

**S.03: CONCRETE: PLAIN & REINFORCED**

These specifications shall be read in conjunction with the CPWD specifications 2019 or latest specification with up-to-date correction slips, MOST/MORTH Specifications for Road and Bridge Works 2013 (Fifth Revision) and other relevant specifications with up-to-date correction slips described in the S.01 of Section-VII-F of these Specifications.

**3.1 Materials**

Before bringing to the site, all materials for concrete shall be approved by the Engineer. All approved samples shall be deposited in the office of the Engineer before placing orders for the materials with suppliers. The materials brought for works shall conform in every respect to their approved samples.

Fresh samples shall be deposited with Engineer whenever type or source of any material changes. The contractor shall check fresh consignment of materials as it is brought on to the works to ensure that they conform to the specifications and/or approved samples.

The Engineer shall have the option to have any of the materials tested to find whether they are in accordance with specifications at the contractor's expense. All bills, vouchers and test certificates which in the opinion of the Engineer are necessary to convince him as to the quality of materials or their suitability shall be produced for his inspection when required.

Any materials which have not been found to conform to the specifications and not approved by the Engineer shall be rejected forthwith and shall be removed from the site by the contractor at his own cost within the time stipulated by the Engineer. The Engineer shall have the powers to cause the contractor to purchase and use materials from any particular source, as may in his opinion be necessary for the proper execution of work.

Contractor shall also ensure that all constituents of exposed concrete shall be taken from same sources to achieve a uniform colour and texture.

**3.2 Cement**

3.1.1.1 The cement used shall be of the following types:

- a) 53 grade Ordinary Portland Cement conforming to IS:269 – 2015.
- b) Blended Cement as per IS 1489 Part-1:2015 on the specific approval by Engineer.

For piling works, type of cement shall be as mentioned in **S.08** of Section-VII-F for pile foundations.

3.1.1.2 Whenever possible all cements of each type shall be obtained from one constant source throughout the contract, cement of different types shall not be mixed together. Different brands of cement, or the same brand of cement from different sources, shall not be used without prior approval of the Engineer.

3.1.1.3 Packaged cement shall be delivered to the site in original sealed bags which shall be labelled with the weight, name of manufacturer, brand and type. Cement received in torn bags shall not be used. Cement shall be used in the order in which it is received. Cement in bags in storage for more than 3 months shall be retested before use. A sample taken once for every 1000 bags or part thereof as per Engineer's decision shall be tested.

Contractor may obtain cement in bulk and store it in suitable silos of adequate capacity. Each type of cement shall be stored in a separate silo and it shall be ensured, that cements of different quality are not mixed up.

Supply of cement in bulk and storage in silos is compulsory at casting depots. Cement supply in bags will be only with the specific approval of the Engineer.

- 3.1.1.4 All cement shall be fresh when delivered and at ambient atmospheric temperature.
- 3.1.1.5 In fair faced elements, the cement used in the concrete for any complete element shall be from 3 single consignments. All cement for exposed concrete shall be from the same approved source and uniform in colour.
- 3.1.1.6 With each and every delivery of cement the contractor shall provide manufacturer's certificate that the cement conforms to the relevant Indian standard. The contractor shall provide complete facilities at site for carrying out the following tests:
- a) Setting time by vicat's apparatus as per IS:4031 and IS:5513.
  - b) Compressive strength of cement as per IS: 4031, IS:650, IS: 10080.
  - c) Fineness & Soundness

The Engineer may require any other form of sampling and tests including chemical analysis (IS 4032) in case the cement supplied is of doubtful quality. The cost of such additional tests shall be borne by the Contractor.

- 3.1.1.7 All physical and chemical properties of OPC-53 should meet the requirements as per IS 269 – 2015. Sampling and testing of OPC 53 grade cement shall be done as per IS 269-2015. The cost of testing shall be borne by the contractor and nothing extra shall be paid in this regard.

