SECTION 2 MATERIALS, WORKMANSHIP, INSPECTION AND TESTING

5 MATERIALS

5.1 Cement

The cement used shall be any of the following and the type selected should be appropriate for the intended use:

a) 33 Grade ordinary Portland cement conforming to IS 269

b) 43 Grade ordinary Portland cement conforming to IS 8112

c) 53 Grade ordinary Portland cement conforming to IS 12269

d) Rapid hardening Portland cement conforming to IS 8041

e) Portland slag cement conforming to IS 455

f) Portland pozzolana cement (fly ash based) conforming to IS 1489 (Part 1)

g) Portland pozzolana cement (calcined clay based) conforming to IS 1489 (Part 2)

h) Hydrophobic-cement conforming to IS 8043

j) Low heat Portland cement conforming to IS 12600

k) Sulphate resisting Portland cement conforming to IS 12330

Other combinations of Portland cement with mineral admixtures (see 5.2) of quality conforming with relevant Indian Standards laid down may also be used in the manufacture of concrete provided that there are satisfactory data on their suitability, such as performance test on concrete containing them.

5.1.1 Low heat Portland cement conforming to IS 12600 shall be used with adequate precautions with regard to removal of formwork, etc.

5.1.2 High alumina cement conforming to IS 6452 or supersulphated cement conforming to IS 6909 may be used only under special circumstances with the prior approval of the engineer-in-charge. Specialist literature may be consulted for guidance regarding the use of these types of cements,

5.1.3 The attention of the engineers-in-charge and users of cement is drawn to the fact that quality of various cements mentioned in 5.1 is to be determined on the basis of its conformity to the performance characteristics given in the respective Indian Standard Specification for that cement. Any trade-mark or any trade name indicating any special features not covered in the standard or any qualification or other special performance characteristics sometimes claimed/ indicated on the bags or containers or in advertisements alongside the 'Statutory Quality Marking' or otherwise

5.1.4 At locations where temperature are predominantly below 15°c for 6months the use of Portland calcined limestone cement should not be permitted in underground structures and structural elements in contact with ground water. have no relation whatsoever with the characteristics guaranteed by the Quality Marking as relevant to that cement. Consumers are, therefore, advised to go by the characteristics as given in the corresponding Indian Standard Specification or seek specialist advise to avoid any problem in concrete making and construction. Composite cement conforming to 15 16415 and containing a declared clinker content not less than 45% fly ash content not more than 25% and a min 28 day compressive strength of 43 MPa can be used for RCC construction.

5.2 Mineral Admixtures

5.2.1 Pozzolanas

Pozzolanic materials as given below may be used

5.2.1.1 Fly ash (pulverized fuel ash)

Fly ash conforming to IS 3812 may be used as part replacement of ordinary Portland cement

5.2.1.2 Silica fume

Silica fume conforming to IS 15388 be used as part replacement of Cement. ensured.

NOTE-The silica fume is usually used in proportion of 5 to 10 percent of the cement content

of a mix,

5.2.1.3 Rice husk ash

Rice husk ash giving required performance and uniformity characteristics may be used with the approval of the deciding authority.

NOTE-Rice husk ash is produced by burning rice husk and contain large proportion of silica. To sichieve amorphous state, rice husk may be burnt at controlled temperature. It is necessary to evaluate the product from a particular source for performance and uniformity since it can be as deleterious as silt when incorporated in concrete. Water deinand and drying shrinkage should be studied before using rice husk.

5.2.1.4 Metakaoline

Metakaoline conforming to IS 16354 may be used as pozzolanic material in may be used as part replacement of ordinary portland cement.

NOTE-Metakaoline is obtained by calcination of pure or refined kaolintic clay at a temperature between 650°C and 850°C, followed by grinding to achieve a fineness of 700 to 900 m^2/kg. The resulting material has high pozzolanicity.

5.2.2 Ground Granulated Blast Furnace Slag

Ground granulated blast furnace slag conforming to IS 16714 may be used as part replacement of ordinary Portland cements.

5.3 Aggregates

Aggregates derived from natural source and from other than natural source shall comply with the requirements of IS 383.

5.3.1 Other types of aggregates such as slag and crushed overburnt brick or tiIe, which may be found suitable with regard to strength, durability of concrete and freedom from harmful effects may be used for plain concrete members, but such aggregates should not contain more than 0.5 percent of sulphates as SO, and should not absorb more than 10 percent of their own mass of water.

5.3.2 Heavy weight aggregates or light weight aggregates such as bloated clay aggregates and sintered fly ash aggregates may also be used provided the engineer-in-charge is satisfied with the data on the properties of concrete made with them. . NOTE-Some of the provisions -of the code would require modification when these aggregates are used; specialist literature may be consulted for guidance.

5.3.3 Size of Aggregate

The nominal maximum size of coarse aggregate should be as large as possible within the limits specified but. in no case greater than one-fourth of the minimum thickness of the member, provided that the concrete can be placed without difficulty so as to surround all . reinforcement thoroughly and fill the corners of the form. For most work, 20 mm aggregate is suitable. Where there is no restriction to the flow of concrete into sections, 40 mm or larger size may be permitted. In concrete elements with thin sections, closely spaced reinforcement or small cover, consideration should be given to the use of 10 mm nominal maximum size. Plums above 160 mm and up to any reasonable size may be used in plain concrete work up to a maximum limit of :to. percent by volume. of concrete when specifically permitted by the engineer-in-charge. The plums shall be distributed evenly and shall be' not closer than 150 mm from the surface.

5.3.3.1 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 5 mm less than the minimum clear distance between the main bars or 5 mm less than the minimum cover to the reinforcement whichever is smaller.

5.3.4 Coarse and fine aggregate shall be batched separately.

5.4 Water

Water natural or treated used for mixing and curing shall be clean and free from-injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel.

Potable water is generally considered satisfactory for mixing concrete. As a guide the following concentrations represent the maximum permissible values:

a) To neutralize 100 ml sample of water, using phenolphthalein as an indicator, it should not require more than 5 ml of 0.02 normal NaOH. The details of test are given in 8.1 of IS 3025 (Part 22).

b) To neutralize 100 rill sample of water, using mixed indicator, it should not require more than 25 ml of 0.02 normal H,SO 4' The details of test shall be a. given in 8 of IS 3025 (Part 23).

c) Permissible limits for solids shall be as given in Table I.

5.4.1 In case of doubt regarding development of strength, the suitability of water for making concrete shall be ascertained by the compressive strength and initial setting time tests specified in 5.4.1.2 and 5.4.1.3.

5.4.1.1 The sample of water taken for testing shall represent the water proposed to be. used for concreting, due account being paid to seasonal variation. The sample shall not receive any treatment before testing other than that envisaged in the regular supply' of water proposed for use in concrete. The sample than be stored in a clean container previously rinsed out with similar water.

5.4.1.2 Average 28 days compressive strength of at least three 150 mm concrete cubes prepared with water proposed to be used shall not be less than 90 percent of the average. of strength. of three similar concrete . cubes prepared with distilled water. The cubes shall be prepared, cured and tested in accordance with the . requirements of lS 516.

5.4.1.3 The initial setting time of test block prepared with the appropriate cement and the water proposed to be. used shall not be less than 30 min and shall not differ by ± 30 min from the initial setting time of control . test block prepared with the same cement and distilled water. The test blocks shall be prepared and tested in accordance with the requirements of IS 4031 (Part 5).

5.4.2 The pH value of water shall be not less than 6.

5.4.3 Sea Water

Sea water shall not be used for mixing or curing of concrete shall not be used because of presence of harmful salts in sea water. Under unavoidable circumstances sea water may be used for mixing or curing in plain concrete with no embedded steel after having given due consideration to possible disadvantages and precautions including use of appropriate cement system.

Table 1 Permissible limit for solids			
Clause 5.4			
Sr. No.		**Tested as per**	**Permissible limit**
1	Organic	IS 3025 (Part 18)	200mg/l
2	Inorganic	IS 3025 (Part 18)	3000mg/l
3	Sulphates (as SO_3)	IS 3025 (Part 24)	400mg/l
4	Chlorides (as Cl)	IS 3025 (Part 32)	2000mg/l for concrete not containing embedded steel and 500mg/l for reinforced concrete work
5	Suspended Matter	IS 3025 (Part 17)	2000mg/l

5.4.4 Water found satisfactory for mixing is also suitable for curing concrete. However, water used for curing should not produce any objectionable stain or unsightly deposit 'on the concrete surface.

