

Chapter 4

REINFORCED CEMENT CONCRETE WORK

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CHAPTER 4: REINFORCED CEMENT CONCRETE WORK

List of Relevant Bureau of Indian Standard Codes to be followed

1	IS: 226	Structural Steel
2	IS: 432 (Part I)	Specification for mild steel and medium tensile steel bars and hard drawn steel wire for concrete reinforcement – Part I mild steel and medium tensile steel bars.
3	IS: 432 (Part II)	Specification for mild steel and medium tensile steel bars and hard drawn steel wire for concrete reinforcement – Part II Hard drawn steel wire
4	IS: 456	Code of Practices for Plain and Reinforced concrete
5	IS: 516	Method of test for strength of concrete
6	IS: 1566	Specification for hard-drawn steel wire fabric for Concrete Requirement
7	IS: 1599	Method for bend test
8	IS: 1608	Method for tensile testing of steel products
9	IS: 1786	Specification for high strength deformed steel and wires for concrete reinforcement
10	IS: 2502	Code of practice for bending and fixing of bars for concrete reinforcement
11	IS: 2751	Recommended practice for welding of mild steel plain and deformed bars for reinforced construction
12	IS: 4925	Batch Plants Specification for concrete batching and mixing plant
13	IS: 6523	Specification for pre-cast reinforced concrete door, window frames

4.0 GENERAL

Reinforced cement concrete work may be cast-in-situ or pre-cast as may be directed by the Engineer according to the nature of work. Reinforced cement concrete work shall comprise the following which may be paid separately or collectively as per the description of the item of work.

- a) Form work (Centering and Shuttering)
- b) Reinforcement
- c) Concreting: 1) Cast-in-situ 2) Pre-cast

4.1 MATERIALS

4.1.1 Water, cement, fine and coarse aggregate shall be as specified under respective clauses of chapter 11 – Building works and chapter 3 - Plain Cement Concrete work, as applicable.

4.1.2 Steel for reinforcement

No reinforcement shall be placed in position until the Engineer inspects the form work and the defects if any, in placement are rectified.

Reinforcement shall be high strength deformed bars as per I.S. 1786. Reinforcement of less than 8mm rods shall be plain steel Grade 1 as per IS 432. Wire mesh shall be in accordance with I.S. 1566. Substitution of reinforcement will not be permitted except upon written approval by the Engineer.

4.1.2.1 The steel used for reinforcement shall be any of the following types:

- a) Mild steel and medium tensile bars conforming to IS 432 (Part I)
- b) High strength deformed steel bars conforming to IS: 1786
- c) Hard drawn steel wire fabric conforming to IS: 1566
- d) Structural steel conforming to Grade A of IS: 2062

4.1.2.2 Types and Grades

Reinforcement supplied in accordance with this standard shall be classified into following types:

- a) Mild steel bars: It shall be supplied in the following two grades
 - i) Mild steel bars grade I designated as Fe 410-S
 - ii) Mild steel bars grade II designated as Fe 410-O
- b) Medium tensile steel bars, grade II designated as Fe 540-W-HT.

4.1.2.3 Mild steel and Medium tensile steel

Physical requirement are given in the following Table 4.1.

TABLE 4.1: Physical Requirements for Steel Reinforcement

Sl. No.	Type and nominal size of bar	Ultimate tensile stress N/mm ² minimum	Yield stress N/mm ² minimum	Elongation per cent minimum
1.	Mild steel grade I			
	For bars up to and including 20mm.	410	250	23
	For bars over 20mm up to and including 50mm	410	240	23
2.	Mild steel grade II			
	For bars up to and including 20mm.	370	225	23
	For bars over 20mm, up to and including 50mm	370	215	23
3.	Medium tensile steel			
	For bars up to & including 16mm	540	350	20
	For bars over 16mm, up to and including 32mm	540	340	20
	For bars over 32mm, up to and including 50mm	510	330	20

Elongation Percent on gauge length $5.65 \times \text{square root of 'so'}$ where 'so' is the cross sectional area of the test piece.

- Note 1.** Grade (II) Mild steel bars are not recommended for the use in structures located in earthquake zone subjected to severe damage and for structures subjected to dynamic loading (other than wind loading) such as railway and highway bridges.
- 2.** Welding of reinforcement bars covered in this specification shall be done in accordance with the requirements of IS: 2751.

Nominal mass / weight: The tolerance on mass/weight for round and square bars shall be percentage given in Table 4.2 of the mass/ weight calculated on the basis of density 0.785 kg/cm³ or 0.00785 kg/mm³.

TABLE 4.2: Tolerance on Nominal Mass

Nominal size in mm	Tolerance on the nominal mass percent		
	Batch	Individual sample +	Individual sample for coil (-x-)
a) up to and including 10	+7	+8	+8
b) Over 10, up to and including 16	+5	-6	+6
c) over 16	+3	-4	+4

+ for individual sample plus tolerance is not specified

(x) for coil batch tolerance is not applicable

Tolerance shall be determined in accordance with method given in IS 1786.

Tests - Following type of lab test shall be carried out

1. Tensile Tests
This shall be done as per IS 1608
2. Bend Test
This shall be done as per IS 1599
3. Test on deformed bars
This shall be done as per IS 1786

Should any one of the test pieces first selected fail to pass any of the tests specified above, two further samples shall be selected for testing with respect to each failure. Should the test pieces from both these additional samples pass, the materials represented by the test samples shall be deemed to comply with the requirement of the particular test. Should the test piece from either of these additional samples fail, the material represented by the test samples shall be considered as not having complied with standard.

4.1.2.4 High strength deformed bars & wires shall conform to IS: 1786. The physical properties for all sizes of steel bars are mentioned below in Table 4.3.

TABLE 4.3: Physical Properties of Reinforcing bars

Sl. No.	Property	Grade		
		Fe 415	Fe 500	Fe 550
1.	0.2% proof Stress/yield stress, min. N/mm ²	415	500	550
2.	Elongation, percent min on gauge length 5.65 A°, Where A is the Cross Sectional Area of the test piece	14.5	12	8
3.	Tensile strength	10% more than actual 0.2% proof stress but not less than 465 N/mm ²	8% more than actual 0.2% proof stress but not less than 545 N/mm ²	6% more than actual 0.2% proof stress but not less than 585 N/mm ²

4.1.3 Stacking and storage

- (a) The reinforcement shall not be kept in direct contact with the ground but stacked on top of an arrangement of timber sleepers or the like.
- (b) If the reinforcing rods have to be stored for a long duration, they shall be coated with cement wash before stacking and/or to be kept under cover or stored as directed by the Engineer.
- (c) Fabricated reinforcement (rebars) shall be carefully stored to prevent damage, distortion, corrosion and deterioration. Corroded reinforcement shall not be used under any circumstances. Spalling of concrete takes place later.

