Proportioning</u>:

$f'_{ck} = f_{ck} + 1.65 \times S$, where

f'_{ck} = Target mean compressive strength at 28 days,

f_{ck} = Characteristic compressive strength at 28 days,

S = Standard deviation N/mm^2

Standard deviation shall be calculated for each grade of concrete using at least 30 test strength of samples (taken from site) when a mix is used for the first time. In case sufficient test results are not available, the values of standard deviation given in Table 1 may be assumed for the proportioning of mixes in the first instance. As soon as the sufficient test results are available, actual standard deviation shall be calculated and used to proportion the mix properly.

TABLE 1 Assumed Standard Deviation

Sl. No.	Grade of Concrete	Assumed Standard Deviation N/mm^2
1	M 10	3.5
2	M 15	
3	M 20	4.0
4	M 25	
5	M 30	5.0
6	M 35	
7	M 40	
8	M 45	
9	M 50	
10	M 55	

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

II. Selection of Water–Cement Ratio:

Concrete made today contains more than four basic ingredients. Use of both chemical and mineral admixtures has changed properties of concrete both in fresh and hardened state for good. Even quality of both coarse and fine aggregates in terms of grading, shape, size and texture has improved with the improvement in crushing technologies. With all these variables playing its role, concretes produced with same water-cement ratio may have different compressive strength. For a given set of materials, it is preferable to establish relationship between compressive strength and free water-cement ratio. If such a relationship is not available, maximum water-cement ratio for various environmental exposure conditions given in Table 5 of IS 456-2000 may be taken as a starting point. Any water-cement ratio assumed based on the previous experience for a particular grade of concrete should be checked against the maximum values permitted from the point of view of durability and lower of the two shall be adopted.

III Selection of Water Content:

The quantity water considered per cubic metre of concrete decides the workability of the mix.. Use of water reducing chemical admixtures in the mix helps to achieve increased workability at lower water contents. Water content given in Table 2 of the standard is the maximum value for a particular maximum nominal size of aggregate(angular) which will achieve a slump in the range of 25 mm to 50 mm. Depending on the performance of an admixture (conforming IS 9103-1999[3]) which is proposed to be used in the mix, a minimum of 20% of water reduction shall be considered in case of superplasticisers. Use of Poly Carboxylic Ether (PCE) based superplasticisers results in water reduction up to 30%.

Water content per unit volume of concrete is required to be reduced when there is increase in aggregate size, use of rounded aggregates, reduction in water-cement ratio and slump.Water content per unit volume of concrete is required to be increased when there is increased temperature, cement content, fine aggregate content, water-cement ratio.

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

Sl. No.	Nominal Maximum Size of Aggregate mm	Maximum Water Content[1] kg
1.	10	208
2	20	186
3.	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

Reduction in water content can be made in following cases:

a) For sub angular aggregates, the water estimate can be reduced by 10 kg.

b) For gravel with crushed particles, the water content can be reduced 20 kg.

c) For rounded gravel, the water content can be reduced by 25 kg.

For higher workability (other than 25 mm to 50 mm) the required water content may be established by trial or an increase by about 3% for every additional 25 mm slump or alternatively by use of chemical admixtures conforming to IS 9103-1999.

Use of water reducing admixture: If use of chemical water reducing admixture is permitted for the job in hand in proportioning of the mix, reduction in assumed water content shall be made depending on the type of admixture. Water reducing admixtures will usually decrease water content by 5 to 10% and superplasticisers decrease water content by 20% and above at appropriate dosages.

IV Calculation of Cementitious content:

Water content calculated in step V is divided by the water-cement ratio selected in step II, to arrive at cement content or cementitious content (if mineral admixtures are used). The total cementitious content so calculated should be checked against the minimum content for the requirements of durability and the greater of the two values adopted. The maximum cement content alone (excluding mineral admixtures such as flyash and GGBS) shall not exceed 450 kg/cu.m as per clause no. 8.2.4.2 of IS 456-2000.

The total cementitious content so calculated should be checked against the minimum cement content for the requirements of durability for various exposure conditions and the greater of the two values adopted.

V Estimation of coarse aggregate proportion

Table 3 of the standard gives volume of coarse aggregate for unit volume of total aggregate for different zones of fine aggregate (as per IS 383-1970[4]) for a water-cement ratio of 0.5 which requires to be suitably adjusted for other water-cement ratios. This table is based on ACI 211.1-1991[5]"Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete". Aggregates of essentially the same nominal maximum size, type and grading will produce concrete of satisfactory workability when a given volume of coarse aggregate per unit volume of total aggregate is used. It can be seen that for equal workability, the volume of coarse aggregate in a unit volume of concrete is dependent on nominal maximum size, water-cement ratio and grading zone of fine aggregate.

Table 3 Volume of Coarse Aggregate per unit volume of Total Aggregate for different Zones of Fine Aggregate

Nominal Maximum Size of Aggregate mm	Volume of Coarse Aggregate[1] per Unit Volume of Total Aggregate for Different Zones of Fine Aggregate (For water-cement ratio=0.5)			
	Zone IV	Zone III	Zone II	Zone I
10	0.50	0.48	0.46	0.44
20	0.66	0.64	0.62	0.60
40	0.75	0.73	0.71	0.69

[1]Volumes are based on Aggregates in Saturated Surface Dry condition

Note: Volume coarse aggregate per unit volume of total aggregate needs to be changed at the rate of -/+ 0.01 for every ±0.05 change in water-cement ratio

VI Combination of different sizes of coarse aggregate fractions:

Coarse aggregates from stone crushers are normally available in two sizes viz., 20 mm (popularly called as ¾" size) and 12.5 mm (popularly called as ½" size). Coarse aggregates of different sizes can be suitably combined so as satisfy graded requirements (cumulative percent passing) as per Table 2 of IS 383-1970 for the particular maximum nominal size of aggregate.