Usage of Fly-Ash as part replacement for Cement is permitted as an eco-friendly move subject to the following conditions:

- a) Fly ash cannot be used as part replacement for cement in PSC members.
- b) Fly ash to be used as part replacement for cement shall conform to the provisions listed in IS 3812 Part I
- c) Blended concrete constituent shall be as per IS 1489 (Part I):2015
- d) Should comply minimum and maximum cement as well as cementitious requirements as per latest revision / amendments / correction slip of the Specifications stated or referred in this contract.

### 3.1.1 Aggregate

Aggregates from natural sources shall conform to the provisions specified in IS:383. Prior to commencing any concrete work, the Contractor shall obtain the Engineer's approval of the proposed types and sources of aggregate. Sampling of aggregates shall be as per IS 2430. The contractor shall submit to the Engineer, certificates of grading and compliance for all consignments of aggregate. In addition, at site from time to time, the contractor shall allow for carrying out such tests and for supplying test records to the Engineer. The aggregates shall be procured from approved sources only as directed by the Engineer from time to time.

For fair faced concrete, the contractor shall ensure that aggregates are free from iron pyrites and impurities, which may cause discoloration. Aggregates shall be stored on paved areas in different compartments according to their nominal size.

#### 3.1.1.1 Fine Aggregate

The contractor shall provide complete facilities at site for determining grading of aggregates by sieves as per IS: 383, IS: 460, IS: 1607, and IS: 2386. The fine aggregate shall be river sand pit sand, crushed sand. It shall be free from clay, loam, earth or vegetable matter, salt or other harmful chemical impurities. It shall be clean, sharp, strong, angular and composed of hard siliceous material. If considered by the Engineer as necessary, the sand shall be washed in screw type mechanical washers in potable water to remove silt, clay and chlorides. This shall be done at least one day before using it in concrete. The washed sand shall be stored on a sloping concrete platform and in such a manner as to avoid contamination. Such sand washing, storing, etc. shall be at the Contractor's cost. The grading of fine aggregate when determined as described in IS: 2386 (part I), shall be within the grading zones I, II. (Usage of stone dust or M. Sand shall only be permitted if the Engineer is satisfied with the performance and Quality of the material. Decision of the Engineer will be deemed as final)

The Contractor shall carry out the following tests at Site and ensure that the appropriate provisions of Indian or other standards, as may be applicable, are complied with:

- a. Proportion of clay, silt and fine dust by sedimentation method as per IS 383 and IS 2386 (Part II)
- b. Moisture content in fine aggregate as per IS 2386 (Part III)
- c. Water absorption as per IS 2386 (Part III) and IRC: 15 (CL. 3.3.4)
- d. Bulk Density of Bulkage as per IS 2386 (Part III)
- e. Grading of fine aggregate as per IS 383 and IS 2386 (Part I)

#### 3.1.1.2 Coarse Aggregate

The nominal maximum size of the coarse aggregate shall be 20 mm, unless otherwise mentioned in the Drawings. The coarse aggregate shall be crushed stone, crushed gravel, natural gravel or a suitable combination thereof. Coarse aggregate obtained from crushed or broken stone shall be angular, hard, strong, dense, durable, clean and free from soft, friable, thin plate, elongated or flaky pieces and any deleterious material.

River gravel or pit gravel shall be sound, hard, clean, non-porous, suitably graded in size with or without broken fragments and free from flat particles of shale, clay, silt, loam, and other impurities.

Except where it can be shown to the satisfaction of the Engineer that a supply of properly graded aggregate of uniform quality can be maintained over the said period of the works, the grading of aggregate shall be controlled by obtaining the coarse aggregate in different sizes and blending them in correct proportions as and when required. Aggregate shall be stored in such a way as to prevent segregation of sizes and avoid contamination with fines.

All coarse aggregate shall conform to IS: 383 and tests for conformity shall be carried out as per IS: 2386, Parts I to VIII.