4.1.4 Measurements

4.1.4.1 Classification of Measurements

Where it is stipulated that the form work shall be paid for separately, measurements shall be taken of the area of shuttering in contact with the concrete surface. Dimensions of the form work shall be measured correct to a cm.

- 4.1.4.2 Centering, and shuttering where exceeding 3.5 metre height in one floor shall be measured and paid for separately.
- 4.1.4.3 Where it is not specifically stated in the description of the item that form work shall be paid for separately, the rate of the RCC item shall be deemed to include the cost of form work.
- 4.1.4.4 No deductions from the shuttering due to the openings/obstructions shall be made if the area of such openings/obstructions does not exceed 0.1 square metre. Nothing extra shall be paid for forming such openings.
- 4.4.4.5 Rate: The rate of the form work includes the cost of labour and materials required for all the operations described above.

4.2 REINFORCEMENT

4.2.1 General requirements: Steel should conform to para 4.1.2.

4.2.1.1 No re-rolled material shall be accepted. The Contractor shall submit the manufacturer's test certificate for the steel. Random Tests on steel supplied by the Contractors may be performed by the Engineer as per relevant Indian Standards. Bars containing cracks or splits shall be rejected. Steel not conforming to specifications shall be rejected. Rods shall be bent through 180 degrees to check whether the steel is sufficiently elastic or not. If it cannot be bent through 180 degrees, it shall be rejected. Such steel may cause serious accidents to the bar bends.

4.2.1.2 All reinforcements shall be clean, free from grease, paint, dirt, loose mill scale, loose rust, dust, bituminous material or any other substances that will destroy or reduce the bond. All rods shall be thoroughly cleaned before being fabricated. Pitted and defective rods shall not be used. No welding of rods to obtain continuity shall be allowed unless approved by the Engineer. If welding is approved, the work shall be carried out as per I.S.2751 according to the best modern practices and as directed by the Engineer. In all cases of important connections, tests shall be made to prove that the points are of full strength of bars welded. Special precautions, as specified by the Engineer, shall be taken in the welding of cold worked reinforcing bars and bars other than mild steel.

4.2.1.2.1 Assembly of Reinforcement: Bars shall be bent correctly and accurately to the size and shape as shown in the detailed drawing or as directed by Engineer. Preferably bars of full length shall be used.

4.2.1.2.2 **Bonds and Hooks Forming End Anchorages:** Reinforcement shall be bent and fixed in accordance with procedure specified in IS 2502, code of practice for bending and fixing of bars for concrete reinforcement.

4.2.1.2.3 Bending

Reinforcement bars supplied bent or in coils, shall be straightened before they are cut to size. Straightening of bars shall be done cold and without damaging the bars.

All bars shall be accurately bent according to the sizes and shapes shown on the approved detailed working drawings / bar bending schedules. Reinforcing bars shall not be straightened and rebent in a manner that will injure the material. They shall be bent cold, except bars of over 25mm in diameter which may be bent hot if specifically approved by the Engineer. Bars which depend for their strength on cold working, shall not be bent hot. Bars bent hot shall not be treated beyond cherry red colour (nor exceeding 845 degree C) and after bending, shall be allowed to cool slowly without quenching. Bars incorrectly bent shall be used only if the means used for straightening and rebending be such as shall not, in the opinion of the Engineer, injure the material. No reinforcement shall be bent when in position in the work without approval, whether or not it is partially embedded in hardened concrete. Bars having links or bends other than those required by design shall not be used.

4.2.1.2.4 Laps

Laps and splices for reinforcement shall be as per IS: 456. Splices in adjacent bars shall be staggered and the locations of all splices shall be approved by the Engineer. No laps should be provided at

- i). Bottom bars at centre of the span.
- ii). Top of supports of beams and slabs.

Staggering of laps for longitudinal steel shall be followed.

4.2.1.3 Anchoring Bars in Tension

Deformed bars may be used without end anchorages provided development length requirement is satisfied, Hooks should normally be provided for plain bars in tension. Development length of bars will be determined as per IS: 456

4.2.1.4 Anchoring Bars in Compression

The anchorage length of straight bar in compression shall be equal to the 'Development length' of bars in compression as specified in IS: 456

4.2.1.5 For binders, stirrups, and links, the straight portion beyond the curve at the end shall be not less than eight times and nominal size of bar.

4.2.1.6 Welding of Bars

Wherever facility for electric arc welding is available, welding of bars shall be done in lieu of overlap. The location and type of welding shall be got approved by the Engineer. Welding shall be as per IS: 2751 and IS 9417.

4.2.2 Placing in Position

4.2.2.1 Fabricated reinforcement bars shall be placed in position as shown in the drawings or as directed by the Engineer. The bars crossing one another shall be tied together at every intersection with two strands of annealed steel wire 0.9 to 1.6 mm thickness twisted tight to make the skeleton of the steel work rigid so that the reinforcement does not get displaced during deposition of concrete.

Tack welding in crossing bars shall also be permitted in lieu of binding with steel wire if approved by Engineer.

4.2.2.2 The bars shall be kept in correct position by the following methods:

- a) In case of beam and slab construction precast cover spacer blocks in cement mortar 1:2 (1 cement : 2 coarse sand) about 4cm x 4cm section and of thickness equal to the specified cover shall be placed between the bars and shutterings, so as to secure and maintain the requisite cover of concrete over reinforcement.
- b) In case of cantilevered and doubly reinforced beams or slabs, the vertical distance between the horizontal bars shall be maintained by introducing 8 mm dia M.S. Steel rod spacer chairs, at 1.0 metre or at shorter spacing to avoid sagging.
- c) In case of other R.C.C. structure such as arches, domes, shells, storage tanks etc. a combination of cover blocks, spacers and templates shall be used as directed by the Engineer.

4.2.2.3 Cover:

Unless indicated otherwise, clear concrete cover for the reinforcement (exclusive of plaster or other decorative finish) shall be as follows:

At each end of reinforcement bar not less than 25mm, nor less than twice the diameter of bar.

- a) For a longitudinal reinforcing bar in a column, not less than 40mm, nor less than diameter of the bar. In case of columns of minimum dimension of 20 cm or under with reinforcing bars of 12mm and less in diameter, a cover of 25mm may be used.

- b) For longitudinal reinforcing bars in a beam, not less than 25mm, nor less than the diameter of the bar.
- c) For tensile, compressive, shear or other reinforcement in a slab, or wall, not less than 13mm nor less than the diameter of such reinforcement.
- d) For any other reinforcement, not less than 13mm nor less than the diameter of such reinforcement.
- e) For footing and other principal structural members in which the concrete is poured on a layer of lean concrete, the bottom cover shall be 50 mm.
- f) For concrete surfaces exposed to earth after removal of forms, such as retaining walls, grade beams, footing sides and tops, etc., not less than 50mm for bars larger than 16mm diameter and not less than 40mm for bars 16mm diameter or smaller.
- g) For liquid retaining structures, the minimum cover to steel shall be 50 mm or the diameter of the main bar, whichever is greater. In the presence of soils and water of a corrosive nature and coastal towns, the cover shall be increased by 10mm.
- h) The correct cover shall be maintained by cement mortar cubes or other approved means. Reinforcement for footings, grade beams and slabs on sub-grade shall be supported on pre-cast concrete blocks as approved by the Engineer. The use of pebbles or stones shall not be permitted.
- i) The 28-day crushing strength of cement mortar cubes / pre-cast concrete cover blocks shall be at least equal to the specified strength of concrete in which these cubes/blocks are embedded.
- j) The minimum clear distance between reinforcing bars shall be inspected in accordance with IS 456.