VII Estimation of Fine Aggregate Proportion:

In the steps mentioned above, all the ingredients of concrete are estimated except the coarse and fine aggregate content. These quantities are determined by finding out the absolute volume of cementitious material, water and the chemical admixture; by dividing their mass by their respective specific gravity, multiplying by 1/1000 and subtracting the result of their summation by unit volume. The value so obtained is the volume of total aggregate. Volume of coarse aggregate for unit volume of total aggregate is already estimated in step V. The contents of coarse and fine aggregate per unit volume of concrete are determined by multiplying with their specific gravities and multiplying by 1000.

VIII Trial Mixes:

The calculated mix proportions shall be checked by means of trial batches as follows:

The calculated mix proportions shall be checked by means of trial batches. The concrete for trial mixes shall be produced by methods of actual production. Ribbon type mixer and pan mixer are required to be used to simulate the site conditions where automatic batching and pan mixers are used for the production of concrete.

Trial Mix No.1: Workability in terms of slump of the trial mix shall be carefullyobserved for freedom from segregation, bleeding and for finishing properties. If the measured slump of Trial mix No.1 is different from targeted value, Trial Mix No.2 shall be carried out as explained below

Trial Mix No.2 : The water and/or admixture content shall be adjusted suitably in the Trial Mix No.1. With this adjustment, the mix proportion shall be recalculatedkeeping the free water cement ratio at the pre-selected value. With this trial more or less the stipulated value of slump will be obtained.In addition two more Trial Mixes No.3 and 4 shall be made with water content same as Trial Mix No.2 and varying the free w/c ratio by ±10% of the preselected value.

After laboratory trials field trial shall be carried out.

ANNEXURE

Illustrative Example for Mix Proportioning of M 20 Grade of Concrete

An example illustrating the mix proportioning for a concrete of M 20 grade is given through

Steps 1 to 11.

1 STIPULATIONS FOR PROPORTIONING

a)	Grade of designation	:	M 20
b)	Type of cement	:	OPC 43 grade conforming to IS 8112-1989[6] (Reaff. 2005)
c)	Maximum nominal size of aggregate	:	20 mm
d)	Minimum cement content	:	300 kg/m^3
e)	Maximum water-cement ratio	:	0.55
f)	Workability in terms of Slump	:	100 mm
g)	Exposure condition	:	Mild (for reinforced concrete)
h)	Method of concrete placing	:	Pumping
i)	Degree of supervision	:	Good
j)	Type of aggregate	:	Crushed angular aggregate
k)	Maximum cement content	:	450 kg/m^3
l)	Chemical admixture type	:	Superplasticiser

2 TEST DATA OF MATERIALS

a)	Cement	:	OPC 43 grade conforming to IS 8112
b)	Specific gravity of cement	:	3.15
c)	Chemical admixture	:	Superplasticizer conforming to IS 9103-1999
d)	Specific gravity of admixture	:	1.145
e)	Specific gravity of:		
	1) Coarse aggregate	:	2.67
	2) Fine aggregate	:	2.60
f)	Water absorption (IS 2386-1963[7])		
	1) Coarse aggregate	:	0.5 percent
	2) Fine aggregate	:	2.0 percent
g)	Free (surface) moisture:		
	1) Coarse aggregate	:	Nil (absorbed moisture also nil)
	2) Fine aggregate	:	3%
h)	Sieve analysis (IS 2386 Part I [8])		
	1) Coarse aggregate	:	

COMBINED SIEVE ANALYSIS OF 20mm AND 12.5mm COARSE AGGREGATE				
Cumulative Sieve Size (mm)	**Cumulative % passing 20mm**	**Cumulative % passing 12.5mm**	**Cumulative % passing when 20mm and 12.5mm are mixed in 60:40 ratio**	**Requirements of Cumulative % passing for 20mm graded aggregates as per IS:383-2016**
40.0	100	100	100	100
20.0	92.6	100	95.6	95 – 100
12.5	7.8	99.0	44.3	--
10.0	0.4	77.6	31.3	25 – 55
4.75	0	2.6	1.0	0 – 10

2) Fine aggregate : Conforming to grading Zone I of Table 4 of IS 383-2016

3 TARGET STRENGTH FOR MIX PROPORTIONING

$$f'_{ck} = f_{ck} + 1.65\ s$$

where

f'_{ck} = target average compressive strength at 28 days

f_{ck} = characteristic compressive strength at 28 days, and

s = standard deviation

From Table 1, standard deviation, s = 4 N/mm^2

Therefore, target strength = 20 + 1.65 x 4 = 26.6 N/mm^2

4 SELECTION OF WATER – CEMENT RATIO

From Table 5 of IS 456, maximum water cement ratio = 0.55 for Mild exposure.