5.5 Chemical Admixtures

5.5.1 Admixture, if used ,shall comply with IS 9103. Previous experience with and data on such materials should be considered in relation to the likely standards of supervision and workmanship to the work being specified.

5.5.2 Admixtures should not impair durability of concrete nor combine with the constituents to form harmful compounds nor increase the risk of corrosion' of reinforcement.

5.5.3' The workability, compressive strength and the slump' loss of concrete with and without the use of admixtures shall be 'established during the trial mixes before use of admixtures.

5.5.4 The-'relative density of liquid admixtures shall be checked for each drum containing admixtures and compared with the specified value before ,acceptance.

5.5.5 The chloride content of admixtures shall be independently tested for each batch before acceptance.

5.5.6 If two or more admixtures are used simultaneously in the same concrete mix, data should be obtained to assess their interaction 'and to ensure, their compatibility.

5.5.7 The amount of admixture added to a mix shall be recorded in the production record. Redosing of admixture is not normally be permitted. In special circumstances, if necessary, additional dose of admixture may be added at project site and mixed adequately in mixer itself to regain the workability of concrete with the mutual agreement between producer/ supplier and purchaser/ user of concrete. However the producer/ supplier shall assure the ultimate quality of concrete supplied by him and maintain record of quantity and time of addition.

5.6 Reinforcement

The reinforcement shall be any of the following:

a) ,Mild steel and medium tensile steel bars conforming 10 IS 432 (Part I).

b) High strength deformed steel bars conforming to IS 1786.

c) , Hard-drawn steel wire fabric conforming 'to

5.6.1 All reinforcement shall be free from loose mill scales, loose rust and coats of paints, oil, mud or any other substances which may destroy or reduce bond. Sand blasting or other treatment is recommended to ·clean reinforcement.

5.6.2 Special precautions like coating of reinforcement may be required for reinforced concrete elements in exceptional cases and for rehabilitation of structures. Specialist literature may be referred to in such cases. Reduction in design bond strength of coated bars shall be looked into.

5.6.3 The modulus of elasticity of steel shall be taken as 200 kN/mm^2. The characteristic yield strength of different steel shall be assumed as the minimum yield stress/0.2 percent proof stress specified in the relevant Indian Standard.

5.7 Fibers

Fibers may be added to concrete for special applications to enhance properties, for which special literature may be referred.

5.8 Storage of Materials

Storage of materials shall be as described in IS 4082.

6 CONCRETE

6.1 Grades

The concrete shall be in grades designed as per Table 2.

6.1.1 The characteristic strength is defined us the strength of material, below which not, more than, 5 percent of the test results are expected 10 fall,

6.1.2 The minimum grade of concrete for plain and reinforced concrete shall be as per Table 5.

6.1.3 Concrete of grades lower than those given in Table 5 may be used for plain concrete constructions, lean concrete, simple foundations, foundation for masonry walls and other simple or temporary reinforced concrete construction.

6.2 Properties of Concrete

6.2.1 Increase of Strength with Age

There is normally a gain of strength beyond 28 days. The quantum of increase depends upon the grade and type of cement, curing and environmental conditions, etc. The design should be based on 28 days characteristic strength of concrete unless there is a evidence to justify a higher strength for a particular structure due to age.

Table 2 Grades of Concrete

Clause 6.1, 9.2.2, 15.1.1 and 36. 1

Group	**Grade designation**	**Specific characteristic compressive strength of 150mm cube at 28 days in N/mm^2**
Ordinary Concrete	M10	10
	M15	15
	M20	20
Standard Concrete	M25	25
	M30	30
	M35	35
	M40	40
	M45	45
	M50	50
	M55	55
	M60	60
High Strength Concrete	M65	65
	M70	70
	M75	75
	M80	80
	M85	85
	M90	90
	M95	95
	M100	100

Notes

1 In the designation of concrete mix M refers to the mix and the number to the specified compressive strength of 150 mrn size cub~ at 28 days, expressed in N/rnrn2 •

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

6.2.1.1 . For concrete of grade M 30 and above, the rate of increase of compressive strength with age shall be based on actual investigations.

6.2.1.2 Where members are subjected to lower direct load during construction, they should be checked for stresses resulting from combination of direct load and . bending during construction.

6.2.2 Tensile Strength of Concrete The flexural and splitting tensile strengths shall be obtained as described in IS 516 and 185816 respectively. When the designer wishes to use an estimate of the tensile strength from the compressive strength, the following formula may be used:

$$\text{Flexural strength, } f_{cr} = 0.7\ \sqrt{f_{ck}}\ \text{N/mm}^2$$

where f_{ck}" is the characteristic cube compressive strength of concrete in N/mm'. 6.2.3 Elastic Deformation The modulus of elasticity is primarily influenced by the elastic properties of the aggregate and to a lesser extent by the conditions of curing alld age of the concrete, the mix proportions and the type of cement. The modulus of elasticity is normally related to the compressive strength of concrete.

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6.2.3.1 The modulus of elasticity of concrete can be assumed as follows:

$$E_c = 5000\sqrt{f_{ck}}$$

where

E, is the short term static modulus of elasticity in N/mm'. Actual measured values may differ by ± 20 percent from the values obtained from the above expression.

6.2.4 Shrinkage The total shrinkage of concrete depends upon the constituents of concrete, size of the member and environmental conditions. For a given humidity and temperature, the total shrinkage of concrete is most influenced by the total amount of water present in the concrete at the time of mixing and, to a lesser extent, by the cement content.

6.2.4.1 In the absence of test data, the approximate value of the total shrinkage straiil for design may be taken as 0.0003 (for more information, see IS 1343).

6.2.5 Creep of Concrete Creep of concrete depends, in addition to the factors listed in **6.2.4**, on the stress in the concrete, age at loading and the duration of loading. As long as the stress in concrete does not exceed one-third of its characteristic compressive strength, creep may be assumed to be proportional to the stress ..

6.2.5.1 In the absence of experimental data and detailed information on the effect of the variables, the ultimate creep strain may be estimated from the following values of creep coefficient (that is, ultimate creep strain! elastic strain at the age of loading); for long span structure, it is advisable to, determine actual creep strain, likely to take place.

Age at Loading	Creep Coefficient
7 days	2.2
28 days	1.6
1 year	1.1
NOTE - The ultimate creep strain, estimate as described above does not include the elastic strain.	

6.2.6 Thermal Expansion

The coefficient of thermal expansion depends on nature of cement, the aggregate, the cement content, the relative humidity and the size of sections, The value of coefficient of thermal expansion for concrete with different aggregates may be taken as below:

Types of Aggregates	Coefficient of Thermal Expansion for concrete/ ▫C
Quartzite	1.2 to 1.3
Sandstone	0.9 to 1.2
Granite	0.7 to 0.95
Basalt	0.8 to 0.95
Limestone	0.6 to 0.9

7 WORKABILITY

7.1 The concrete mix proportions chosen should be such that the concrete is of adequate workability for the placing conditions of the concrete and can properly be compacted with the means available. Suggested ranges of workability of concrete measured in accordance with IS 1199 are given below:

Placing Conditions	Degree of Workability	Slump (mm)
Blinding concrete		
Shallow section		
Pavement using pavers	Very Low	**see 7.1.1**
Mass concrete		
Lightly reinforced sections in slabs, beams, walls, columns.		
Floors		
Hand placed pavements		
Canal lining		
Strip footing	Low	25-75
Heavily reinforced		
section in slabs, beams, walls, columns		50-100
Slipform work		
Pumped concrete	Medium	75-100
Trench fill	High	100-150
Tremie concrete	Very high	**see 7.1.2**
NOTE-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 to be used (**see also 13.3)** determined based on the density and spacing of reinforcement bars and thickness of sections. For trem.ie concrete, 'vibrators are not required to be used (see also 13.3).		

7.1.1 In the 'very low' category of workability where strict control is necessary, for example pavement quality concrete, measurement of workability by determination of compacting factor will be more appropriate than slump (see IS 1199) and a value of compacting fuctor of 0.75 to 0.80 is suggested.

7.1.2 In the 'very high' category of workability, measurement of workability by determination of flow will be appropriate (see IS 9103).