4.2.2.4 Tolerance on Placing of Reinforcement

Unless otherwise specified by the Engineer, reinforcement shall be placed within the following tolerances:

Tolerance in spacing

- | | |
|------------------------------------------|--------|
| a) For effective depth, 200 mm or less | +10 mm |
| b) For effective depth, more than 200 mm | +15 mm |

4.2.2.5 Bending at Construction Joints

Where reinforcement bars are bent aside at construction joints and afterwards bent back into their original position care should be taken to ensure that at no time the radius of the bend is 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 bars is not damaged.

4.2.3 Measurement

Reinforcement including authorized spacer bars and laps shall be measured in length of different diameters, as actually (not more than as specified in the drgs.) used in the work nearest to a centimeter and their weight calculated on the basis of standard weight given in Table 4.4 below. Wastage and unauthorized overlaps shall not be paid for. Annealed steel wire required for binding or tack welding shall not be measured, its cost being included in the rate of reinforcement.

Wherever tack welding is used in lieu of binding, such welds shall not be measured. Chairs separators etc, shall be provided as directed by the Engineer and measured separately and paid for.

TABLE 4.4: Cross Sectional Area and Mass of Steel Bar

Nominal Size mm	Cross Sectional Area Sq. mm	Mass per metre Run Kg
6	28.3	0.222
7	38.5	0.302
8	50.3	0.395
10	78.6	0.617
12	113.1	0.888
16	201.2	1.58
18	254.6	2.00
20	314.3	2.47
22	380.3	2.98
25	491.1	3.85
28	616.0	4.83
32	804.6	6.31
36	1018.3	7.99
40	1257.2	9.85
45	1591.1	12.50
50	1964.3	15.42

Note: These are as per clause 5.2 of IS 1786

- 4.2.3.1 Rate:** The rate for reinforcement shall include the cost of labour and materials required for all operations described above such as cleaning of reinforcement bars, straightening, cutting, hooking, bending, binding, placing in position etc. as required or directed including tack welding on crossing of bars in lieu of binding with wires.

4.3 CONCRETING

- 4.3.1** The concrete shall be as specified under Chapter 3 Plain Cement Concrete Work. The proportion by volume or by weight of ingredients shall be as specified.

- 4.3.2 Consistency:** The concrete which will flow sluggishly into the forms and around the reinforcement without any segregation of coarse aggregate from the mortar, shall be used. The consistency shall depend on whether the concrete is vibrated on or hand tamped. It shall be determined by slump test.

4.3.3 Strength of Concrete

The compressive strength on work tests for different mixes shall be as given in Table 4.5 below:-

TABLE 4.5: Compressive Strength of Mixes.

Concrete Grade	Compressive Strength in (Kg/sq cm)	
	7 days'	28 days'
M25	210	250
M20	175	200

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.

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.

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

No construction joints shall 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 silico-fluoride coatings or stone facing bedded with bitumen.

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.

CONCRETE MIX PROPORTIONING

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.

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.

Design Mix Concrete

As the guarantor of quality of concrete used in the construction, the constructor shall carry out the mix design and the mix to 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.

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 A. The target mean strength of concrete mix should be equal to the characteristic strength plus 1.65 times the standard deviation.

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.

TABLE A: Grades of Concrete

Group	Grade Designation	Specified Characteristic compressive strength of 150 mms Cube at 28 days in N/mm ²
(1)	(2)	(3)
Ordinary Concrete	M 10	10
	M 15	15
	N 20	20
Standard Concrete	M 25	25
	M 30	30
	M 35	35

Group	Grade Designation	Specified Characteristic compressive strength of 150 mms Cube at 28 days in N/mm ²
	M 40	40
	M 45	45
	M 50	50
	M 55	55
High Strength Concrete	M 60	60
	M 65	65
	M 70	70
	M 75	75
	M 80	80

NOTES

1. In the designation of concrete mix M refers to the mix and the number to the specified compressive strength of 150 mm size cube at 28 days, expressed in N/mm².
2. For concrete of compressive strength greater than M 55, design parameters given in the standard may not be applicable and the values may be obtained from specialized literatures and experimental results.

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 B.

The cement content of the mix specified in Table B 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-cement ratio as specified is not exceeded.

TABLE B: Proportions for Nominal Mix Concrete

Grade of Concrete	Total Quantity of Dry Aggregates by Mass per 50 kg of Cement, to be taken as the sum of the individual masses of Fine and Coarse Aggregates, Kg. Max	Proportion of Fine Aggregate in 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 1:1½ and a lower limit of 1:2½	60
M 7.5	625		45
M 10	480		34
M 15	330		32
M 20	250		30

NOTE: 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.

Example

For an average grading of fine aggregate (that is, Zone 11 of Table 4 of IS 383), the proportions shall be 1:1½, 1:2 and 1:2½ for maximum size of aggregates 10 mm, 20mm and 40 mm respectively.

CONCRETE

Grades

The concrete shall be in grades designated as per Table A.

The characteristic strength is defined as the strength of material below which not more than 5 percent of the test results are expected to fall.

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

Table C: 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

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

NOTES

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

4.3.4 Testing of Concrete

4.3.4.1 Regular mandatory tests on the workability of the fresh concrete shall be done to achieve the specified compressive strength of concrete. These will be of two types

- (a) Mandatory Lab Test
- (b) Mandatory Field Test

Results of Mandatory Field Test will prevail over mandatory Lab Test.

4.3.4.2 **Visual Inspection Test:** The concrete will be inspected after removal of the form work.

The concrete is liable to be rejected if

- i it is porous or honeycombed

- ii the reinforcement has been displaced beyond tolerance specified; or construction tolerances have not been met.

However, the hardened concrete may be accepted after carrying out suitable remedial measures to the satisfaction of the Engineer at the risk and cost of the Contractor.

4.3.5 Joints

4.3.5.1 Construction Joints

Construction joints are defined as joints in the concrete introduced for convenience in construction at which special measures are taken to achieve subsequent continuity without provision for further relative movement.