Let us adopt water – cement ratio as 0.55 only

5 SELECTION OF WATER CONTENT

From Table 2, maximum water content for 20 mm aggregate = 186 kg. (for 25 to 50 mm slump range)

Estimated water content for 100mm slump $= 186 + \frac{6}{100} \times 186$

$= 197$ kg

As superplasticizer is used, the water content can be reduced up to 20 percent and above

Based on trials with superplasticizer, water content reduction of 20 percent has been achieved. Hence, the arrived water content = 197 x 0.80 = 157.6 kg.

6 CALCULATION OF CEMENT CONTENT

Water-cement ratio = 0.55

Cement content = $\frac{157.6}{0.55}$

= 286.5 kg/m^3

From Table 5 of IS 456, minimum cement content for 'mild' exposure condition = 300 kg/m^3

286.5 kg/m^3 <300 kg/m^3, hence, adopt Minimum Cement content = 300 kg/m^3

For this cement content total water content (for SSD condition) becomes 165 kg/cu.m of concrete.

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.

In the present case water-cement ratio is 0.55. Therefore, volume of coarse aggregate is required to be decreased to increase the fine aggregate content. As the water-cement ratio is higher by 0.05, the proportion of volume of coarse aggregate is decreased by 0.01 (at the rate of -/+ 0.01 for every $\pm$ 0.05 change in water-cement ratio). Therefore, corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.55 = 0.59.

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

For pumpable concrete it is desirable to reduce these values up to 10 percent

Considering a reduction of 5% in the volume of coarse aggregate, we have

volume of coarse aggregate = 0.59 x 0.95 = 0.56

Volume of fine aggregate content = 1 – 0.56 = 0.44

8 MIX CALCULATIONS

a)Volume of concrete = $1\ m^3$

b)Volume of cement = $\frac{\text{Mass of cement}}{\text{Specific gravity of cement}} \times \frac{1}{1000}$

= $\frac{300}{3.15} \times \frac{1}{1000}$

= $\mathbf{0.0952\ m^3}$

c) Volume of water = $\frac{\text{Mass of water}}{\text{Specific gravity of water}} \times \frac{1}{1000}$

= $\frac{165}{1} \times \frac{1}{1000}$

= $\mathbf{0.165\ m^3}$

d) Volume of chemical admixture (superplasticizer)(@ 1.0percent by mass of cementitious material) = $\frac{\text{Mass of chemical admixture}}{\text{Sp. gravity of admixture}} \times \frac{1}{1000}$

= $\frac{3}{1.145} \times \frac{1}{1000}$

= $\mathbf{0.00262\ m^3}$

e) Volume of all in aggregate = [a-(b+c+d)]

= 1-(0.0952+0.165+0.00262)

= $\mathbf{0.737\ m^3}$

f) Mass of coarse aggregate = e x volume of coarse aggregate x Sp.Gr. of coarse aggregate x 1000

= 0.737 x 0.56 x 2.67 x 1000

= **1101.96 kg**

g) Mass of fine aggregate = e x volume of fine aggregate x Sp.Gr. of fine aggregate x 1000

= 0.737 x 0.44 x 2.6 x 1000

= **843.13 kg**

9 MIX PROPORTIONS FOR TRIAL NUMBER 1

Cement	=	300 kg/m^3
Water	=	165 kg/m^3
Fine aggregate	=	843 kg/m^3
Coarse aggregate	=	1102 kg/m^3
Chemical admixture	=	3 kg/m^3
Water Cement ratio	=	0.55

NOTE : Aggregates should be used in saturated surface dry condition. If otherwise, when computing the requirement of mixing water, allowance shall be made for the free (surface) moisture contributed by the fine and coarse aggregates. On the other hand, if the aggregates are dry, the amount of mixing water should be increased by an amount equal to the moisture likely to be absorbed by the aggregates. Necessary adjustments are also required to be made in mass of aggregates. The surface water and percent water absorption of aggregates shall be determined according to IS 2386[7].

Adjustments for moisture in aggregates and water absorption of aggregates:

Correction for aggregates:

Fine aggregate (for 3% surface moisture) = 843 x 1.03

= 868.3 kg (wet)

It may be noted that absorbed water does not become the part of the mixing water and must be excluded from the adjustment in added water.

Thus, the surface water contributed by fine aggregates = 3-2= 1 percent.

Corrected water content = 165 - 843 (0.01)

= 156.57 kg.

The estimated batch masses (after corrections) are as given below:

Cement	=	300	kg/m^3
Water	=	156.7	kg/m^3
Fine aggregate	=	868.3	kg/m^3
Coarse aggregate	=	1102	kg/m^3
Chemical admixture	=	3	kg/m^3

10 The slump shall be measured and the water content and dosage of admixture shall be adjusted for achieving the required slump based on trial, if required. The mix proportion shall be reworked for the actual water content and checked for durability requirements

11 Two more trials having variation of $\pm$ 10 percent of water-cement ratio in A-10 shall be carried out and a graph between three water-cement ratios and their corresponding strengths shall be plotted to work out the mix proportions for the given target strength for field trials. However, durability requirement shall be met.

Mix Proportioning for manual placing of Concrete for M 20 Grade without the use of Admixture (as is the practice in normal house constructions)

For manual placing concrete (non pumpable) workability in terms of slump required will be in the range of 25 mm to 50 mm.