8 DURABILITY OF CONCRETE

8.1 General

A durable concrete is one that performs satisfactorily in the working environment during its anticipated exposure conditions during service. The materials and mix proportions specified and used should be such as to maintain its integrity and, if applicable, to protect embedded metal from corrosion.

8.1.1 One of the main characteristics influencing the durability of concrete is its permeability to the ingress of water, oxygen, carbon dioxide, chloride, sulphate and other potentially deleterious substances. Impermeability is governed by the constituents and workmanship used in making the concrete. With normal-weight aggregates a suitably low permeability is achieved by having an adequate cement content, sufficiently low free water cement ratio, by ensuring complete compaction of the concrete, and by adequate curing.

The factors influencing durability include:

a) the environment;

b) the cover to embedded steel;

c) the type and quality of constituent materials;

d) the cement ·content and water - cement ratio of the concrete;

e) workmanship, to obtain full compaction and efficient curing; and

f) the shape and size of the member.

The degree of exposure anticipated for the concrete during its service life together with other relevant factors relating to mix composition, workmanship, design and detailing should be considered. The concrete mix to provide adequate durability under these conditions should be chosen taking account of the accuracy of testing regimes for control and compliance as described in this standard.

8.2 Requirements for Durability

8.2.1 Shape and Size of Member

The shape or design details of exposed structures should be such as to promote good drainage of water and to avoid standing pools and rundown of water. Care should also be taken to minimize any cracks that may collect or transmit water. Adequate curing is essential to avoid the harmful effects of early loss of moisture (see 13.5).Member profiles and their intersections with other members shall be designed and detailed in a way to ensure easy flow of concrete and proper compaction during concreting.

Concrete is more vulnerable to deterioration due to chemical or climatic attack when it is in thin sections, in sections under hydrostatic pressure from one side only, in partially immersed sections and at corners and edges of elements. The life of the structure can be lengthened by providing extra cover to steel, by chamfering the corners or by using circular cross sections or by using surface coatings which prevent or reduce the ingress of water, carbon dioxide or aggressive chemicals.

8.2.2 Exposure Conditions

8.2.2.1 General environment

The general environment to which the concrete will he exposed during its working life is classified into five levels of severity, that is, mild, moderate, severe, very severe and extreme as described in Table 3.

Table 3 Environmental Exposure Conditions		
Clause 8.2.2.1 and 35.3.2		
Sr. No.	**Environment**	**Exposure Condition**
1	Mild	Concrete surfaces protected against weather or aggressive conditions, except those situated in coastal area.
2	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
3	Severe	Concrete surfaces exposed to severe rain alternate wetting and drying or occasional freezing whilst wet or severe condensation.
4	Very severe	Concrete completely immersed in sea water
		Concrete exposed to coastal environment
		Concrete surfaces ex posed to sea water spray. corrosive fumes or severe freezing conditions whilst wet
5	Extreme	Concrete in contact with or buried under aggressive sub-soil ground water Surface of members in tidal zone
		Members in direct contact with liquid, solid, aggressive chemicals

8.2.2.2 Abrasive

Specialist literatures may be referred to for durability requirements of concrete surfaces exposed to abrasive action, for example, in case of machinery and metal tyres.

8.2.2.3 Freezing and thawing

Where freezing and thawing actions under wet conditions exist, enhanced durability can be obtained by the use of suitable air entraining admixtures. When concrete lower than grade M 50 is used under these conditions, the mean total air content by volume of the fresh concrete at the time .of delivery into the construction should be:

Nominal Maximum Size Aggregate (mm)	**Entrained Air Percentage**
20	5 $\pm$ 1
40	4 $\pm$ 1
10 & 12.5	6 $\pm$ 1

Since air entrainment reduces the strength, suitable adjustments may be made in the mix design for achieving required strength.

8.2.2.4 Exposure to sulphate attack Table 4 gives recommendations for the type of cement, maximum free water/cement ratio and minimum cement content, which are required at different sulphate concentrations in near-neutral ground water having pH of 6 to 9.

For the very high sulphate concentrations in Class 5 conditions, some form of lining such as polyethylene or polychloroprene sheet; or surface coating based on asphalt, chlorinated rubber, epoxy; or polyurethane' materials should also be used to prevent access by the sulphate solution.

8.2.3 Requirement of Concrete Cover

8.2.3.1 The protection of the steel in concrete against corrosion depends upon an adequate thickness of good quality concrete .

8.2.3.2 The nominal cover to the reinforcement shall be provided as per 26.4.

8.2.4 Concrete Mix Proportions

8.2.4.1 General

The free water-cement ratio is an important factor in governing the durability of concrete and should all ways be the lowest value. Appropriate values for minimum cement content and the maximum free water-cement ratio are given in Table 5 for different exposure conditions. The minimum cement content and maximum water-cement ratio apply to 20 mm nominal maximum size aggregate. For other sizes of aggregate they should be changed as given in Table 6.

8.2.4.2 Maximum cement content

Cement content not including fly ash and ground granulated blast furnace slag in excess of 450 kg/m^3 should not be used unless special consideration has been given in design ta the increased risk of cracking due to drying shrinkage in. thin sections, or to early thermal cracking and ta the increased risk of damage due to alkali silica reactions.

Table 4 Requirements for concrete exposed to sulphate attack							
Clause 8.2.2.4 and 9.1.2							
Sr. No.	**Class**	**Concentration of sulphates, expressed as S03**			**Type of Cement**	**Dense, Fully Compacted Concrete. Made with 20 mm Nominal Maximum Size Aggregates Complying with IS 383**	
		In soil		In Ground Water		Minimum Cement Content (Kg/m^3)	Maximum Water - Cement Ratio
		Total SO3	SO3;in 2:1 Water: Soil Extract				
		Percent	g/l	g/l			
1	2	3	4	5	6	7	8
1	1	Traces (<0.2)	Less than 1.0	Less than 0.3	Ordinary Portland cement or Portland slag cement or Portland pozzolana cement	280	0.55
2	2	0.2 to 0.5	1.0 to 1.9	0.3 to 1.2	Ordinary Portland cement Of Portland slag cement or Portland pozzolana cement	330	0.5
					Super sulphated cement or sulphate resisting Portland cement	310	0.5

3	3	0.5 to 1.0	1.9 to 3.1	1.2 to 2.5	Supersulphated cement or sulphate resisting Portland cement	330	0.5
					Portland pozzolana cement or Portland slag cement	350	0.45
4	4	1.0 to 2.0	3.1 to 5.0	2.5 to 5.0	Supersulphated or sulphate resisting Portland cement	370	0.45
5	5	More than 2.0	More than 5.0	More than 5.0	Sulphate resisting Portland cement or supersulphated cement with protective coatings	400	0.4
Notes							
1. Cement content given in this table is irrespective of grades of cement.							
2. Use of supersulphated cement is generally restricted where the prevailing temperature is above 40°C.							
3. Supersulphated cement gives an acceptable life provided that the concrete is dense and prepared with a water - cement ratio of 0.4 or less, in mineral acids, down to pH 3.5.							
4. The cement contents given in col 6 of this table are the minimum recommended. For SOl contents near the upper limit of any class, cement contents above these minimum are advised. For purpose of calculations of SO3 context if the test results are in the form of SO3, following shall be used SO3 = 0.833SO4							
5. For severe conditions, such as thin sections under hydrostatic pressure on one side only and sections partly immersed, considerations should be given to a further reduction of water - cement ratio.							
6. Portland Pozzolana Cement conforming to IS 1489 (Part 1) having at least 25% of flyash content. Portland slag cement conforming to IS' 455 with slag content more than 50 percent slag content give acceptable sulphate resisting properties.							
7. Where chloride is encountered along with sulphates in soil or ground Water. ordinary Portland cement with C, A content from 5 to 8 percent shall be desirable to be used in concrete, instead of sulphate resisting cement. Altenatively, Portland slag cement conforming to IS 455 having atleast 50 percent slag or a blend of ordinary Portland cement and slag may be used provided sufficient information is available on performance of such blended cements in these conditions.							

8.2.5 Mix Constituents

8.2.5.1 General

For concrete to be durable, careful selection of the mix and materials is necessary, so that deleterious constituents do not exceed the limits.