The maximum size of coarse aggregate shall be such that the concrete can be placed without difficulty so as to surround all reinforcement thoroughly and fill the corners of formwork. The grading of coarse aggregate shall be such that not more than 5% shall be larger than the maximum size and not more than 10% shall be smaller than the smallest size. Between these sizes the coarse aggregate shall be well graded. Unless otherwise permitted by the Engineer the nominal maximum size shall not exceed 20 mm.

The Contractor shall carry out the following tests at site and ensure that the appropriate provisions of following Indian standards as may be applicable are complied with:

- a. Moisture content in coarse aggregate as per IS 2386 (Part III)

- b. Water absorption as per IS 2386 (Part III) and IRC 15 (CL. 3.3.3)
- c. Bulk density and voids as per IS 2386 (Part III)
- d. Grading of coarse aggregate as per IS 383 and IS 2386 (Part I)

#### 3.1.1.3 Water

Water used in the works shall be potable water and free from deleterious materials. Water used for mixing and curing concrete as well as for cooling and/or washing aggregate shall be fresh and clean free from injurious amounts of oil, salts, acids, alkali, sugar, other chemicals and organic matter.

Water shall be from the source approved by the Engineer and shall be in accordance with clause 5.4 of IS: 456. However, chloride content in water shall not exceed 500 mg/litre.

Before starting any concreting work and wherever the source of water changes, the water shall be tested for its chemical and other impurities to ascertain its suitability for use in concrete for approval of the Engineer. No water shall be used until tested and found satisfactory. Cost of all such tests shall be borne by the contractor.

#### 3.3 Blending of aggregates:

In order to obtain optimum workability, individual aggregates of nominal size 20 mm, 10 mm, 4.75 mm and 2.36 mm will be blended in such a way that the grading curve for all aggregates will be a smooth curve from size 0.15 mm to 25 mm falling within the established envelop grading curve. Contractor shall establish envelop grading curve for each grade of concrete for given maximum size of aggregates and get it approved by Engineer before finalising the mix design.

#### 3.4 Admixtures:

- i Chemical admixtures are not to be used until permitted by the Engineer. In case their use is permitted, the type, amount and method of use of any admixtures proposed by the Contractor shall be submitted to the Engineer for approval. The minimum cement content specified shall not be reduced on account of the use of these Admixtures.
- ii The contractor shall further provide the following information concerning each admixture to the Engineer
  - a. Normal dosage and detrimental effects if any of under dosage and over dosage.
  - b. The chemical names of the main ingredients in the admixtures.
  - c. The chloride content, if any, expressed as a percentage by weight of admixture. The admixture shall be chloride free.
  - d. Whether or not the admixture leads to the entrainment of air when used with in the manufacturer's recommended dosage.
- iii The chemical admixtures when used shall conform to IS: 9103. The suitability of all admixtures shall be verified by trial mixes.
- iv The addition of calcium chloride to concrete containing embedded metal will not be permitted under any circumstances.
- v Fibre reinforcement will be Propex (Fiber mesh 300-e3 / Fiber mesh 150-e3) or equivalent make polypropylene fibres, shall be added to ready-mixed concrete wherever the material is to be used for parapet, box girder etc. Bar reinforcement is still considered primary reinforcement. Under normal condition, add to the ready-mix at the plant in the quantity recommended by the manufacturer subjected to the approval of engineer-in-charge. If job conditions warrant fiber reinforcement may be added at the job site provided that fibers are evenly distributed in the mix. Notwithstanding the same, Fibre reinforcement shall conform to IRC:SP:46 (2013).