Considering the same data as in illustrative example for pumpable methodof placing, mix proportioning steps from 1 to 4 remain same.

5 SELECTION OF WATER CONTENT

From Table 2, maximum water content for 20 mm aggregate = 186 litre (for 25 to 50 mm slump range)

6 CALCULATION OF CEMENT CONTENT

Water-cement ratio = 0.55

Cement content = $\frac{186}{0.55}$

= 338.18 kg/m^3

From Table 5 of IS 456, minimum cement content for 'mild' exposure condition = 300 kg/m^3

338 kg/m^3 >300 kg/m^3, hence O.K.

7 PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONENT

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.

In the present case water-cement ratio is 0.55. Therefore, volume of coarse aggregate is required to be decreased to increase the fine aggregate content. As the water-cement ratio is higher by 0.05, the proportion of volume of coarse aggregate is decreased by 0.01 (at the rate of -/+ 0.01 for every $\pm$ 0.05 change in water-cement ratio). Therefore, corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.55 = 0.59.

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.

Volume of fine aggregate content = 1 – 0.59 = 0.41

8 MIX CALCULATIONS

a)Volume of concrete	=	1 m^3
b)Volume of cement	=	$\frac{\text{Mass of cement}}{\text{Specific gravity of cement}} \times \frac{1}{1000}$
	=	$\frac{338}{3.15} \times \frac{1}{1000}$
	=	**0.1073 m^3**
c) Volume of water	=	$\frac{\text{Mass of water}}{\text{Specific gravity of water}} \times \frac{1}{1000}$
	=	$\frac{186}{1} \times \frac{1}{1000}$
	=	**0.186 m^3**
d) Volume of all in aggregate	=	[a-(b+c)]
	=	1-(0.1073+0.186)
	=	**0.7067 m^3**
e) Mass of coarse aggregate	=	d x volume of coarse aggregate x Sp.Gr. of coarse aggregate x 1000
	=	0.7067 x 0.59 x 2.67 x 1000
	=	**1113 kg**
g) Mass of fine aggregate	=	e xvolume of fine aggregate x Sp.Gr. of fine aggregate x 1000
	=	0.7067 x 0.41 x 2.6 x 1000
	=	**753.3 kg**

9 MIX PROPORTIONS FOR TRIAL MIX NUMBER 1

Cement	=	338 kg/m^3
Water	=	186 kg/m^3
Fine aggregate	=	753 kg/m^3
Coarse aggregate	=	1113 kg/m^3
Water Cement ratio	=	0.55

Adjustments for moisture in aggregates and water absorption of aggregates:

Correction for aggregates:

Fine aggregate (for 3% surface moisture) = 753 x 1.03

= 775.59 kg (wet)

It may be noted that absorbed water does not become the part of the mixing water and must be excluded from the adjustment in added water.

Thus, the surface water contributed by fine aggregates = 3-2= 1 percent.

Corrected water content = 186 - 753 (0.01)

= 178.47 kg.

The estimated batch masses (after corrections) are as given below:

Cement	=	338.0kg/m^3
Water	=	178.47 kg.kg/m^3
Fine aggregate	=	775.59 kg/m^3
Coarse aggregate	=	1102 kg/m^3

NOTE: Based on the experience it can be mentioned here that both water content and cement content per cubic meter of concrete mentioned above is very much on the higher side for M 20 Grade of Concrete. For M 20 grade of concrete a minimum cement content of 300 kg/m^3 will suffice the requirements. With this cement content, water content works out to be 165 kg/m^3 for maximum w/c ratio of 0.55 for mild exposure condition. Revised mix proportions shall be calculated and verified for required workability in terms of slump.

Revised Mix Proportions are:

Cement	=	300 kg/m^3
Water	=	165 kg/m^3
Fine aggregate	=	788 kg/m^3
Coarse aggregate	=	1165 kg/m^3
Water Cement ratio	=	0.55

10 TRIAL MIX NUMBER 2 : The water content shall be adjusted suitably in the Trial Mix No.1. With this adjustment, the mix proportion shall be recalculated keeping the free water cement ratio at the pre-selected value. With this trial more or less the stipulated value of slump will be obtained. In addition two more Trial Mixes No.3 and 4 shall be made with water content same as Trial Mix No.2 and varying the free w/c ratio by ±10% of the preselected value.

An example illustrating the mix proportioning for a concrete of M 30 grade is given in Steps 1 to 11

1 STIPULATIONS FOR PROPORTIONING

a)	Grade designation	:	M 30
b)	Type of cement	:	OPC 43 grade conforming to IS 8112
c)	Maximum nominal size of aggregate	:	20 mm
d)	Minimum cement content	:	320 kg/m^3
e)	Maximum water-cement ratio	:	0.45
f)	Workability	:	100 mm (Slump)
g)	Exposure condition	:	Severe (for reinforced concrete)
h)	Method of concrete placing	:	Pumping
i)	Degree of supervision	:	Good
j)	Type of aggregate	:	Crushed angular aggregate
k)	Maximum cement content	:	450 kg/m^3
l)	Chemical admixture type	:	Superplasticizer

2 TEST DATE FOR MATERIALS

a) Cement used : OPC 43 grade conforming to IS 8112

b) Specific gravity of cement : 3.15

c) Chemical admixture : Superplasticizer conforming to IS 9103

d) Specific gravity of:

1) Coarse aggregate : 2.70

2) Fine aggregate : 2.67

e) Water absorption:

1) Coarse aggregate : 0.5 percent

2) Fine aggregate : 1.0 percent

f) Free (surface) moisture:

1) Coarse aggregate : Nil (absorbed moisture also nil)

2) Fine aggregate : Nil

g) Sieve analysis

1) Coarse aggregate :

COMBINED SIEVE ANALYSIS OF 20mm AND 12.5mm COARSE AGGREGATE

Cumulative Sieve Size (mm)	Cumulative % passing 20mm	Cumulative % passing 12.5mm	Cumulative % passing when 20mm and 12.5mm are mixed in 60:40 ratio	Requirements of Cumulative % passing for 20mm graded aggregates as per IS:383-2016
20.0	100	100	100	95 – 100
10.0	0	71.2	28.5	25 – 55
4.75	0	9.4	3.7	0 – 10

2) Fine aggregate : Conforming to grading Zone I of Table 4 of IS 383-2016

3 TARGET STRENGTH FOR MIX PROPORTIONING

$$f'_{ck} = f_{ck} + 1.65\ s$$

where

f'_{ck}	=	target average compressive strength at 28 days
f_{ck}	=	characteristic compressive strength at 28 days, and
s	=	standard deviation

From Table 1, standard deviation, s = 5 N/mm^2

Therefore, target strength = 30 + 1.65 x 5 = 38.25 N/mm^2

4 SELECTION OF WATER – CEMENT RATIO

From Table 5 of IS 456, maximum water cement ratio = 0.45

Adopt water – cement ratio as 0.45

5 SELECTION OF WATER CONTENT

From Table 2, maximum water content for 20 mm aggregate = 186 kg (for 25 to 50 mm slump range)

Estimated water content for 100mm slump = $186 + \frac{6}{100} \times 186$

= 197 kg.

As superplasticizer is used, the water content can be reduced up to 20 percent and above

Based on trials with superplasticizer, water content reduction of 20 percent has been achieved. Hence, the arrived water content = 197 x 0.80 = 157.6 kg.

6 CALCULATION OF CEMENT CONTENT

Water-cement ratio = 0.45

Cement content = $\frac{157.6}{0.45}$

= 350 kg/m^3

From Table 5 of IS 456, minimum cement content for ‘severe’ exposure condition = 320 kg/m^3

350 kg/m^3 > 320 kg/m^3, hence, OK

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.

In the present case water-cement ratio is 0.45. Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by 0.05, the proportion of volume of coarse aggregate is increased by 0.01 (at the rate of -/+ 0.01 for every $\pm$ 0.05 change in water-cement ratio). Therefore, corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.40 = 0.61.

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

For pumpable concrete these values should be reduced by 10 percent

Therefore, volume of coarse aggregate = 0.61 x 0.9 = 0.55

Volume of fine aggregate content = 1 – 0.55 = 0.45

8 MIX CALCULATIONS

a) Volume of concrete = 1 m^3

b) Volume of cement = $\frac{\text{Mass of cement}}{\text{Specific gravity of cement}} \times \frac{1}{1000}$

$= \frac{350}{3.15} \times \frac{1}{1000}$

= **0.111 m^3**

c) Volume of water = $\frac{\text{Mass of water}}{\text{Specific gravity of water}} \times \frac{1}{1000}$

$= \frac{157.6}{1} \times \frac{1}{1000}$

= **0.157 m^3**

d) Volume of chemical admixture (superplasticizer)(@ 1.0percent by mass of cementitious material) = $\frac{\text{Mass of chemical admixture}}{\text{Specific gravity of admixture}} \times \frac{1}{1000}$

$= \frac{3.5}{1.145} \times \frac{1}{1000}$

= **0.0026 m^3**

e) Volume of all in aggregate = [a-(b+c+d)]

= 1-(0.111+0.157+0.0026)

= **0.727 m^3**

f) Mass of coarse aggregate = e x volume of coarse aggregate x specific gravity of coarse aggregate x 1000

= 0.727 x 0.55 x 2.70 x 1000

= **1079.6 kg**

g) Mass of fine aggregate = e x volume of fine aggregate x specific gravity of fine aggregate x 1000

= 0.727 x 0.45 x 2.67 x 1000

= **873.5 kg**

9 MIX PROPORTIONS FOR TRIAL NUMBER 1

Cement	=	350 kg/m^3
Water	=	157.6 kg/m^3
Fine aggregate	=	873 kg/m^3
Coarse aggregate	=	1079 kg/m^3
Chemical admixture	=	3.5 kg/m^3
Water Cement ratio	=	0.45

Adjustments for moisture in aggregates and water absorption of aggregates:

Correction for aggregates:

Free (surface) moisture is nil in both fine and coarse aggregates.

Thus, the surface water contributed by fine aggregates = 3-2= 1 percent.

Corrected water content = 186 + 873 (0.01) + 1079 (0.005)

= 171.7 kg.

The estimated batch masses (after corrections) are as given below:

Cement	=	350.0 kg/m^3
Water	=	171.7 kg/m^3
Fine aggregate	=	873.0 kg/m^3
Coarse aggregate	=	1079 kg/m^3
Superplasticiser	=	3.5 kg/m^3

10 The slump shall be measured and the water content and dosage of admixture shall be adjusted for achieving the required slump based on trial, if required. The mix proportion shall be reworked for the actual water content and checked for durability requirements

11 Two more trials having variation of $\pm$ 10 percent of water-cement ratio in A-10 shall be carried out and a graph between three water-cement ratios and their corresponding strengths shall be plotted to work out the mix proportions for the given target strength for field trials. However, durability requirement shall be met.