8.2.5.2 Chlorides in concrete

Whenever there is chloride in concrete there is an increased risk of corrosion of embedded metal. The higher the chloride content, or if subsequently exposed to warm moist conditions, the greater the risk of corrosion. All constituents may contain chlorides and concrete may be contaminated by chlorides from the external environment. To minimize the chances of deterioration of concrete from harmful chemical salts, the levels of such harmful salts in concrete coming from concrete materials, that is, cement, aggregates water and admixtures, as well as by diffusion from the environment should be limited. The total amount of chloride content (Cl) in the concrete at the time of placing shall be as given in Table 7.

The total acid soluble chloride content should be calculated from the mix proportions and the measured chloride contents of each of the constituents. Wherever possible, the total chloride content of the concrete should be determined.

8.2.5.3 Sulphates in concrete

Sulphates are present in most cements and in some aggregates; excessive amounts of water-soluble sulphate from these or other mix constituents can cause expansion and disruption of concrete. To prevent this, the total water-soluble sulphate content of the concrete mix, expressed as SO_3 where $SO_3 = 0.833SO_4$ should not exceed 4 percent by mass of the cement in the mix. The sulphate content should be calculated as the total from the various constituents of the mix. The 4 percent limit does not apply to concrete made with super sulphated cement(complying with IS 6909).

8.2.5.4 Alkali-aggregate reaction

Some aggregates containing particular varieties of silica may be susceptible to attack by alkalis (Na_2O and K_2O) originating from cement or other sources, producing an expansive reaction which can cause cracking and disruption of concrete. Damage to concrete from this reaction will normally only occur when all the following are present together:

a) A high moisture level, within the concrete;
b) A cement with high alkali content, or another source of alkali;
c) Aggregate containing an alkali reactive constituent.

Where the service records of particular cement/aggregate combination are well established, and do not include any instances of cracking due to alkali-aggregate reaction, no further precautions should be necessary. When the materials are unfamiliar, precautions should take one or more of the following forms:

a) Use of non-reactive aggregate from alternate sources.
b) Use of low alkali ordinary Portland cement having total alkali content not more than 0.6 percent (as Na_2O equivalent).

   Further advantage can be obtained by use of fly ash ground conforming to IS 3812 (Part 1)or granulated blast furnace slag conforming to IS 12089 as part replacement of ordinary Portland cement (having total alkali content as Na_2O equivalent not more than 0.6 percent), provided fly ash content is at least 20 percent or slag content is at least 50 percent.

c) Measures to reduce the degree of saturation of the concrete during service such as use of impermeable membranes.
d) Limiting the cement content in the concrete mix and thereby limiting total alkali content in the concrete mix. For more guidance specialist literatures may be referred.

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

Clause 6.1.2, 8.2.4.1 and 9.1.2

Sr. No.	Exposure	Plain Concrete			Reinforced Concrete		
		Minimum Cement Content (kg/m^3)	Maximum Water Cement Ratio	Minimum Grade of Concrete	Minimum Cement Content (kg/m^3)	Maximum Water Cement Ratio	Minimum Grade of Concrete
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	Mild	220	0.6		300	0.55	M20
2	Moderate	240	0.6	M15	300	0.5	M25
3	Severe	250	0.5	M20	320	0.45	M30
4	Very severe	260	0.45	M20	340	0.45	M35
5	Extreme	280	0.4	M25	360	0.4	M40

NOTE
1 Cement content prescribed in this table is irrespective of the grades of cement and it is inclusive of additions mentioned in S.2. The additions such as fly ash or ground granulated blast furnace slag may be taken into account in the concrete composition with respect to the cement content and water-cement ratio not exceed the limit of pozzolona and slag specified in IS 1489 (Part I) and IS 455 respectively, beyond which these addition, through permitted, shall not be considered for these purpose.
2 Minimum grade for plain concrete under mild exposure condition is not specified.
3 The minimum cement content, maximum free water - cement ratio and minimum grade for concrete are individually related to exposure.

Table 6 Adjustments to Minimum Cement Contents fo. Agg

(Clause 8.2.4.1)

Sr. No.	Nominal Maximum Aggregate Size mm	Adjustments to Minimum Cement Contents in Table 5 kg/m^3
1	10	+40
2	20	0
3	40	-30

Table 7 Limits of Chloride Content of Concrete		
(Clause 8.2.5.2)		
Sr. No.	Type or Use of Concrete	Maximum Total Acid Soluble Chloride Content Expressed as kg/m3 of Concrete
1	Concrete containing metal and steam cured at elevated tempe rature and pre-stressed concrete	0.4
2	Reinforced concrete of plain concrete containing embedded metal	0.6
3	Concrete not containing embedded metal Of any material requiring protection from chloride	3

8.2.6 Concrete in Aggressive Soils and Water

8.2.6.1 General

The destructive action of aggressive waters on concrete is progressive. The rate of deterioration decreases as the concrete is made stronger and more impermeable, and increases as the salt content of the water increases. Where structures are only partia1ly immersed or are in contact with aggressive soils or waters on one side only evaporation may cause serious concentrations of salts with subsequent deterioration, even where the original salt content of the soil or water is not high.

NOTE-Guidance regarding requirements for concrete exposed to sulphate attack is given in **8.2.2.4.**

8.2.6.2 Drainage

At sites where alkali concentrations are high or may become very high, the ground water should be lowered by drainage so that it will not come into direct contact with the concrete.

Additional protection may be obtained by the use of impermeable barriers.

8.2.7 Compaction, Finishing and Curing

Adequate compaction without segregation should be ensured by providing suitable workability and by employing appropriate placing and compacting equipment and procedures. Full compaction is particularly important in the vicinity of construction and movement joints and of embedded water bars and reinforcement.

Good finishing practices are essential for durable concrete.

Overworking to the surface and the addition of water cement to aid in finishing should be avoided; the resulting laitance will have impaired strength and durability and will be particularly vulnerable to • freezing and thawing under wet conditions.

It is essential to use proper and adequate curing techniques to reduce the permeability of the concrete. and enhance its durability by extending the hydration of the cement, particularly in its surface zone (see 13.5).

8.2.8 Concrete in Sea-water

Concrete in sea-water or exposed directly along the sea-coast shall be at least M 20 Grade in the. case of plain concrete and M 30 in case of reinforced concrete. The use of slag or pozzolana cement is advantageous under such conditions.

8.2.8.1 Special attention shall be given to the design of the mix to obtain the densest possible concrete; slag, broken brick, soft limestone, soft sandstone, or other porous or weak aggregates shall not be used.

8.2.8.2 As far as possible, preference shall be given to precast members unreinforced, wen-cured and hardened, without sharp corners, and having trowel smooth finished surfaces free Iron crazing, cracks or other defects; plastering should be avoided.

8.2.8.3 No construction joint< shal1 be allowed within 600 mm below low water-level or within 600 mm of the upper and lower planes of Wave action. Where unusually severe conditions or abrasion are anticipated, such parts of the work shall be protected by bituminous or silica-fluoride coatings or stone facing bedded with bitumen.

8.2.8.4 In reinforced concrete structures, care shall be taken to protect the reinforcement from exposure to saline atmosphere during storage, fabrication and use. It may be achieved by treating the surface of reinforcement with cement wash or by suitable methods.

9 . CONCRETE MIX PROPORTIONING

9.1 Mix Proportion

The mix proportions shall be selected to ensure the workability of the fresh concrete and when concrete is hardened, it shall have the required strength, durability and surface finish.

9.1.1 The determination of the proportions of cement, aggregates and water to attain the required strengths shall be made as follows:

a) By designing the concrete mix; such concrete shall be called 'Design mix concrete', or

b) By adopting nominal concrete mix; such concrete shall be called 'Nominal mix concrete'.

Design mix concrete is preferred to nominal mix. If design mix concrete cannot be used for any reason'on the work for grades of M 20 or lower, nominal mixes may be used with the permission of engineer-in-charge, which, however, is likely to involve a higher cement content.

9.1.2 Information Required

In specifying a particular grade of concrete, the following information shall be included:

a) Type of mix, that is, design mix concrete or nominal mix concrete;

b) Grade designation;

c) Type of cement;

d) Maximum nominal size of aggregate;

e) Minimum cement content (for design mix concrete);

f) Maximum water-cement ratio;

g) Workability;

h) Mix proportion (for nominal mix concrete);

j) Exposure conditions as per Tables 4 and 5;

k) Maximum temperature of concrete at the time of placing;

m) Method of placing; and

n) Degree of supervision.

9.1.2.1 In appropriate circumstances, the following additional information may be specified:

a) Type of aggregate,

b) Maximum cement content, and

c) Whether an admixture shall or shall not be used and the type of admixture and the condition of use.