**3.5 Batching Plants, Mixers and Vibrators:**

1. Unless specified in the schedule of items, for all structural concreting work the Contractor shall provide automatic weigh-batching plant of suitable capacity. The plant used shall conform to IS: 4925.
2. The Contractor shall provide Concrete mixers (IS: 1791 - Batch type concrete mixers, IS: 2438 - Roller Pan Mixer) and Vibrators (IS: 2505 - Concrete Vibrators Immersion Type, IS: 2506 - Screed board concrete vibrators, IS: 4656 - Form Vibrators for Concrete) supplied by recognised manufacturers.

**3.6 Grade of Concrete:**

The concrete is designated as follows:

Concrete M 25 / 20

The letter M refers to the mix

The number 25 represents the characteristic compressive strength of 15cm cubes at 28 days in MPa (Mega Pascal: 1 MPa: 10 kg/cm<sup>2</sup> approximately). M25 concrete thus, has a characteristic strength of 250 kg/cm<sup>2</sup>. Other mix design will also be denoted in same way. The number 20 represents the nominal size of the aggregate in mm.

**3.7 Mix Design**

For all items of concrete, only design mix shall be used. Prior to the commencement of construction, the Contractor shall design the mix and submit the proportions of materials, including admixtures to be used to the Engineer for obtaining approval. Suitable water reducing admixtures or super-plasticizing and viscosity modifying agent (VMA) admixtures shall be used for achieving desired workability and strength of the concrete only after obtaining prior approval from the Engineer. **No extra payment shall be made for such admixtures.**

It is the complete responsibility of the Contractor to design the concrete mixes by approved standard methods and to produce the required concrete conforming to the specifications and the strength, workability requirements approved by the Engineer.

Mix Design Once approved must not be altered without prior approval of Engineer and shall be revalidated after every one year. However, should the contractor anticipate any change in quality of future supply of materials than that used for preliminary mix design, he should inform the Engineer quite in advance and bring fresh samples sufficiently in advance, to carry out fresh trial mixes. Design mix will indicate by means of graphs and curves etc., the extent of variation in the grading of aggregates which can be allowed.

The total amount of acid soluble chloride content in RCC and PSC mix shall not exceed 0.6 Kg/Cum and 0.4 Kg/Cum respectively and sulphate contents in concrete mix shall not exceed 4.0 percent respectively by weight of cement.

Limits of Water and Cement Contents

Maximum water/cement ratio

- |                                    |   |      |
|------------------------------------|---|------|
| a) For RCC members including piles | - | 0.40 |
| b) For PSC members                 | - | 0.40 |

For piling under water, water-cement ratio of 0.40 is applicable to cement concrete including 10% extra cement above the design mix or minimum cement whichever is greater.

**Trial Mixes:**

- a) The Contractor is entirely responsible for the design of the concrete mixes. However, the design shall have approval from the Engineer. At least 8 weeks before commencing any concreting in the works, the Contractor shall make trial mixes using samples of coarse aggregates, sand, water, superplasticiser and cement, typical of those to be used in the Works, and which have been tested in an approved laboratory. A clean dry mixer shall be used, and the first batch shall be discarded.
- b) The mix shall be designed to produce the grade of concrete having the required workability, durability and a characteristic strength. Trial mixes shall be prepared under full-scale site conditions and tested in accordance with IS 10262.
- c) Whenever there is a significant change in the quality of any of the ingredients concrete, the Engineer, at his discretion, may order the carrying out of fresh trial mixes. All costs for trial mixes and tests shall be borne by the Contractor's and held to be included in the contract rates.
- d) Before commencing the Works, the Contractor shall submit full details of the preliminary trial mixes and tests to the Engineer for approval.

#### **Cementitious Content**

Maximum cementitious material content shall be limited to 500 Kg/Cum for both RCC and PSC work.

Maximum cement content shall be limited to 450 Kg/Cum for both RCC and PSC work.

Cementitious content in concrete shall not be less than 400 kg/ cum for RCC work and 400 kg/ cum for PSC work under moderate exposure as per Clause 5.4 of IRS CBC (Note: The corrigendum 12 and addendum to this clause shall not be followed.) In case of piling work minimum cement content shall be as specified under Pile Foundations. Use of Fly Ash conforming to IS 3812 Part-I shall be permitted except for pre stressed superstructure.