ILLUSTRATIVE EXAMPLE OF MIXPROPORTIONING OF CONCRETE (USING FLYASH AS PART REPLACEMENT OF OPC)

An example illustrating the mix proportioning for a concrete of M 30 grade using flyashis given below:

Considering the same data as in illustrative example for M 30 Grade of concrete, mix proportioning steps from 1 to 5 remain same.

The procedure of using Flyash as a partial replacement to OPC has been explained in step 6.

6 CALCULATION OF CEMENT CONTENT

Water-cement ratio = 0.45

Cement content $= \frac{157.6}{0.45}$

$= 350\ kg/m^3$

From Table 5 of IS 456, minimum cement content for 'severe' exposure condition = 320 kg/m^3

350 kg/m^3 > 320 kg/m^3, hence, OK

Now, to proportion a mix containing flyash following steps are suggested.

a) Decide percentage of flyash to be used based on project requirement and quality of materials.

b) In certain situations increase in cementitious material content may be warranted. The decision on increase in cementitious material content and its percentage may be based on experience and trial (*see* note)

Note: This illustrative example is with increase of 10% in cementitious material content.

Cementitious material content = 350 x 1.1 = 385 kg/m^3

Water content = 157.6 kg/m^3

So, water-cement ratio = 157.6/385 = 0.41

Flyash @ 35% of total cementitious material content= 385 x 30%= 134.75kg/m^3

Say 135 kg/m^3

Cement OPC = 385 -135 = 250 kg/m^3

Saving of cement while using flyash = 350 – 250 = 100 kg/m^3, and

Flyash being utilized = 135 kg/m^3

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.

In the present case water-cement ratio is 0.41. Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by approximately 0.1, the proportion of volume of coarse aggregate is increased by 0.02 (at the rate of -/+ 0.01 for every $\pm$ 0.05 change in water-cement ratio). Therefore, corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.40 = 0.62.

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

For pumpable concrete these values should be reduced by 10 percent

Therefore, volume of coarse aggregate = 0.62 x 0.9 = 0.56

Volume of fine aggregate content = 1 – 0.56 = 0.44

8 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 $= \frac{\text{Mass of cement}}{\text{Specific gravity of cement}} \times \frac{1}{1000}$

$= \frac{250}{3.15} \times \frac{1}{1000}$

$=$ **0.0794** $\mathbf{m^3}$

c) Volume of Flyash $= \frac{\text{Mass of Flyash}}{\text{Specific gravity of Flyash}} \times \frac{1}{1000}$

$= \frac{135}{2.2} \times \frac{1}{1000}$

$=$ **0.0614** $\mathbf{m^3}$

d) Volume of water $= \frac{\text{Mass of water}}{\text{Specific gravity of water}} \times \frac{1}{1000}$

$= \frac{157.6}{1} \times \frac{1}{1000}$

$=$ **0.157** $\mathbf{m^3}$

e) Volume of chemical admixture (superplasticizer)(@ 1.0percent by mass of cementitious material) $= \frac{\text{Mass of chemical admixture}}{\text{Specific gravity of admixture}} \times \frac{1}{1000}$

$= \frac{3}{1.145} \times \frac{1}{1000}$

$=$ **0.0026** $\mathbf{m^3}$

f) Volume of all in aggregate $= [a-(b+c+d+e)]$

$= 1-(0.0794+0.0614+0.157+0.0026)$

$=$ **0.6996** $\mathbf{m^3}$

g) Mass of coarse aggregate =f x volume of fine aggregate x Specific gravity of fine aggregate x 1000

= 0.6996 x 0.56 x 2.70 x 1000

= **1057.8 kg**

h) Mass of coarse aggregate = f x volume of fine aggregate x Specific gravity of fine aggregate x 1000

	=	0.6996 x 0.44 x 2.67 x 1000
	=	**821.9 kg**

9 MIX PROPORTIONS FOR TRIAL NUMBER 1

Cement	=	250 kg/m^3
Flyash	=	135 kg/m^3
Water	=	157.6 kg/m^3
Fine aggregate	=	862 kg/m^3
Coarse aggregate	=	1097 kg/m^3
Chemical admixture	=	7 kg/m^3
Water Cement ratio	=	0.41

Note : Aggregates should be used in saturated surface dry condition. If otherwise, when computing the requirement of mixing water, allowance shall be made for the free (surface) moisture contributed by the fine and coarse aggregates. On the other hand, if the aggregates are dry, the amount of mixing water should be increased by an amount equal to the moisture likely to be absorbed by the aggregates. Necessary adjustments are also required to be made in mass of aggregates. The surface water and percent water absorption of aggregates shall be determined according to IS 2386.

10 The slump shall be measured and the water content and dosage of admixture shall be adjusted for achieving the required slump based on trial, if required. The mix proportion shall be reworked for the actual water content and checked for durability requirements

11 Two more trials having variation of $\pm$ 10 percent of water-cement ratio in B-10 shall be carried out and a graph between three water-cement ratios and their corresponding strengths shall be plotted to work out the mix proportions for the given target strength for field trials. However, durability requirement shall be met.