- i. Submittal: No concreting shall be started until the Engineer has approved the method of placing, the positions and form of the construction joints and the size of lifts.
- ii. Jointing: The face of a construction joint shall have all laitance removed and the aggregate exposed prior to the placing of fresh concrete. The laitance shall wherever practicable be removed by spraying the concrete surface with water under pressure and brushing whilst the concrete is still green. Where the laitance cannot be removed whilst the concrete is green, the concrete surface forming part of the joint shall be hacked to expose the aggregate. Where aggregate is damaged during hacking, it shall be removed from the concrete face by further hacking. All loose matter shall be removed and the exposed surface thoroughly cleaned by wire brushing, and washing down, and the surface to which fresh concrete is applied shall be clean and damp.

4.3.5.2 Expansion Joints

Expansion joints are defined as joints intended to accommodate relative movement between adjoining parts of a structure special provision being made where necessary for maintaining the water tightness of the joint.

- i. The joint location and type will be as indicated in the drawing.
 - a) The Contractor shall comply with the instructions of manufacturers of proprietary jointing materials and shall, if required by the Engineer, demonstrate that the jointing materials can be applied satisfactorily and will last the life of the structure.
 - b) Flexible water stops shall be fully supported in the formwork, free of nails and clear of reinforcement and other fixtures. Damaged waterstops shall be replaced and during concreting care shall be taken to place the concrete so that water stops do not bend or distort.
- ii. Jointing: The surface of set concrete shall not be disturbed and concrete shall be placed against the dry finished surface.
 - a) If ingress of water or corrosive agents in the joint is possible, the steel, where such steel is continued, shall be cleaned and coated with two coats of an approved bituminous paint to a distance not exceeding 10 mm.
 - b) Where specified, the surface of the set concrete shall be painted with two coats of an approved bituminous paint which shall be allowed to dry before placing new concrete against it. Care shall be taken to prevent paint getting on the waterstop, if any.
 - c) Expansion joints shall be formed by a separating strip of pre-formed compressible unperishable joint filler, to be approved by the Engineer.

4.3.5.3 Caulking Grooves

Grooves shall be provided and sealed where specified. Before the application of any surface sealer the Contractor shall demonstrate to the satisfaction of the Engineer that the men to be employed on the work have had sufficient instruction and experience in this type of work.

- i. The grooves shall be formed neatly by tapered battens covered in mould oil, so as to enable easy removal.
- ii. After the concrete has cured, the groove shall be wire brushed and cleaned out thoroughly and fried to provide a firm bond with the sealant.
- iii. Sealing material shall be supplied by approved manufacturers and incorporated in movement joints in accordance with manufacturer's instructions as shown on the Drawings or as directed by the Engineer. The joint sealant shall conform to IS. 1838. The types of rubber/bitumen / polysulphide surface sealers are as follows:
 - a) Type 1 - Rubber / bitumen sealer hot poured into grooves formed at joints in floors.
 - b) Type 2 - Rubber/bitumen sealer for trowelling or gunning into grooves formed at joints in walls.
 - c) Type 3 - Two pack polysulphaide sealer for cold pouring into grooves formed in floors.
 - d) Type 4 - Two pack polysulphaide for application by gun, trowelled to required profile into grooves formed in walls.
- iv. The joint grooves shall be primed strictly in accordance with the manufacturer's recommendations, and the filler strip if any, shall be placed. The sealer shall be heated if recommended and applied to the prepared grooves by hot-pouring, trowelling or gunning as appropriate. No overheating of the material shall be permitted.
- v. The two pack polysulphide sealer shall be mixed with an approved tool in accordance with the manufacturer's instructions. The sealers shall be applied in accordance with the manufacturer's recommendations and shall be surface worked by means of a specially shaped trowel to ensure adequate bond to the sides of the groove and the correct surface profile.
- vi. At all caulked joints, the face of the caulking strip and 50 mm width of concrete on either side shall be painted with the coats of paint having the same base as the caulking compound.
- vii. Any surface sealers which are defective after curing period has elapsed, or which are subsequently damaged, shall be cut out and made good to the satisfaction of the Engineer.

4.3.6 Protection of Concrete

- 4.3.6.1 Concrete placed below ground level shall be protected from falling earth during and after placing. Concrete placed in ground containing deleterious substances, shall be kept free from contact with such ground and with water draining there during placing for a period of three days or as otherwise instructed thereafter.
- 4.3.6.2 No load of any kind, however light, shall be allowed on concrete which has not adequately set, and unless it has been so directed by the Engineer.
- 4.3.6.3 Immediately on completion of compacting the concrete, Contractor shall ensure that it is adequately protected from the weather. Protective materials shall be kept continuously damp and in position for a minimum period of fourteen days or such other time as the Engineer may direct.
- 4.3.6.4 Where large sections of concrete are poured special precautions as approved by the Engineer shall be taken to reduce and dissipate the heat generated by the setting and hardening of the concrete.

4.3.7 Measurement

- 4.3.7.1 Concrete: Dimensions shall be measured nearest to a cm except for the thickness of slab which shall be measured correct to 0.5cm. The areas shall be worked out nearest to 0.01sq.m. The cubical contents shall be worked out to nearest 0.01 cubic metre.
- 4.3.7.2 Reinforced cement concrete whether cast-in-situ or precast shall be classified and measured

separately.

4.3.7.3 No deduction shall be made for the following:

- (a) Ends of dissimilar materials (e.g. Joists, beams, post girders, rafters, purlins, trusses, corbels steps, etc.), up to 500 sq cm in cross-section.
- (b) Opening up to 0.1 sq. m.

Note: In calculating area of openings up to 0.1 sq.m. the size of opening shall include the thickness of any separate lintels or sills. No extra labour for forming such openings or voids shall be paid for.

- (c) The volume occupied by reinforcement.
- (d) The volume occupied by water pipes, conduits, etc. not exceeding 25sq.cm. each in cross sectional area. Nothing extra shall be paid for leaving and finishing such cavities and holes.

4.3.7.4 Measurement shall be taken before any rendering is done in concrete members. Measurement will not include rendering. The measurement of R.C.C. work between various units shall be regulated as below:

- (a) Slabs shall be taken as running continuously through, except when slab is monolithic with the beam. In that case it will be from the face to face of the beam.
- (b) Beams shall be measured from face to face of columns and shall include haunches, if any, between columns and beam. The depth of the beam shall be from the bottom of slab to the bottom of beam if beam and slab are not monolithic. In case of monolithic construction where slabs are integrally connected with beam, the depth of beam shall be from the top of the slab to the bottom of beam.
- (c) The columns measurement shall be taken through.

4.3.7.5 Tolerances

Subject to the condition that structural safety is not impaired and architectural concept does not hamper, the tolerances in dimensions of R.C.C. members shall be as specified in the drawings by the designer. Whenever these are not specified, the permissible tolerance shall be decided by the Engineer after consultations with the Designer, if necessary.

When tolerances in dimensions are permitted, following procedure for measurements shall apply

- (a) If the actual dimensions of R.C.C. members do not exceed or decrease the design dimensions of the members plus or minus tolerance limit specified above, the design dimensions shall be taken for the purpose of measurements.