9.2 Design Mix Concrete

9.2.1 As the guarantor of quality of concrete used in the 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 within the limitations of parameters and other stipulations laid down by this standard. If so desired, the employer shall be provided with supporting data including graphs showing strength versus water-cement ratio for range of proportions, complete trial mix proportioning details to substantiate the choice of cement content, fine and coarse aggregate content, water, mineral admixtures, chemical admixtures, etc..

9.2.2 The mix shall be designed to produce the grade of concrete having the required workability and a characteristic strength not less than appropriate values given in Table 2. 'Proportion/grading of aggregates shall be made by trial in such a way as to make densest possible concrete. The target mean strength of concrete mix should be equal to the characteristic strength plus 1.65 times the standard deviation.

9.2.3 Mix design done earlier not prior to one year may be considered adequate for later work provided there is no change in source and the quality of the materials.

9.2.4 Standard Deviation

The standard deviation for each grade of concrete shall be calculated, separately.

9.2.4.1 Standard deviation based on test strength of sample .

a) Number of test results of samples - The total number of test strength of samples required to constitute an acceptable record for calculation of standard deviation shall be not less than 30 . Attempts should be made to obtain the 30 samples, as early as possible, when a mix is used for the first time.

b) In case of significant changes in concrete When significant changes are made in the production of concrete batches (for example changes in the materials used, mix design, equipment or technical control), the standard deviation value shall be separately calculated for such batches of concrete.

c) Standard deviation to be brought up to date The calculation of the standard deviation shall be brought up to date after every change of mix design.

9.2.4.2 Assumed standard deviation

Where sufficient test results for a particular grade of concrete are not available, the value of standard deviation given in Table 8 may be assumed for design of mix in the first instance. As soon as the results of samples are available, actual calculated standard deviation shall be used and the mix designed properly. However, when adequate past records for a similar grade exit and justify to the designer a value of standard deviation different from that shown in Table 8, it shall be permissible to use that value.

Table 8 Assumed Standard Deviation	
(Clause 9.2.4.2 and Table 11)	
Grade of Concrete	**Assumed Standard Deviation (N/mm)**
M10	3.5
M15	
M20	4
M25	
M30	5
M35	
M40	
M45	
M50	
M60	
NOTE	
1. 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 N/mm^2.	
2 For grades above M 60, the standard deviation shall be established by actual trials based on assumed proportions, before finalizing the mix.	

9.3 Nominal Mix Concrete

Nominal mix concrete may be used for concrete of M 20 or lower. The proportions of materials for nominal mix concrete shall be in accordance with· Table 9.

9.3.1 The cement content of the mix specified in Table 9 for any nominal mix shall be proportionately increased if the quantity of water in a mix has to be increased to overcome the difficulties of placement and compaction so that the water-cementitious as specified is not exceeded.

10 PRODUCTION OF CONCRETE

10.1 Quality Assurance Measures

10.1.1 In order that the properties of the completed structure be consistent with the requirements and the assumptions made during the planning and the design, adequate quality assurance measures shall be taken. The construction should result in satisfactory strength, serviceability and long term durability so as to lower . the overall life-cycle cost. Quality assurance in construction activity relates to proper design. use of adequate materials and components to be supplied by the producers, proper workmanship in the execution of works by the contractor and ultimately proper care during the use of structure including timely maintenance and repair by the owner.

10.1.2 Quality assurance measures are both technical and organizational. Some common cases should be specified in a general Quality Assurance Plan which shall identify the key elements necessary to provide fitness of the structure and the means by which they are to be provided and measured with the overall purpose to provide confidence that the realized project will work satisfactorily in service fulfilling intended needs. The job of quality control and quality assurance would involve quality audit of both the inputs as well as the outputs. Inputs are in the form of materials for concrete; workmanship in all stages of batching, mixing, transportation, placing, compaction and curing; and the related plant, machinery and equipment resulting in the output in the form of concrete in place. To ensure proper performance, it is necessary that each step in concreting which will he covered by the ·next step is inspected as the work proceeds (see also 17).

Table 9 Proportions for Nominal Mix Concrete

(Clause 9.3 and 9.3.1)

Grade of Concrete	Total Quantity of Dry Aggregate by Mass per 50 kg of Cement, to be Taken as the Sum of the Individual Masses of Fine and Coarse Aggregates, kg, Mux	Proportion of Fine Aggregate to Coarse Aggregate (by Mass)	Quantity of Water per 50 kg of Cement, Max
1	2	3	4
M5	800	Generally 1:2 but subject to an upper limit of $1:1\frac{1}{2}$ and a tower limit of $1:2\frac{1}{2}$	60
M7.5	625		45
M10	480		34
M15	330		32
M20	250		30

NOTE

1. The proportion of the fine to coarse aggregates should be adjusted from upper limit to lower limit progressively as the grading of fine aggregates becomes finer and the maximum size of coarse aggregate becomes larger. Graded coarse aggregate shall be used.

2. Quantity of water required from durability point of view may be less than the value given above:

Example: For an average grading of fine aggregate (that is, Zone II of Table 4 of IS 383), the proportions shall be 1: $1\frac{1}{2}$, 1:2 and 1 :$2\frac{1}{2}$ for maximum size of aggregates 10 rom. 20 mm and 40 rom respectively.

10.1.3 Each party involved in the realization of a project should establish and implement a Quality Assurance Plan, for its participation in the project. Supplier's and subcontractor's activities shall be covered in the plan. The individual Quality Assurance Plans shall fit into the general Quality Assurance Plan. A Quality Assurance Plan shall define the tasks and responsibilities of all persons involved, adequate control and checking procedures, and the organization and maintaining adequate documentation of the building process and its results. Such documentation should generally include:

a) test reports and manufacturer's certificate for materials, concrete mix design details;

b) pour cards for site organization and clearance for, concrete placement;

c) record of site inspection of workmanship, field tests;

d) non-conformance reports, change orders;

e) quality control charts;

f) and statistical analysis.

NOTE- Quality control charts are recommended wherever the concrete is in continuous production over considerable period.

10.2 Batching

To avoid confusion and error in batching, consideration should be given to using the smallest practical number of different concrete mixes on any site Of in anyone plant. In batching concrete, the quantity of both cement and aggregate shall be determined by mass; admixture, if solid, by mass; liquid admixture may however be measured in volume or mass; water shall be weighed or measured by volume in a calibrated tank (see also IS 4925).

For large and medium project sites, the concrete shall be sourced from ready-mixed concrete plants or from captive on-site or off-site automatic batching and mixing plants. The concrete produced and supplied by ready mixed concrete plants shall be in accordance with IS 4926. In case of concrete from captive on-site or off-site automatic batching and mixing plants, similar quality control shall be followed.

10.2.1 The grading of aggregate should be controlled by obtaining the coarse aggregate in different sizes and blending them in the right proportions, the different sizes being stocked in separate stock-piles.

10.2.2 The accuracy of the measuring equipment shall be within ± 2 percent of the quantity of cement being 24 measured and within ± 3 percent of the quantity of aggregate, admixtures and water being measured. In a batching plant, the concrete production equipment shall be calibrated initially at the time of installation or reconditioning of the equipment and subsequently at the following intervals:

a) Mechanical knife edge systems: At least once every two months

b) Electrical/ load cell systems : At least once every three months.

10.2.3 Proportion/Type and grading of aggregates shall be made by trial in such a way so as to obtain densest possible concrete. All ingredients of the concrete should be used by mass except water and chemical admixture which may be by volume.

10.2.4 Volume batching may be allowed only where weigh-batching is not practical and provided accurate bulk densities of materials to be actually used in concrete have earlier been established. Allowance for bulking shall be made in accordance with IS 2386 (Part 3). The mass volume relationship should be checked as frequently as necessary, the frequency for the given job being determined by engineer-in-charge to ensure that the specified grading is maintained.

10.2.5 It is important to maintain the water-cement ratio constant at its correct value. To this end, determination of moisture contents in both fine and coarse aggregates shall be made as frequently as possible, the frequency for a given job being determined by the engineer-in-charge according to weather conditions. The amount of the added water shall be adjusted to compensate for any observed variations in the moisture contents. For the determination of moisture content in the aggregates, IS 2386 (Part 3) may be referred to. 'Where batching plants are used, it is recommended to determine moisture content by moisture probes fitted to the batching plants. To allow for the variation in mass of aggregate due to variation in their moisture content. suitable adjustments in the masses of aggregates shall also be made. In the absence of exact data, only in the case of nominal mixes, the amount of surface water may be estimated from the values given in Table 10.