ILLUSTRATIVE EXAMPLE OF MIXPROPORTIONING OF CONCRETE (USING GROUND GRANULATED BLAST FURNACE SLAB (G.G.B.S.) AS PART REPLACEMENT OF OPC)

An example illustrating the mix proportioning for a concrete of M 30 grade using GGBS is given below:

Considering the same data as in illustrative example for M 30 Grade of concrete, mix proportioning steps from 1 to 5 remain same.

The procedure of using G.G.B.S. as a partial replacement to OPC has been explained in step 6.

6 CALCULATION OF CEMENT CONTENT

Water-cement ratio = 0.45

Cement content = $\frac{157.6}{0.45}$

= 350 kg/m^3

From Table 5 of IS 456, minimum cement content for 'severe' exposure condition = 320 kg/m^3

350 kg/m^3 > 320 kg/m^3, hence, OK

Now, to proportion a mix containing flyash following steps are suggested.

a) Decide percentage of GGBS to be used based on project requirement and quality of materials.

b)In certain situations increase in cementitious material content may be warranted. The decision on increase in cementitious material content and its percentage may be based on experience and trial (*see* note)

Note: This illustrative example is with increase of10% in cementitious material content.

Cementitious material content = 350 x 1.1 = 385 kg/m^3

Water content = 157.6 kg/m^3

So, water-cement ratio = 157.6/385 = 0.41

GGBS @ 50% of total cementitious material content= 385 x 50%= 192.5kg/m^3

Say 135 kg/m^3

Cement OPC = 385 -192.5 = 192.5 kg/m^3

Saving of cement while using GGBS = 350 – 192.5 = 157.5 kg/m^3 , and

GGBS being utilized = 192.5 kg/m^3

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.

In the present case water-cement ratio is 0.41. Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by approximately 0.1, the proportion of volume of coarse aggregate is increased by 0.02 (at the rate of -/+ 0.01 for every $\pm$ 0.05 change in water-cement ratio). Therefore, corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.40 = 0.62.

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

For pumpable concrete these values should be reduced by 10 percent

Therefore, volume of coarse aggregate = 0.62 x 0.9 = 0.56

Volume of fine aggregate content = 1 – 0.56 = 0.44

8 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

$$= \frac{\text{Mass of cement}}{\text{Specific gravity of cement}} \times \frac{1}{1000}$$

$$= \frac{192.5}{3.15} \times \frac{1}{1000}$$

$$= \mathbf{0.0611\ m^3}$$

c) Volume of GGBS

$$= \frac{\text{Mass of GGBS}}{\text{Specific gravity of GGBS}} \times \frac{1}{1000}$$

$$= \frac{192.5}{2.85} \times \frac{1}{1000}$$

$$= \mathbf{0.0675\ m^3}$$

d) Volume of water

$$= \frac{\text{Mass of water}}{\text{Specific gravity of water}} \times \frac{1}{1000}$$

$$= \frac{157.6}{1} \times \frac{1}{1000}$$

$$= \mathbf{0.157\ m^3}$$

e) Volume of chemical admixture (superplasticizer)(@ 1.0percent by mass of cementitious material) = $\frac{\text{Mass of chemical admixture}}{\text{Specific gravity of admixture}} \times \frac{1}{1000}$

= $\frac{3}{1.145} \times \frac{1}{1000}$

= **0.0026 m^3**

f) Volume of all in aggregate = [a-(b+c+d+e)]

= 1-(0.0611+0.0675+0.157+0.0026)

= **0.7118 m^3**

g) Mass of coarse aggregate = f x volume of fine aggregate x Specific gravity of fine aggregate x 1000

= 0.7118 x 0.56 x 2.70 x 1000

= **1076.2 kg**

h) Mass of fine aggregate = f x volume of fine aggregate x Specific gravity of fine aggregate x 1000

= 0.7118 x 0.44 x 2.67 x 1000

= **843.5 kg**

9 MIX PROPORTIONS FOR TRIAL NUMBER 1

Cement	=	192.5 kg/m^3
GGBS	=	192.5 kg/m^3
Water	=	157.6 kg/m^3
Fine aggregate	=	862 kg/m^3
Coarse aggregate	=	1097 kg/m^3
Chemical admixture	=	7 kg/m^3
Water Cement ratio	=	0.41

Note : Aggregates should be used in saturated surface dry condition. If otherwise, when computing the requirement of mixing water, allowance shall be made for the free (surface) moisture contributed by the fine and coarse aggregates. On the other hand, if the aggregates are dry, the amount of mixing water should be increased by an amount equal to the moisture likely to be absorbed by the aggregates. Necessary adjustments are also required to be made in mass of aggregates. The surface water and percent water absorption of aggregates shall be determined according to IS 2386.

10 The slump shall be measured and the water content and dosage of admixture shall be adjusted for achieving the required slump based on trial, if required. The mix proportion shall be reworked for the actual water content and checked for durability requirements

11 Two more trials having variation of $\pm$ 10 percent of water-cement ratio in B-10 shall be carried out and a graph between three water-cement ratios and their corresponding strengths shall be plotted to work out the mix proportions for the given target strength for field trials. However, durability requirement shall be met.