As regards trial mixes, acceptance criteria, acceptance specification, lot size, sampling and testing and sampling size for piling work, PSC girders (cast-in-situ and precast post-tensioned) and general work, the requirement of the relevant codes, standards and directions of the Engineer shall be followed.

### **3.8 Additional tests for Concrete:**

As frequently as the Engineer may require, additional testing shall be carried out for concreting in addition to mandatory tests specified in CPWD specifications 2019 / relevant IS Code / MOST/MORTH Specifications. All the codes shall be latest and updated irrespective of the version mentioned in these technical specifications.

- a. Permeability test for Concrete:  
The concrete will be verified for permeability by the following procedure and shall conform to IS: 3085-1965 - 'Permeability of Cement Mortar & Concrete', Section 1717.7.5 of MORTH Specification and DIN 1048.
- b. The Engineer shall select random batches of concrete for examination at his discretion and sampling will generally be done at the point of discharge from the mixer and at placing point. From the batches thus selected two concrete cylinders shall be made in accordance DIN 1048.
- c. All cylinders shall be made, cured, stored, transported and tested in accordance with clause 1717.7.5 of MORTH Specifications. The tests shall be carried out in a laboratory approved by the Engineer.
- d. At least two cylinders shall be made on each day's concreting until 60 cylinders have been made for each grade of concrete. The cylinders will be tested as per the procedure, given in Clause 5 next.

Permeability of concrete shall be checked as per the latest relevant standard for all the grade of concrete to the frequency set by the Engineer at own or 3<sup>rd</sup> party laboratory approved by the Engineer.

e. Test Procedure:

The permeability of concrete will be verified by the following procedure.

- i. Prepare a cylindrical test specimen of 150 mm dia and 160mm high.
- ii. After 28 days of curing, the test will be conducted between 28 and 35 days. The test specimen shall be fitted in a machine such that the specimen can be placed in water under pressure up to 7 bars. The typical machine shall be similar to one shown in Appendix 1700/I of MORTH.
- iii. The concrete specimen shall be subjected to a water pressure of 0.5N/mm<sup>2</sup> from the top for a period of 3 days. The pressure shall be maintained constant throughout the test period. If the water penetrates through to the underside of the specimen, the test may be terminated and specimen rejected as failed.
- iv. After three days, the pressure shall be released and the sample shall be taken out. The specimen shall be split in the middle by compression applied on two round bars on opposite sides above and below.
- v. The water penetration in the broken core is measured with scale and the depth of penetration assessed in mm (max permissible limit 25 mm).

f. Acceptability Criteria:

The concrete shall pass the permeability test if it is properly compacted and is not considered permeable when tested as per DIN, and the water penetration in the broken core is less than 25mm.

No extra payment shall be made for this test and cost of the same will be included in his rate for concrete work.

### 3.9 Batching of Concrete Ingredients:

Unless permitted by the Engineer, all concreting shall be either produced in automatic weigh batching plant installed at site or Ready Mix Concrete manufactured in automatic weigh batching plant. Prior approval of RMC plant shall be obtained from the Engineer before supply. The Engineer or his representative will evaluate the condition of plant, QMS and consistency of RMC in accordance with IS: 4925 to deliver quality concrete before giving the approval. Engineer has the power to reject approved RMC at any point of time if he is not satisfied with the quality or service maintained by the agency. Engineer's decision will be deemed as final.

### 3.10 Placing temperatures:

During extreme hot or cold weather, the concreting shall be done as per procedures set out in IS: 7861, Parts I & II.