Table 10 Surface Water Carried by Aggregate

(CIause 10.2.5)

Sr. No.	**Aggregate**	**Approximate Quantity of Surface Water**	
		Percent by Mass	l/m
1	2	3	4
1	Very wet sand	7.5	120
2	Moderately wet sand	5	80
3	Moist sand	2.5	40
4	Moist gravel or crushed rock	1.25-2.5	20-40
Coarser the aggregate. less the water it will carry,			

10.2.6 No substitutions in materials used on the work or alterations in the established proportions, except as permitted in 10.2.4 and 10.2.5 shall be made without additional tests to show that the quality and strength of concrete are satisfactory.

10.3 Mixing

Concrete shall be mixed in a mechanical mixer (IS 1791 and IS 12119). it 'shall be ensured that stationary or central mixers and truck mixers shall comply with the performance criteria of mixing efficiency as per IS 4634. Mixing efficiency test shall be performed at least once in a year.

10.3.1 As a guidance, the mixing time shall be at least 2 min for conventional free fall (drum) batch type concrete mixers. For other types of more efficient mixers, manufacturers' recommendations Shall he followed.

10.3.2 Workability should be checked at frequent intervals (see IS 1199).

10.3.3 Dosages of retarders, plasticisers and superplasticisers shall be restricted to 0.5, 1.0 and 2.0 percent respectively by weight of cementitious materials and unless a higher value is agreed upon between the manufacturer and the constructor based , on performance test.

11 FORMWORK

11.1 General

The form work shall be designed and constructed so as to remain sufficiently rigid during placing and compaction of concrete, and shall be such as to prevent loss of slurry from tbe concrete. For further details regarding design, detailing, etc, reference may be made to IS 14687. The tolerances on the shapes, lines and dimensions shown in the drawing shall be within the limits given below:

a)	Deviation from specified dimensions of cross section of columns and beams	+12 -5mm
b)	Deviation from dimensions of footings	
	1) Dimensions in plan	+50 -10mm
	2) Eccentricity	0.02 times the width of the footing in the direction of deviation but not more than 50mm
	3) Thickness	+50 -10mm or ± 0.05 times the specified thickness

These tolerances apply to concrete dimensions only, and not to positioning of vertical reinforcing steel or dowels.

11.2 Cleaning and Treatment of Formwork

All rubbish, particularly, chippings, shavings and sawdust shall be removed from the interior of the forms before the concrete is placed. The face of formwork in contact with the concrete shall be cleaned and treated with form release agent. Release agents should be applied so as to provide a thin uniform coating to the forms without coating the reinforcement.

11.3 Stripping Time

Forms shall not be released until the concrete has achieved a strength of at least twice the stress to which the concrete may be subjected at the time of removal of formwork. The strength referred to shall be that of concrete using the same cement and aggregates and admixture, if any, with the same proportions and cured under conditions of temperature and moisture similar to those existing on the work.

11.3.1 While the above criteria of strength shall be the guiding factor for removal of fmmwork, ill normal circumstances where ambient temperature does not fall below 15°C and following striking period may deem to satisfy the guideline given in **11.3:**

Sr. No.	Type of Formwork	For Concrete Made Using OPC	For Concrete Made Using Cement Other than OPC or Using Mineral Admixtures Like Fly Ash and Slag
i)	Vertical formwork to columns, walls, beams	16–24 h	16–24 h
ii)	Soffit formwork to slabs (Props to be refixed immediately after removal of formwork)	3 days	7 days
iii)	Soffit formwork to beams (Props to be refixed immediately after removal of formwork)	7 days	10 days
iv) 1)	Props to slabs: Spanning up to 4.5 m	7 days	10 days
iv) 2)	Props to slabs: Spanning over 4.5 m	14 days	14 days
v) 1)	Props to beams and arches: Spanning up to 6 m	14 days	14 days

v) 2)	Props to beams and arches: Spanning over 6 m	21 days	21 days

For lower temperature, the stripping time recommended above may be suitably modified.

11.3.1.1 In case of use of cements other than OPC or in case of use of mineral admixtures like fly ash and slag, in lieu of the minimum period specified in **11.3.1** col 3, the stripping of formwork may be done in accordance with the provisions of **11.3.1** col 2, provided concrete cube testing is done to ensure that the following minimum strength is achieved:

a) 3 days : 45 percent of specified strength

b) 7 days : 60 percent of specified strength

c) 14 days : 85 percent of specified strength

11.3.2 The number of props left under, their sizes and disposition shall be such as to be able to safely carry the full dead load of the slab, beam or arch as the case may be together with any live load likely to occur during curing or further construction.

11.3.3 Where the shape of the element is such that the formwork has re-entrant angles, the formwork shall be removed as soon as possible after the concrete has set, to avoid shrinkage cracking occurring due to the restraint imposed.

12 ASSEMBLY OF REINFORCEMENT

12.1 Reinforcement shall be bent and fixed in accordance with procedure specified in IS 2502. The high strength deformed steel bars should not be re-bent or straightened without the approval of engineer-in charge. Bar bending schedules shall be prepared for all reinforcement work.

12.2 All reinforcement shall be placed and maintained in the position shown in the drawings by providing proper cover blocks, spacers, supporting bars, etc.

12.2.1 Crossing bars should not be tack-welded for assembly of reinforcement unless permitted by engineer-in-charge.

12.3 Placing of Reinforcement

Rough handling, shock loading (prior to embedment) and the dropping of reinforcement from a height should be avoided. Reinforcement should be secured against displacement outside the specified limits.

12.3.1 Tolerances on Placing of Reinforcement Unless otherwise specified by engineer-in-charge, the reinforcement shall be placed within the following tolerances:

a)	for effective depth 200 mm or less	±10mm
b)	for effective depth more than 200mm	±15mm

12.3.2 Tolerance for Cover

Unless specified otherwise, actual concrete cover should not deviate from the required nominal cover ±10mm. Nominal cover as given in **26.4.1** should be specified to all steel reinforcement including links. Spacers between the links (or the bars where no links exist) and the form work should be of the same nominal size as the nominal cover.

Spacers, chairs and other supports detailed on drawings, together with such other supports as may be necessary, should be used to maintain the specified nominal cover to the steel reinforcement. Spacers or chairs should be placed at a maximum spacing of 1m and closer spacing may sometimes be necessary. Spacers, cover blocks should be of concrete of same strength or PVC.

12.4 Welded Joints or Mechanical Connections Welded joints or mechanical connections in reinforcement may be used but in all cases of important connections, tests shall be made to prove that the joints are of the lull strength of bars connected. Welding of reinforcements shall be done in accordance with the recommendations of IS 2751 and IS 9417.

12.5 Where reinforcement bars up to 12 mm for high· strength deformed steel bars and up to 16 mm for mild steel bars are bent aside at construction joints and afterwards bent back into their original positions, care should be taken to ensure that at no time is the radius of the bend less than 4 bar diameters for plain mild steel or 6 bar diameters for deformed bars. Care shall also be taken when bending back bars, to ensure that the concrete around the bar is not damaged beyond the band.

12.6 Reinforcement should be placed and tied in such a way that concrete placement be possible without segregation of the mix. Reinforcement placing should allow compaction by immersion vibrator. Within the concrete mass, different types of metal in contact should be avoided to ensure that bimetal corrosion does not take place.

13 TRANSPORTING, PLACING, COMPACTION AND CURING

13.1 Transporting and Handling

After mixing, concrete shall be transported to the formwork as rapidly as possible by methods which will prevent the segregation or loss of any of the ingredients Of ingress of foreign matter or water and maintaining the required workability.

13.1.1 During hot or cold weather, concrete shall be transported in deep containers. Other suitable methods to reduce the loss of water by evaporation in hot weather and heat loss in cold weather may also be adopted.

13.2 Placing

The concrete shall be deposited. as nearly as practicable in its final position to avoid rehandling. The concrete shall be placed and compacted before initial setting of concrete commences and should not be subsequently disturbed. Methods of placing should be such as to preclude segregation. Care should be taken to avoid displacement of reinforcement or movement of form work. As a general guidance, the maxi mum permissible free fall of concrete may be taken as 1.5 m.