CONCLUSION:

The objective of concrete mix proportioning is to arrive at the most economical, practical and robust combination of different ingredients to produce a concrete that will satisfy the pereformance requirements under specified use. An integral part of the concrete mix proportioning is the preparation of trials and effect adjustments to such trials to strike a balance between requirements of placing, that is workability and strength, simultaneously satisfying durability requirements. As per IS 456-2000, as a guarantor of quality of concrete used in construction, the constructor shall carry out the mix design and the mix so designed (not the method of design) shall be approved by the engineer-in-charge. It is worthwhile to mention that the method given in IS 10262-2009 is to be regarded as guidelines only and the standard does not bar the adoption of any other method of concrete mix proportioning

REFERENCES

1. _____ Code of Practice for Plain and Reinforced Cement Concrete , IS 456 : 2000 (Fourth Revision) [Reaffirmed in 2002], Bureau of Indian Standards, New Delhi.
2. _____ Concrete Mix Proportioning- Guidelines (First Revision), IS 10262 : 2009, Bureau of Indian Standards, New Delhi.
3. _____ Specifications for admixtures for concrete (First Revision) , IS 9103 : 1999 [Reaffirmed in 2004], Bureau of Indian Standards, New Delhi.
4. _____Specifications for coarse and fine aggregates from natural sources forconcrete , IS 383 : 2016, Bureau of Indian Standards, New Delhi.
5. _____ “Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete”,ACI 211.1-1991
6. _____Specification for Ordinary Portland Cement 43 Grade , IS 8112 : 1970 (Second Revision) [Reaffirmed in 2007], Bureau of Indian Standards, New Delhi.

7. _____ Methods of test for aggregates for concrete Part 3 Specific gravity, density, voids, absorption and bulking, IS 2386 : 1963 (Fourth Revision) [Reaffirmed in 2007], Bureau of Indian Standards, New Delhi.
8. _____ Methods of tests for aggregates for concrete, IS 2386 (Part I) :1963 [Reaffirmed in 2007], Bureau of Indian Standards, New Delhi.
9. _____ Specifications for pulverized fuel ash (Second Revision) , IS 3812 Part 1 : 2003, For use as Pozzolana in cement, cement mortar and concrete, Bureau of Indian Standards, New Delhi.
10. Neville A. M. (1995). “PropertiesofConcrete,” Longman, 4th edition, chapter. 3, pp. 108-181.

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APPENDIX

Table 2 of IS 456-2000 Grades of Concrete

Group	Grade Designation	Specified characteristic compressive strength of 150 mm cube at 28 days N/mm^2
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 Concretes	M 60	60
	M 65	65
	M 70	70
	M 75	75
	M 80	80

Table 3 of IS 456-2000

ENVIRONMENT EXPOSURE CONDITIONS

- MILD Concrete surfaces protected against weather or aggressive conditions except those situated in coastal area.
- 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.
- 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.
- VERY SEVERE Concrete surfaces exposed to sea water spray, corrosive fumes or severe freezing conditions whilst wet. Concrete exposed to aggressive subsoil ground water or coastal environment.
- EXTREME Surface of members in tidal zone. Members in direct contact with liquid/solid aggressive chemicals.

TABLE 4 of IS 456-2000

MINIMUM CEMENTITIOUS CONTENTS,MAXIMUM W/C RATIO AND MINIMUM GRADE OF CONCRETE FOR DIFFERENT EXPOSURE WITH NORMAL WEIGHT AGGREGATES OF 20 mm NOMINAL MAXIMUM SIZE

EXPOSURE	PLAIN CONCRETE		REINFORCED CONCRETE		MINIMUM GRADE OF CONCRETE	
	MIN. CEMENT kg/m^3	MAX. FREE W/C	MIN. CEMENT kg/m^3	MAX. FREE W/C	P.C.C.	R.C.C.
MILD	220	0.60	300	0.55	--	M20
MODERATE	240	0.60	300	0.50	M15	M25
SEVERE	250	0.50	320	0.45	M20	M30
VERY SEVERE	260	0.45	340	0.45	M20	M35
EXTREME	280	0.40	360	0.40	M25	M40

- Cement content prescribed in the above table is irrespective of the grades of cement.
- The additions such as flyash or ground granulated blast furnace slag may be taken into account in the concrete composition with respect to the cement content and w/c ratio if suitability established and as long as the maximum amounts taken into account do not exceed the limit of pozzolana and slag specified in IS 1489(part1) and IS 455 respectively.

TABLE 5 of IS 456-2000

WORKABILITY OF CONCRETE

Placing Conditions	Degree of Workability	Slump(mm)
Blinding concrete; Shallow concrete; Pavements using pavers;	Very low	0.75-0.80 (Compaction factor)
Mass concrete; Lightly reinforced sections in slabs, beams, walls, columns, floors ; Hand placed pavements; Canal lining; Strip footings	Low	25-75
Heavily reinforced sections in slabs, beams, walls, columns;	Medium	50-100
Slip form work; Pumped concrete	Medium	75-100
Trench fill; *In-situ piling*	High	100-150
Tremie concrete	Very High	150-200 (Flow test as per IS 9103-1999)
For most of the placing conditions, internal vibrators (needle vibrators) are suitable. The diameter of the needle shall be determined based on the density and spacing of reinforcement bars and thickness of sections. For tremie concrete vibrators are not required.		

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