4.3.7.6 **Steel:** The length shall be measured correct to one cm and other dimensions correct to 0.5 cm. Cement concrete shall be measured as per gross dimensions of the encasing exclusive of the thickness of plaster. No deduction shall be made for the volume of steel sections, expanded metal, mesh or any other reinforcement used therein. However, in case of boxed stanchions or girders, the boxed portion only shall be deducted.

Fabric reinforcement such as expanded metal shall be measured separately in square metres stating the mesh and size of strands.

The description shall include the bending of the fabric as necessary. Raking or circular cutting and waste shall be included in the description.

4.3.8 Rate

4.3.8.1 The rate includes the cost of materials and labour involved in all the operations described in the various sections of this chapter 4.

4.4 PRECAST REINFORCED CONCRETE

4.4.1 General Requirements:

Precast reinforced concrete units such as columns, fencing posts, door and window frames, lintels, chajjas, copings, sills, shelves, slabs, louvers, etc. shall be of grade of mix as specified and cast in forms or moulds. The forms/moulds shall be of fiber glass or of steel sections for better finish. Provision shall be made in the forms and moulds to accommodate fixing devices such as nibs, clips, hooks, bolts and forming of notches and holes. The Contractor may precast units on cement or steel platform which shall be adequately oiled provided the surface finish is of the same standard as obtained in the forms. Each unit shall be cast in one operation.

- 4.4.1.1 Concrete used for precasting the units should be well proportioned, mixed, placed and thoroughly compacted by vibrations or tamping to give a dense concrete free from voids and honey combing.
- 4.4.1.2 Precast articles shall have a dense surface finish showing no coarse aggregate and shall have no cracks or crevices likely to assist in disintegration of concrete or rusting of steel or other defects that would interfere with the proper placing of the units. All angles of the precast units with the exception of the angles resulting from the splayed or chamfered faces shall be true right angles. The rises shall be clean and sharp except those specified or shown to be rounded. The wearing surface shall be true to the lines. On being fractured, the interior of the units should present a clean homogenous appearance.
- 4.4.1.3 The longitudinal reinforcement shall have a minimum cover of 12mm or twice the diameter of the main bar, whichever is more, unless otherwise directed in respect of all items except fencing posts or electric posts where the minimum cover shall be 25 mm.

4.4.2 Curing

After having been cast in the mould or form the concrete shall be adequately protected during setting in the first stages of hardening from shocks and from harmful effects of frost, sunshine, drying winds and cold. The concrete shall be cured at least for 7 days from the date of casting.

- 4.4.2.1 The precast articles shall be matured for 28 days before erection or being built in so that the concrete shall have sufficient strength to prevent damage to units when first handled.
- 4.4.2.2 Marking: Precast units shall be clearly marked to indicate the top of member and its location and orientation in the structure.
- 4.4.2.3 Precast units shall be stored, transported and placed in position in such a manner that they will not be overstressed or damaged.

4.4.3 Sampling and Testing for Quality Control of Concrete

4.4.3.1 Fresh Concrete

Fresh concrete shall be tested for

- Slump
- Compacting Factor/Workability
- Consistency
- Weight per cubic metre, cement factor and air content

4.4.3.2 Strength of Concrete

The compressive strength on work tests for different mixes shall be as given in Table 4.6 below:

Table 4.6

Concrete Grade	Compressive Strength in (kg/sq.cm)	
	7 days	28 days
M25	210	250
M20	175	200

4.4.4 Testing of Concrete

4.4.4.1 Regular mandatory tests of fresh concrete shall be done to ensure that the specified compressive strength of concrete is achieved. These will be of two types

- (a) Mandatory Lab. Test
- (b) Mandatory Field Test

Results of Mandatory Field Test will prevail over mandatory Lab. Test.

4.4.4.2 Work Test-Mandatory Lab Test shall be carried out as given below.

One sample (consisting of six cubes $15 \times 15 \times 15$ cm shall be taken for every 20 cum or part less than 5 cum or as often as considered necessary by the Engineer. The test of concrete cubes shall be carried out in accordance with the procedure as described below. A register of cubes shall be maintained at the site of work. The casting of cubes, concrete used for cubes and all other incidental charge, such as curing, carriage to the testing laboratory shall be borne by the contractors.

Test procedure

Mould

The mould shall be of size $15 \text{ cm} \times 15 \text{ cm} \times 15 \text{ cm}$ for the maximum nominal size of aggregate not exceeding 40 mm. For concrete with aggregate size more than 40 mm, size of mould shall be specified by the Engineer, keeping in view the fact that the length of the mould should be about four times the size of aggregate.

The moulds for test specimens shall be made of non-absorbent material and shall be substantially strong enough to hold their form during the moulding of test specimens. They shall not vary from the standard dimensions by more than one percent. The moulds shall be so constructed that there is no leakage of water from the test specimen during moulding. All the cube moulds for particular site should, prior to use, be checked for accuracy in dimensions and geometric form and such test should at least be made once a year.

Each mould shall be provided with a base plate having a plane surface and made of non-absorbent material. This plate shall be large enough in diameter to support the moulds properly without leakage. Glass plates not less than 6.5 mm thick or plain metal not less than 12 mm thick shall be used for this purpose. A similar plate shall be provided for covering the top surface of the test specimen when moulded.

Note: Satisfactory mould can be made from machine or steel castings, rolled metal plates or galvanized iron.

Sample of concrete

Sample of concrete for test specimen shall be taken at the mixer or in the case of ready mixed concrete from the transportation vehicle discharge or as directed by the Engineer. Such samples shall be obtained by repeatedly passing a scoop or pail through the discharge stream of concrete. The sampling operation should be spread over evenly to the entire discharging

operation. The samples thus obtained shall be transported to the place of moulding of the specimen. To counteract segregation, the concrete shall be mixed with a shovel until it is uniform in appearance. The location in the work of the batch of concrete thus sampled shall be noted for further reference. In case of paving concrete, samples shall be taken from the batch immediately after deposition of the subgrade. At least five samples shall be taken from different portion of the pile and these samples shall be thoroughly mixed before being used to form the test specimen. The sampling shall be spread as evenly as possible through out the day. When wide changes occur during concreting, additional samples shall be taken if so desired by the Engineer.

Preparation of Test Specimens

The interior surfaces of the mould and base plate shall be lightly oiled before the concrete is placed in the mould. The samples of concrete obtained as described under the test specimen shall be immediately moulded by one of the following methods as indicated below:-

When the job concrete is compacted by manual methods, the test specimen shall be moulded by placing the fresh concrete in the mould in three layers, each approximately one third of the volume of the mould. In placing each scoopful of concrete the scoop shall be moved around the top edge of the mould as the concrete there slides from it, in order to ensure a uniform distribution of concrete within the mould. Each layer shall be rodded 35 times with 16mm rod, 60 cm in length, bullet pointed at the lower end. The strokes shall be distributed in uniform manner over the cross section of the mould and shall penetrate into underlying layer. The bottom layer shall be rodded through in its depth. After the top layer has been rodded, the surface of the concrete shall be struck off with a trowel and covered with a glass plate at least 6.5 mm thick or a machined plate. The whole process of moulding shall be carried out in such a manner as to preclude the change of the water cement ratio of the concrete, by loss of water either by leakage from the bottom or over flow from the top of the mould.