13.3 Compaction

Concrete should be thoroughly compacted and fully worked around the reinforcement, around embedded fixtures and into corners of the formwork.

13.3.1 Concrete shall be compacted using mechanical vibrators complying with IS 2505, IS 2506, IS 2514 and IS 4656.

Whenever vibration has to be applied externally, the design of formwork and the disposition of vibrators should receive special consideration to ensure efficient compaction and to avoid surface blemishes.

13.4 Construction Joints and Cold Joints

Joints are a common source of weakness and, therefore, it is desirable to avoid them. If this is not possible, their number shall be minimized. Concreting shall be carried out continuously up to construction joints, the position and arrangement of which shall be indicated by the designer.

Construction joints shall be placed at accessible locations to permit cleaning out of laitance, cement slurry and unsound concrete, in order to create rough/ uneven surface. It is recommended to clean out laitance and cement slurry by using wire brush on the surface of joint immediately after initial setting of concrete and to clean out the same immediately thereafter. The prepared surface should be in a clean saturated surface dry condition when fresh concrete is placed, against it.

In the case of construction joints at locations where the previous pour has been cast against shuttering the recommended method of obtaining a rough surface for the previously poured concrete is to expose the aggregate with a high pressure water jet or any other appropriate means.

Fresh concrete should be thoroughly vibrated near construction joints so that mortar from the new concrete flows between large aggregates and develop proper bond with old ~pncrete. . Where high shear resistance is required at the construction joints, shear keys may be provided. Sprayed curing membranes and release agents should be thoroughly removed from joint surfaces.

13.5 Curing

Curing is the process of preventing the loss of moisture from the concrete .whilst maintaining a satisfactory temperature regime. The prevention of moisture loss from the concrete is particularly important if the water cement ratio is low, if the cement has a high rate of strength development, if the concrete contains granulated blast furnace slag or pulverised fuel .sh. The curing regime should also prevent the development of high temperature gradients within the concrete.

The rate of strength development at early ages of concrete made with super sulphated cement is significantly reduced at lower temperatures. Super sulphated cement concrete is seriously affected by inadequate curing and the surface has to be kept moist for at least seven days.

13.5.1 Moist Curing

Exposed surfaces of concrete shall be kept continuously in a damp or wet condition by ponding or by covering with a layer of sacking, canvas, hessian or similar materials and kept constantly wet for at least seven days from the date of placing concrete in case of ordinary Porthind Cement and at least 10 days where mineral admixtures or blended cements are used. The period of curing shall not be less than 10 days for concrete exposed to dry and hot weather conditions. In the case of concrete where mineral admixtures or blended cements are used, it is recommended that above minimum periods may be extended to 14 days.

13.5.2 Membrane Curing

Approved curing compounds may be used in lieu of moist curing with the permission of the engineer-in charge. Such compounds shall be applied to all exposed surfaces of the concrete as soon as possible after the concrete has set. Impermeable membranes such as polyethylene sheeting covering closely the concrete surface may also be used to provide effective barrier against evaporation.

13.6 Supervision

It is exceedingly difficult and costly to alter concrete once placed. Hence, constant and strict supervision of all the items of the construction is necessary during the progress of the work, including the proportioning and mixing of the concrete. Supervision is also of extreme importance to check the reinforcement and its placing before being covered.

13.6.1 Before any important operation; such as concreting or stripping of the formwork is 'started adequate notice shall be given to the construction supervisor.

14 CONCRETING UNDER SPECIAL' CONDITIONS

14.1 Work in Extreme Weather Conditions During hot or cold weather, the concreting should be done as per the procedure set out in IS 7861 (Part I) or IS 7861 (Part 2).

14.2 Under-Water Concreting

14.2.1 When it is necessary to deposit concrete under water, the methods, equipment, materials and proportions of the mix to be used shall be submitted to and approved by the engineer-in-charge before the work is started.

14.2.2 Under-water concrete should have a slump recommended in **7.1.** The water-cement ratio shall not exceed 0.6 for plain conc. and 0.5 for R.C.C and may need to be smaller, depending on the grade of concrete or the type of chemical attack. For aggregates of 10mm, 20mm & 40 mm maximum particle size, the cement content shall be at least 420kg/m^3, 380kg/m^3 & 350 kg/m^3 concrete.

14.2.3 Coffer-dams or forms shall be sufficiently tight to ensure still water if practicable, and in any case to reduce the flow of water to less than 3m/min through the space into which concrete is to be deposited. Coffer-dams or forms in still water shall be sufficiently tight to prevent loss of mortar through the walls. De-watering by pumping shall not be done while concrete is being placed or until 24 h thereafter.

14.2.4 Concrete cast under water should not fall freely through the water. Otherwise it may be leached and become segregated. Concrete shall be deposited continuously until it is brought to the required height. While depositing, the top surface shall b. kept as nearly level as possible and the formation of seams avoided. The methods to be used for depositing concrete under water shall be one of the following:

a) Tremie-The concrete is placed through vertical pipes the lower end of which is always inserted sufficiently deep into the concrete which has been placed previously but has not set. The concrete emerging from the pipe pushes the material that has already been placed to the side and upwards and thus does not come into direct contact with water.

When concrete is to be deposited under water by means of tremie, the top section of the tremie shall be a hopper large enough to hold one entire batch of the mix or the entire contents the transporting bucket, if any. The tremie pipe shall be not less than 200 mm in diameter and shall be large enough to allow a free flow of concrete and strong enough to withstand the external pressure of the water in which it is suspended, even if a partial vacuum develops inside the pipe. Preferably, flanged steel pipe of adequate strength for the job should be used. A separate lifting device shall be provided for each tremie pipe with its hopper at the upper end. Unless the lower end of the pipe is equipped with an approved automatic check valve, the upper end of the pipe shall be plugged with a wadding of the gunny sacking or other approved material before delivering the concrete to the tremie pipe through the hopper, so that when the concrete is forced down from the hopper to the pipe, it will force the plug (and along with it any water in the pipe) down the pipe and out of the bottom end, thus establishing a continuous stream of concrete. It will be necessary to raise slowly the tremie in order to cause a uniform flow of the concrete, but the tremie shall not be emptied so that water enters the pipe. At all times after the placing of concrete is started and until all the concrete is placed, the lower end of the tremie pipe shall be below the top surface of the plastic concrete. This will cause the concrete to build up from below instead of flowing out over the surface, and thus avoid formation of laitance layers. If the 'charge in the Iremie is lost while depositing, the tremie shall be raised above ihe concrete surface, and unless sealed by a check valve, it shall be re-plugged at the top end, as at the beginning, before refilling for depositing concrete.

b) Direct placement with pumps-As in the case of the tremie method, the vertical end piece of the pipe line is always inserted sufficiently deep into the previously cast concrete and should not move to the side during pumping.

c) Drop bottom bucket -The top of the bucket shall be covered with a canva, flap. The bottom doors shall open freely downward and outward when tripped. The bucket shall be filled completely and lowered slowly to avoid backwash. The bottom doors shall not be opened until the bucket rests on the surface upon which the concrete is to be deposited and when discharged, shall be withdrawn slowly until well above the concrete.

d) Bags -- Bags of at least 0.028 m' capacity of jute or other coarse cloth shall be filled about two-thirds full of concrete, the spare end turned under so that bag is square ended and securely tied. They shall be placed carefully in header and stretcher courses so that the whole mass is interlocked. Bags used for this purpose shall be free from deleterious materials.

e) Grouting-A series of round cages made from 50 mm mesh of 6 mm steel and extending over the full height to be concreted shall be prepared and laid vertically over the area to be concreted so that the distance between centres of the cages' and also to the faces of the concrete shall not exceed one metre. Stone aggregate of not less than 50 mm nor more than 200 mm size shall be deposited outside the steel cages over the full area and height to be concreted with due care to prevent displacement of the cages.

A stable 1:2 cement-sand grout with a water cement ratio of not less than 0.6 and not more than 0.8 shall be prepared in a mechanical mixer and sent down under pressure (about 0.2 N/mm^2) through 38 to 50 mm diameter pipes terminating into steel cages, about 50mm above the bottom of the concrete. As the grouting proceeds, the pipe shall be raised gradually up to a height of not more than 6 000 mm above its starting level after which it may be withdrawn and placed into the next cage for further grouting by the same procedure.