In hot weather with temperature exceeding 40 degree Celsius, the stock piles of fine and coarse aggregates for concreting shall be kept shaded from direct rays of sun and the concrete aggregates sprinkled with water for a sufficient time before concreting in order to ensure that the temperature of these ingredients is as low as possible prior to batching. The mixer and batching equipment shall be also shaded and if necessary painted white in order to keep their temperatures as low as possible. **The**

**placing temperature of concrete shall be as low as possible in warm weather but in no case more than 35 degree Celsius** and care shall be taken to protect freshly placed concrete from overheating by sunlight in the first few hours of its laying. The time of day selected for concreting shall also be chosen so as to minimise placing temperatures. In case of concreting in exceptionally hot weather the Engineer may in his discretion specify the use of ice either flaked and used directly in the mix or blocks used for chilling the mixing water. In either case, the Contractor shall not be paid extra for cost of ice, additional labour involved in weighing and mixing etc. All salt and saw dust shall be removed from ice before use. Quality of water used for making ice shall confirm to IS: 456. It is mandatory to establish a chiller plant near batching plant to cater to the needs of acceptable temperature of fresh concrete. Nothing extra shall be paid in this regard. Contractor is solemnly responsible for delivering concrete within restricted temperature at site.

### 3.11 Transporting, Placing, Compacting and Curing:

Transporting, placing, compacting and curing of concrete shall be in accordance with IS: 456.

#### a. Transporting:

The mix after discharging from the mixer shall be transported by transit mixers, buckets, pumps etc. or as approved by the engineer without causing segregation and loss of cement slurry and without altering its desired properties with regard to water cement ratio, slump, air content, cohesion and homogeneity. It should be ensured that the concrete is moved to its final destination before it attains an initial set.

The transportation is to be done by agitating transit mixers, pumps or other approved methods. During hot weather, concrete shall be transported in deep containers. Other suitable methods to reduce the loss of water by evaporation in hot weather such as covering/wrapping transit mixer's drum by hessian cloth may also be adopted.

#### b. Placing :

The method of placing shall be such as to prevent segregation by providing windows in the formwork for pouring concrete or by Tremie pipe. The thickness of horizontal layers shall not exceed 300mm. High velocity discharge of concrete causing segregation of mix shall be avoided. The concrete shall be placed in the forms gently and not dropped from a height exceeding 1.5m except in columns where the maximum allowed will be 2.0m. Each layer of concrete shall be compacted fully before the succeeding layer is placed and separate batches shall follow each other so closely that the succeeding layer shall be placed and fully compacted before the layer immediately below has taken initial set.

For piers, pier heads, portal columns and portal beams the concreting is to be carried out in single stage i.e. in first stage concreting will be from kicker to just below pier head bottom and second stage of concreting will be pier head including shear key and cross girder (in station zone stages as given in drawings for all heights by using tremie/ pumps at the rate not more than 1.5m / hr or as approved by the Engineer.

Concreting of any portion or section of the work shall be carried out in one continuous operation and no interruption of concreting work will be allowed without; approval of the Engineer.

#### c. Compaction:

Internal (needle) and surface (screed board) vibrators of approved make shall be used for compaction of concrete.



Internal vibrators shall be used for compaction of concrete in foundations, columns, buttresses arch section, slabs etc., and if required surface vibrators shall also be used. Depending on the thickness of layer to be compacted, 25 mm, 40 mm, 60 mm and 75 mm dia internal vibrators will be used. The concrete shall be compacted by use of appropriate diameter vibrator by holding the vibrator in position until:

- i) Air bubbles cease to come to surface.
  - ii) Resumption of steady frequency of vibrator after the initial short period of drop in the frequency, when the vibrator is first inserted.
  - iii) The tone of the vibrated concrete becomes uniform.
  - iv) Flattened, glistening surface, with coarse aggregates particles blended into it appears on the surface.
  - v) Use of curing compounds may be permitted with specific approval of Engineer.  
After the compaction is completed, the vibrator should be withdrawn slowly from the concrete so that concrete can flow in to the space previously occupied by the vibrator. To avoid segregation during vibration the vibrator shall not be dragged through the concrete nor used to spread the concrete. The vibrator shall be made to penetrate, into the layer of fresh concrete below if any for a depth of about 150mm. The vibrator shall be made to operate at a regular pattern of spacing. The effective radii of action will overlap approximately half a radius to ensure complete compaction.
  - vi) To secure even and dense surfaces free from aggregate pockets, vibration shall be supplemented by tamping or rodding by hand in the corners of forms and along the form surfaces while the concrete is plastic.
  - vii) A sufficient number of spare vibrators shall be kept readily accessible to the place of deposition of concrete to assure adequate vibration in case of breakdown of those in use.
  - viii) Form vibrators whenever used shall be clamped to the sides of formwork and shall not be fixed more than 450 mm above the base of the new form work and concrete shall be filled not higher than 230mm above the vibrator. The formwork must be made specially strong and watertight where this type of vibrator is used.  
Care must be taken to guard against over vibration especially where the workability of the concrete mix is high since this will encourage segregation of the concrete.
  - ix) Plain concrete in foundations shall be placed in direct contact with the bottom of the excavation, the concrete being deposited in such a manner as not to be mixed with the earth. Plain concrete also shall be vibrated to achieve full compaction.
- d. Concrete placed below the ground 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 from during placing and for a period of seven days or as otherwise instructed thereafter. Approved means shall be taken to protect immature concrete from damage by debris, excessive loading, abrasion, vibrations, deleterious ground water, mixing with earth or other materials, and other influences that may impair the strength and durability of the concrete.
- e. Curing:
- i. Curing of concrete shall be complete and continuous using potable water free from chlorides and sulphates. Water that is free of harmful amounts of deleterious materials that may attach stain or discolour the concrete as per IS 456. The concrete shall be kept constantly wet for a minimum period of 14 (fourteen) days by ponding or covering with a layer of wet (but not dripping) sacking, canvas, hessian or similar absorbent material.

- ii. Method of curing and their duration shall be such that the concrete will have satisfactory durability and strength and members will suffer a minimum distortion, be free from excessive efflorescence and will not cause undue cracking in the works by shrinkage.
- iii. Steam curing with approved methodology can be adopted if required, for precast segments. No extra payment will be made for adopting steam curing. Before concrete products are subjected to any accelerated method of curing, the cement to be used shall be tested in accordance with accepted standards (relevant IS codes) especially for soundness, setting time and suitability for steam curing. In the case of elements manufactured by accelerated curing methods, concrete admixtures to reduce the water content may be allowed to be as permitted by applicable codes of practice subject to the approval of the Engineer. The normal aeration agents used to increase the workability of concrete shall not be allowed. The steam curing of concrete products shall take place under hoods, under chambers or in tunnels. Use of insulated tarpaulin may be permitted. The steam shall have a uniform quality throughout the length of the member. The precast elements shall be stacked with sufficient clearance between each other and the bounding enclosure, so as to allow proper circulation of steam. The surrounding walls, the top cover and the floor of steam curing chamber or tunnel or hood shall be so designed as not to allow more than 1 kcal/m<sup>2</sup>/h/ degC. The inside face of the steam curing chamber, tunnel or hood shall have a damp-proof layer to maintain the humidity of steam. Moreover, proper slope shall be given to the floor and the roof to allow the condensed water to be easily drained away. At first, when steam is let into the curing chambers, the air inside shall be allowed to go out through openings provided in the hoods or side walls which shall be closed soon after moist steam is seen jetting out. Preferably, steam should be let in at the top of the chamber through perforated pipelines to allow uniform entry of steam throughout the chamber. In no case shall steam impinge directly on concrete products. The fresh concrete in the moulds shall be allowed to get the initial set before allowing the concrete to come into contact with steam. The regular heating up of fresh concrete product from 20 °C to 35 °C shall start only after a waiting period ranging from 2 to 5 hours depending on the setting time of cement used. The second stage in steam curing process shall be to heat up the concrete elements, moulds and the surroundings in the chamber. The air-space around the member shall be heated up to a temperature of 75°C to 80°C at a gradual rate, not faster than 30° C per hour. This process shall continue 1 1/2 to 2 1/2 hours depending upon the outside temperature. The third stage of steam curing shall be to maintain the uniform temperature and pressure for a duration depending upon thickness of the section. This may vary from 3 to 5 1/2 hours. The fourth stage of steam curing shall be the gradual cooling down of concrete products and surroundings in the chamber and normalization of the pressure to bring it at par with the outside air. The maximum cooling rate, which is dependent on the thickness of the member, shall not exceed 30° C per hour. In all these cases, the difference between the temperature of the concrete product and the outside temperature shall not be more than 60°C for concrete up to M 30 and 75°C for concrete greater than M 45. In the case of light weight concrete, the difference in temperature shall not be more than 60°C for concrete less than M 25. For concrete greater than M 50, the temperature differences may go up to 75°C. After the steam curing is completed, the elements shall be further water cured for about 3 to 7 days.