When the job concrete is placed by vibration and the consistency of the concrete is such that the test specimens cannot be properly moulded by handrodding as described above, the specimens shall be vibrated to give a compaction corresponding to that of the job concrete. The fresh concrete shall be placed in mould in two layers, each approximately half the volume of the mould. In placing each scoopful of concrete the scoop shall be moved around the top edge of the mould as the concrete there slides from it, in order to ensure a symmetrical distribution of concrete within the mould. Either internal or external vibrators may be used. The vibration of each layer shall not be continued longer than is necessary to secure the required density. Internal vibrators shall only the layer to be compacted. In compacting the first layer, the vibrators shall not be allowed to rest on the bottom of the mould. In placing the concrete for top layer care shall be taken to see that there will be no mortar loss during vibrations. After vibrating the second layer enough concrete shall be added to bring level above the top of the mould. The surface of the concrete shall then be struck off with a trowel and covered with a glass or steel plate as specified above. The whole process of moulding shall be carried out in such a manner as to preclude the alteration of water-cement ratio of the concrete by loss of water, either by leakage from the bottom or over flow from the top of the mould.

Curing and storage of test specimen

In order to ensure reasonably uniform temperature and moisture conditions during the first 24 hours for curing the specimen and to protect them from damage, moulds shall be covered with wet straw or gunny sacking and placed in a storage box so constructed and kept on the work site that its air temperature when containing concrete specimens shall remain 22°C to 33°C. Other suitable means which provide such a temperature and moisture conditions may be used.

NOTE: It is suggested that the storage box be made of 25 mm dressed tongued and grooved timber, well braced with battens to avoid warping. The box should be well painted inside and outside and should be provided with a hinged cover and padlock.

The test specimen shall be removed from the moulds at the end of 24 hours and stored in a moist condition at a temperature within 24°C to 30°C until the time of test. If storage in water is desired, a saturated lime solution shall be used.

Testing

The specimens shall be tested in accordance with procedure as described below:

- a) The tests shall be made at an age of concrete corresponding to that for which the strengths are specified.
- b) Compression tests shall be made immediately upon removal of the concrete test specimen from the curing room i.e., the test specimen shall be loaded in damp condition. The dimensions of the test specimens shall be measured in mm accurate to 0.5 mm.
- c) The metal bearing plates of the testing machine shall be placed in contact with the ends of the test specimens. Cushioning materials shall not be used. In the case of cubes, the test specimen shall be placed in the machine in such a manner that the load is applied to sides of the specimens as cast. An adjustable bearing block shall be used to transmit the load to the test specimen. The size of the bearing block shall be the same or slightly larger than that of test specimen. The upper or lower section of the bearing block shall be kept in motion as the head of the testing machine is brought to a bearing on the test specimen.
- d) The load shall be applied axially without shock at the rate of approximately 140 kg per sq.cm. per minute. The total load indicated by the testing machine at failure of test specimen shall be recorded and the unit compressive strength is calculated in kg per sq.cm. using the area computed from the measured dimensions of the test specimen. The type of failure and Appearance of the concrete shall be noted.

4.4.4.3 Additional Test: Additional test, if required, shall be carried out as given below.

In case the concrete fails when tested as per the method prescribed in 4.4.2, one or more of the following check tests may be carried out at the discretion of the Engineer to satisfy the strength of the concrete laid. All testing expenditure shall be borne by the contractor. The number of additional tests to be carried out shall be determined by the Engineer. He shall be the final authority for interpreting the results of additional test and shall decide upon the acceptance or otherwise. His decision in this regard shall be final and binding. For the purpose of payment, the Hammering test results only shall be the criteria. Some of the tests are outlined below:

Rebound Hammer Test

If a rebound hammer is regularly used by trained personnel in accordance with procedure described in IS 13311 (part II) and a continuously maintained. individual charts are kept showing a large number of readings and the relation between the readings and strength of concrete cubes made from the same batch of concrete, such charts may be used in conjunction with hammer readings to obtain an approximate indication of the strength of concrete in a structure or element. If calibration charts are available from manufacturers, it can be used, when making rebound hammer test each result should be the average of at least 12 readings. Readings should not be taken within 20 mm of the edge of concrete members and it may be necessary to distinguish between readings taken on a trowled face and those on a moulded face. When making the tests on precast unit, special care should be taken to bed them firmly against the impact of the hammer.

Cutting Cores

This method involves drilling and testing cores from the concrete for determination of compressive strength. In suitable circumstances, the compressive strength of the concrete in the structure may be assessed by drilling cores from the concrete and testing. The procedure used shall comply with the requirements of IS – 1199 and IS 516.

The points from which cores shall be taken shall be representative of the whole concrete and atleast three cores shall be obtained and tested. If the average of the strength of all cores cut from the structure is less than the specified strength, the concrete represented by the cores shall be liable to rejection and shall be rejected if a static load test either cannot be carried out or is not permitted by the Engineer.

Ultrasonic Test

If an ultrasonic apparatus is regularly used by trained personnel in accordance with IS 13311 (part I) and continuously maintained individual charts are kept showing a large number of readings and the relation between the reading and strength of cubes made from the same batch of concrete, such charts may be used to obtain approximate indications of the strength of concrete in the structures. In cases of suspected lack of compaction or low cube strength the results obtained from the ultrasonic test results on adjacent acceptable sections of the structures may be used for the purpose of assessing the strength of concrete in the suspected portion.

Load Tests on individual Precast Units

The load tests described in this clause are intended as check on the quality of the units and should not be used as substitute for normal design procedures. Where members require special testing, such special testing procedures shall be in accordance with the specification. Test loads shall be applied and removed incrementally.

Non-destructive Tests

The unit shall be supported at its designed points of support and loaded for five minutes with a load equal to the sum of the characteristic dead load plus one and a quarter time the characteristic imposed load. The deflection is then recorded. The maximum deflection after application of the load shall be in accordance with the requirements defined by the Engineer. The recovery is measured five minutes after the removal of the load and the load then reimposed. The percentage recovery after the second loading shall be not less than that after the first loading nor less than 90% of the deflection recorded during the second loading. At no time during the tests, shall the unit show any sign of weakness or faulty construction as defined by the Engineer in the light of reasonable interpretation of relevant data.

Destructive Tests

The unit is loaded while supported at its design point of support and must not fail at its design load for collapse, within 15 minutes of time when the test load becomes operative. A deflection exceeding 1/40 of the test span is regarded as failure of the unit.