After grouting the whole area for a height of about 600 mm, the same operation shall be repeated, if necessary, for the next layer of 600 mm and so on.

The amount of grout to be sent down shall be sufficient to fill all the voids which may be either ascertained or assumed as 55 percent of the volume to be concreted.

14.2.5 To minimize the formulation of laitance, great care shall be exercised not to disturb the concrete as far as possible while it is being deposited.

15 SAMPLING AND STRENGTH OF DESIGNED CONCRETE MIX

15.1 General

Samples from fresh concrete shall be taken as per IS 1199 and cubes shall be made, cured and tested at 28 days in accordance with IS 516.

15.1.1 In order to get a relatively quicker idea of the quality of concrete, optional tests on beams for modulus of rupture at 72 ± 2 h .or at 7 days, or compressive strength tests at 7 days may be carried out in addition to 28 days compressive strength test. For this purpose the values should be arrived at based on actual testing. In all cases, the 28 days compressive strength specified in Table 2 shall alone be the criterion for acceptance or rejection of the concrete in accordance with 16.

15.2 Frequency of Sampling

15.2.1 Sampling procedure

A random sampling procedure shall he adopted to ensure that each concrete batch shall have a reasonable chance of being tested that is, the sampling should he spread over the entire period of concreting and cover all mixing units.

15.2.2 Frequency The minimum frequency of sampling of concrete of each grade shan be in accordance with the following:

Quantity of Concrete in the work, m^3	Number of Samples
1-5	1
6 – 15	2
16 – 30	3
31 – 50	4
51 and above	4plus one additional sample for each additional $50m^3$ or part thereof

Note - At least one sample shall be taken from each shift. Where concrete is produced at continuous production unit, such as ready mixed concrete plant, frequency of , sampling may be agreed upon mutually by suppliers and purchasers.

15.3 Test Specimen

Three test specimens shall be made for each sample for testing at 28 days. Additional specimen may be required for various purposes such as to determine the strength of concrete at 7 days or at the time of striking the formwork, or to determine the duration of curing, or to check the testing error. Additional specimen may also be required for testing specimen cured by accelerated methods as described in IS 9103. The specimen shall be tested as described in IS 516.

15.4 Test Results of Sample

The test results of the sample shall be the average of the strength of three specimens. The individual variation should not be more than ±15 percent of the average. If more, the test results of the sample are invalid.

16 ACCEPTANCE CRITERIA

16.1 Compressive Strength

The concrete shall be deemed to comply with the strength requirements when both the following condition are met:

a) The mean strength determined from any group of four consecutive test results compiles with the appropriate limits in col 2 of Table II.

b) Any individual test result complies with the appropriate limits in col 3 of Table 11.

16.2 Flexural Strength

When both the following conditions are met, me concrete complies with the specified flexural strength.

a)The mean strength determined from any group of four consecutive test results exceeds the specified characteristic strength by at least 0.3 N/mm^2.

b) The strength determined from any test result is not less than the specified characteristic strength less 0.3N/mm'.

16.3 Quantity of Concrete Represented by Strength Test Results .

The quantity of concrete represented by a group of four consecutive non overlappinng test results shall include the batches from which the first and last samples were taken together with all intervening batches.

For the individual test result requirements given in col 3 of Table 11 or in item (b) of **16.2**, only the particular batch from which the sample was taken shall be at risk. Where the mean rate of sampling is not specified the maximum quantity of concrete that four consecutive test results represent shall be limited to 60 m^3.

16.4 If the concrete is deemed not to comply persuant to 16.1 or 16.2 as the case may be, the structural adequacy of the parts affected shall be investigated (see 17) and any consequential action as needed shall be taken.

16.5 Concrete of each grade shall be assessed separately.

16.6 Concrete is liable to be rejected if it is porous or honey-combed. its placing has been interrupted without providing a proper construction joint. the reinforcement has been displaced beyond the tolerances specified, or construction tolerances have not been mel. However. the hardened concrete may be accepted after carrying out suitable remedial measures to the satisfaction of the engineer· in-charge.

17 INSPECTION AND TESTING OF STRUCTURES

17.1 Inspection

To ensure that the construction complies with the design an inspection procedure should be set up covering materials, records, workmanship and construction.

17.1.1 Tests should be made on reinforcement and the constituent materials of concrete in accordance with the relevant standards. Where applicable. use should be made of suitable quality assurance schemes.

17.1.2 Care should be taken to see that:

a) design and detail are capable of being executed to a suitable standard. with due allowance for dimensional tolerances;

b) there are clear instructions on inspection standards;

c) there are clear instructions on permissible deviations;

d) elements critical to workmanship, structural performance, durability and appearance are identified; and

e) there is a system to verify that the quality is satisfactory in individual parts of the structure, especially the critical ones.

17.2 Immediately after stripping the formwork, all concrete shall be carefully inspected and any defective work or small defects either removed or made good before concrete has thoroughly hardened.

17.3 Testing

In case of doubt regarding the grade of concrete used, either due to poor workmanship or based on results of cube strength tests, compressive strength tests of concrete on the basis of17.4 and for load test (see 17.6) may be carried out.

17.4 Core Test

17.4.1 The points from which cores are to be taken and the number of cores required shall be at the discretion of the engineer-in-charge and shall be representative of the whole of concrete concerned. In no case, however, shall fewer than three cores be tested.

17.4.2 Cores shall be prepared and tested as described in IS 516.

17.4.3 Concrete in the member represented by a core test shall be considered acceptable if the average equivalent cube strength of the cores is equal to at least 85 percent of the cube strength of the grade of concrete specified for the corresponding age and no individual core has a strength less than 75 percent.

17.6 Load Tests for Flexural Member

17.6.1 Load tests should be carried out as soon as possible after expiry of 28 days from the time of placing of concrete.

Table 11 Characteristic Compressive Strength Compliance Requirement

(Clauses 16.1 and 16.3)

Specified Grade	**Mean of the Group of 4 Non - Overlapping Consecutive Test Results in N/mm^2**	**Individual Test Results in N/mm^2**
M15 and above	$\geq f_{ck}$ + 0.825X established standard deviation (rounded off to nearest 0.5 N/mm^2) or f_{ck} + 3 N/mm^2 , whichever is greater	$\geq f_{ck}$ - 3 N/mm^2

1. In the absence of established value of standard deviation, the values given in Table 8 may be assumed, and attempt should be made to obtain results of 30 samples as early as possible to establish the value of standard deviation.

2. For concrete of quantity up to 30 m3 (where the number of samples to be taken is less than four as per the frequency of sampling given in 15.2.2), the mean of test results of all such samples shall be f_{ck} + 4 N/mm^2 , minimum and the requirement of minimum individual test-results shall be f_{ck} - 2N/mm^2 minimum. However if when the number of sample is only one as per .15.2.2, the requirement shall be f_{ck} + 4N/mm^2, minimum.

17.6.2 The structure should be subjected to a load equal to full dead load of the structure plus 1.25 times the imposed load for a period of 24 h and then the imposed load shall be removed.

> **NOTE**-Dead load includes self weight of the structural members plus weight of finishes and walls or partitions, if any, as considered in the design.

17.6.3 The deflection due to imposed load only shall be recorded. If within 24 h of removal of the imposed load, the structure does not recover at least 75 percent of the deflection under superimposed load, the test may be repeated after a lapse of 72 h. If the recovery is less than 80 percent, the structure shall be deemed to be unacceptable.

17.6.3.1 If the maximum deflection in mm, shown during 24 h under load is less than $40l^2/ D$, where I is the effective span in m; and D, the overall depth of the section in rom, it is not necessary for the recovery to be measured and the recovery provisions of **17.6.3** shall not apply.

17.7 Members Other Than Flexural Members

Members other than flexural members should be preferably investigated by analysis.

17.8 Non-destructive Tests

Non-destructive tests are used to obtain estimation of the properties of concrete in the structure. These methods include ultrasonic pulse velocity [see IS 13311 (Part 1)] and rebound hammer [IS 13311 (Part 2)], probe penetration, pullout and maturity. Non-destructive tests methods are also core tests for estimating the strength of concrete in a structure, or can supplement the data obtained from a limited number of cores. These methods are useful in measuring a concrete property that bears some relationship to strength. The accuracy of these methods, in part, is determined by the degree of correlation between strength and the physical quantity measured by the test method.

Any of these methods may be adopted, in which case the acceptance criteria shall be agreed upon prior to testing.