Special Tests

For very large units or units not readily amenable to the above test e.g. columns, the precast parts of composite beams and members designed for continuity or fixity, the testing arrangements shall be agreed upon before such units are cast.

Load Test of Structures or Parts of Structures

The test described in this clause are intended as a check where there is a doubt regarding structural strength. Test loads are to be applied and removed incrementally.

Age at Tests

The test is to be carried as soon as possible after the expiry of 28 days from the time of placing of the concrete. When the test is for a reason other than the quality of concrete in the structure being in doubt, the test may be carried out earlier, provided that the concrete has already reached its specified characteristic strength.

Test load

The test loads to be applied for the limit states of deflection and local damage are the appropriate design loads i.e., the characteristic dead and superimposed loads. When the limit state of collapse is being considered the test load shall be equal to the sum of characteristic dead load plus one and a quarter times the characteristic imposed load and shall be maintained for a period of 24 hours. In any of the test temporary supports of sufficient strength to take the whole load shall be placed in position underneath but not in contact with the members being tested. Sufficient precautions must be taken to safeguard persons in the vicinity of the structure.

Measurements during Tests

Measurements of deflection and crack width shall be taken immediately after applications of the load and, in the case of 24 hour sustained load test, at the end of 24 hour loaded period, after removal of the load and after 24 hour recovery period. Sufficient measurements shall be taken to enable side effects to be taken in account. Temperature and weather conditions shall be recorded during the tests.

Assessment of Results

In assessing the strength of a structure or a part of the structure following a loading test, the possible effects of variation in temperature and humidity during the period of the test shall be considered.

The following requirements shall be met:

- The maximum width of any crack measured immediately on application of the test load for local damage, is to be not more than $2/3$ of the value of the appropriate limit state requirement.
- For members spanning between two supports the deflection measured immediately on application of the test load for deflection is to be not more than $1/500$ of the effective span. Limits shall be agreed upon before testing cantilevered portions of structures.
- If maximum deflection in mm shown during 24 hour under load is less than $40L^2/D$ where L is effective span in mm and D is overall depth of construction in mm, it is not necessary for the recovery to be measured and the requirement (d) does not apply, and
- If within 24 hours of the removal of test load for collapse as calculated in clause (a) a reinforced concrete structure does not show a recovery of at least 75 percent of the maximum deflection shown during the 24 hour under load, the loading should be repeated. The structure should be considered to have failed to pass the test if the recovery after second loading is not at least 75 percent of the maximum deflection shown during the second loading.

4.4.4.4 Slump Test: This test shall be carried out as laid down in clause 3.2.2.

4.4.4.5 Visual Inspection Test: The concrete will be inspected after removal of the form work as described in clause 3.2.5.11. The question of carrying out mandatory test or other tests described above will arise only after satisfactory report of visual inspection.

The concrete is liable to be rejected if

- (i) it is porous or honeycombed.

- (ii) its placing has been interrupted without providing a proper construction joint;
- (iii) the reinforcement has been displaced beyond tolerance specified; or construction tolerances have not been met.

However, the hardened concrete may be accepted after carrying out suitable remedial measures to the satisfaction of the Engineer at the risk and cost of the contractor.

4.4.5 Standard of Acceptance – for nominal mix

4.4.5.1 Mandatory Lab. Test

For concrete sampled and tested as prescribed under 4.4.4.2, the following requirement shall apply.

4.4.5.2 Out of six sample cubes, three cubes shall be tested at 7 days and remaining three cubes at 28 days.

4.4.5.3 7 days' tests

Sampling: The average of the strength of three specimens shall be accepted as the compressive strength of the concrete provided the variation in strength of individual specimen is not more than 15% of the average. Difference between the maximum and minimum strength should not exceed 30% of average strength of three specimens. If the difference between maximum and minimum strength exceeds 30% of the average strength, then 28 days' test shall have to be carried out.

Strength: If the actual average strength of sample is equal to or higher than specified strength upto 15%, their strength of the concrete shall be considered in order.

In case the actual average strength of sample accepted is lower than the specified or higher by more than 15% then 28 days' test shall have to be carried out to determine the compressive strength of concrete cubes.

4.4.5.4 28 days' test

- (a) The average of the strength of three specimen be accepted as the compressive strength of the concrete provided the strength of any individual cube shall neither be less than 70% nor higher than 130% of the specified strength.
- (b) If the actual average strength of accepted sample exceeds specified strength by more than 30%, the Engineer, if he so desires, may further investigate the matter. However, if the strength of any individual cube exceeds more than 30% of specified strength, it will be restricted to 130% only for computation of strength.
- (c) If the actual average strength of accepted sample is equal to or higher than specified strength upto 30% then strength of the concrete shall be considered in order and the concrete shall be accepted at full rates.
- (d) If the actual average strength of accepted sample is less than specified strength but not less than 70% of the specified strength, the concrete may be accepted at reduced rate at the discretion of the Engineer.
- (e) If the actual average strength of accepted sample is less than 70% of specified strength, the Engineer shall reject the defective portion of work represented by sample and nothing shall be paid for the rejected work. Remedial measure necessary to retain the structure shall be taken at the risk and cost of the contractor. If, however, the Engineer so desires, he may order additional tests (See 4.4.3) to be carried out to ascertain if the structure can be retained. All the charges in connection with these additional tests shall be borne by the contractor.

4.4.4.5 Acceptance Criteria of Field Test (Additional Test – Not Mandatory)

Preparation of Standard Test Cubes for Calibration of Rebound Hammer at Site

- (a) In the beginning the standard test cubes of the specified mix shall be prepared by field units before undertaking any concrete work in each project.
- (b) At least 18 standard cubes necessary for formation of one specimen of specified mix, shall be cast by the staff well in advance. From these 18 cubes any 3 cubes may be selected at random to be tested for crushing strength of 7 days. The crushing strength obtained should satisfy the specified strength for the mix as per specification or agreement. If the strength is satisfactory then the remaining cubes will form the standard samples for calibration of rebound hammer. In case of failure, the site staff should totally reject the samples and remove them also and then make another set of samples by fresh mixing or alternatively, out of the remaining 15 cubes, 3 cubes will be tested on 28 days. If the 28 days' tests are found satisfactory then remaining 12 cubes will form the standard sample for calibration at 28 days' strength otherwise all samples shall be rejected and whole procedure repeated to form a fresh specimen. All the results shall be recorded in a register.
- (c) No concreting will be allowed unless the standard specimen cubes are obtained
The criteria for acceptance and calibration of hammer will be 28 days' strength. The 7 days' strength is only to facilitate the work to start.
- (d) No work (for the concrete cast between 8th and 28th day) shall be allowed to be paid unless 28 days' cube strength is obtained. For the concrete cast between 8th and 28th day, the decision to make the payment may be taken by the Engineer on the basis of existing criteria. Concrete work will be rejected if 28 days' strength falls short as per acceptance criteria. No further work will be allowed till the acceptable standard cubes are obtained.
- (e) Frequency: It will be once in each quarter or as per the direction and discretion of the Engineer. Whenever the acceptance criteria is changed or concrete mix or type of cement is changed or the Engineer feels it necessary for recorded reasons with the approval of the authority according technical sanction, fresh specimen shall be prepared.

Calibration of Hammer

- (a) Simultaneously, same three cubes to be tested on 28 days as referred in 5.4.4.5 (b) above shall be used to correlate the compressive strength of their concrete with rebound number as per procedure described in para 5.2 of the IS 13311 (Part 2) "Indian standard for non-destructive testing of Concrete Method of test by rebound hammer which is given below in para (b). The average of values of the rebound number (minimum readings) obtained in respect of same three cubes passing on 28 days' work test shall form the datum reference for remaining cubes for the strength of cubes.
- (b) The concrete cubes specimens are held in a compression testing machine under a fixed load, measurements of rebound hammer taken and then compressive strength determined as per IS 516. The fixed load required is of the order of 7N/mm^2 when the impact energy of the hammer is about 2.2 NM.

If the specimen are wet cured, they should be removed from wet storage & kept in the laboratory atmosphere for about 24 hours before testing.

Only the vertical faces of the cubes as cast should be tested for rebound number. At least nine readings should be taken on each of the three vertical faces accessible in the compression testing machine when using rebound hammers. The points of impact on

the specimen must not be nearer than 20 mm from the edge & should not be less than 20 mm from each other. The same points must not be impacted more than once.

- (c) The rebound number of hammer will be determined on each of the remaining (18-3-3=12) cubes. Whenever the rebound number of hammer of any individual cube varies by more than +25% from the datum readings referred to in para (a) above, that cube will be excluded and will not be considered for standard specimen cubes for calibration. It must be ensured that at least 8 cubes out of 12 that is 66.67% are within the permissible range of variation of rebound number i.e. +25% or otherwise whole procedure shall have to be repeated and fresh specimen prepared.

These 8 cubes will form one standard sample in the beginning before commencement of work and shall be kept carefully for the visiting officers who will calibrate their hammers on these cubes.

- (d) This calibration will be done by the quality control personnel of the contractor with their hammer and then chart of calibration giving the details of the average readings, date & month of casting, mix of the concrete etc. shall be prepared and signed by the Engineer and will be duly preserved for future reference as and when required.

Preservation of Cubes at Site

Standard sample cubes cast shall be carefully preserved at site under the safe custody of the Engineer or his representative for making them available together with the charts.

Testing at Site

- (a) Testing will be done generally by non-destructive methods like rebound hammers etc. The contractor will purchase rebound hammers and keep them in working order at work site. The testing will be done only by hammers which are duly calibrated.
- (b) The relative strength of actual field work will be tested with reference to strength of these standard cubes and calibration charts of a hammer for determining the rebound number on the field work. The hammer will be used as per manufacturer's guide lines at various locations chosen at random. The number of location/reading on each wall, beam or column etc. shall not be less than 12. All the readings should be within the +25% range of values prescribed in calibration chart normally. However, reading indicating good strength will be when it is at par with calibrated value or between 100% & 125% and very good if more than 125%, any value between 100% & 75% of calibrated value shall be considered satisfactory. Values from 75% to 50% shall be considered for payment at rates reduced on prorata basis. The concrete indicating rebound number less than 50% of calibrated value shall be rejected and not paid for.
- (c) **Acceptance of Field Tests and Strength**
If the relative strength of actual field work is found satisfactory considering the calibration charts with reference to the standard cube test kept at site, the representative work will be considered satisfactory. If the work is considered below satisfactory, the same will be dealt as stated in para (b) above.
- (d) **7 days' Strength in Rare Cases only**
Normally cube crushing strength on 28 days' test shall form the basis of acceptance. However in rare cases of time bound projects/urgent repairs 7 days' cube test strength criteria may be adopted on similar lines using 7 days' standard test cubes and calibration graphs/curves/charts for 7 days' in lieu of 28 days' and testing work done at 7 days'.
- (e) **Precautions**
The testing shall be done generally as per the guidelines of manufacturer of the apparatus and strictly in accordance with the procedure laid down in clause 6 or IS

13311 (Part 2) : Indian Standard for Non-Destructive Testing of concrete-Method of Test by Rebound Hammer.

The rebound hammers are influenced by a number of factors like type of cement aggregate, surface conditions, moisture content, age of concrete, extent of calibration of concrete etc. Hence care shall be taken to compare the cement, aggregate etc. and tested under the similar surface conditions having more or less same moisture content and age. However effect of age can be ignored for concrete between 3 days & 3 months old.

4.5 LIST OF MANDATORY TESTS

Following are the mandatory tests to be conducted at appropriate stages of the work

TABLE 4.7: List of Mandatory Tests

Material	Clause	Test	Field/ Laboratory	Min. Qty of Material for Carrying out test.	Frequency of Testing
Reinforced Cement Concrete (Nominal Mix)	4.3.2	a) Slump Test	Field / Lab	i) 5cum in case of column	i) Every 5cum or part thereof
				ii) 20cum for slabs, beams and connected columns	ii) Every 20cum or part thereof
				iii) 20cum for other RC.C. Work for. All other small items. and where RC.C. done in a day is less than 5cum, test may be carried out as required by Engineer.	iii) Every 20cum or part thereof
	4.4.3.2	b) Cube Test	Lab	i) 5cum in case of column	i) Every 5cum or part thereof
				ii) 20cum for slabs, beams and connected columns	ii) Every 20cum or part thereof
				iii) 20cum for other RC.C. Work for all other small items and where RC.C done in a day is less than 5cum test may be carried out as required by Engineer.	iii) Every 20cum or part thereof

TABLE 4.7: List of Mandatory Tests

Material	Clause	Test	Field/ Laboratory	Min. Qty of Material for Carrying out test.	Frequency of Testing	
Steel for Reinforced Cement Concrete	4.1.2	A) Physical Test			a) For consignment below 100 tones	b) for consignment over 100 Tons
		a) Tensile strength	Lab I Field IS. 1608		i) Under 10mm dia, one sample for each 25 tons or part thereof	i) Under 10mm dia, one sample for each 40 tons or part thereof
		b) Retest	Lab I Field IS. 1786		ii) 10mm to 16mm dia one sample for each 35 tonnes or part thereof	ii) 10mm to 16mm dia, one sample for each 45 tons or part thereof
		c) Rebound Test	Lab I Field IS. 1786		iii) over 16mm dia one sample for each 45 tons or part thereof	iii) over 16mm dia, one sample for each 50 tons or part thereof
		d) Nominal Mass	Lab I Field IS. 1786			
		e) Bend Test	Lab I Field IS. 1599			
		f) Elongation Test	Lab I Field IS. 1786			