Curing Compound shall be used only after specific approval from Engineer-in-Charge. Clear, water based, non-toxic, non-film forming, reactive silicate treatment with indefinite shelf life suitable as a complete replacement to any water curing procedures such as water soak, ponding, blankets and plastic sheets for all horizontal and vertical surfaces. Manufacturer shall supply written proof of completed, successful projects for upto 30 years.

Approved curing compounds may be used in lieu of moist curing with the permission of the engineer. Such compounds shall be applied to all exposed surfaces of the concrete along with stripping of form work. Tests shall be done to ascertain: (i) Loss of moisture in concrete with and without curing compound. (ii) Cube strength of concrete with moist curing and curing compound. (iii) Permeability of concrete.

Application of curing compound shall be done after prior approval from the Engineer or his representative at site. Nothing extra will be paid for any related activity for supplying or applying the curing compound in lieu of moist curing or grinding it after the curing period for painting the structure if any.

- iv. Curing compound should have been successfully tested by CRRI as a replacement for water curing and accredited by IRC also. Material test result should be in compliance with ASTM C 309 and ASTM 1315°.

**No curing compound is allowed for superstructure members.**

### 3.12 Construction Joints:

Construction joints in all concrete work shall be made as directed by the Engineer. Where vertical joints are required, these shall be shuttered as directed and not allowed to take the natural slope of the concrete.

Before fresh concrete is placed against a vertical joint, the old concrete shall be chipped, cleaned and moistened.

No separate payment shall be allowed to the Contractor for forming joints or chipping and cleaning them. When a horizontal construction joint is formed, provision shall be made for interlocking with the succeeding layer by the embedment of saturated wooden blocks or wooden strips bevelled on four sides to facilitate their removal. Prior to the next pour the wooden pieces shall be loosened and removed in such a manner as to avoid injury to the concrete.

Construction joints in concrete walls and slabs for liquid retaining structures shall be prepared in a similar manner to normal construction joints. If use of metal, rubber or plastic water stops is specified, this shall be cast in to joints. Measures shall be taken by the contractor to ensure that no displacement or distortion of water stops takes place during placing of concrete. The construction joints shall ensure proper bond and leak proof joint. Construction joint is not permitted in superstructure members.

### 3.13 Cracks:

If cracks, which in the opinion of the Engineer may be detrimental to the strength of the construction, develop in concrete construction, the Contractor at his own expense shall test the structure as specified in clause 1.1.16 of 'Load Testing' of these Specifications. If under such test loads the cracks develop further, the Contractor shall dismantle the construction, carry away the debris, replace the construction and carry out all consequential work thereto.

If any cracks develop in the concrete construction, which in the opinion of the Engineer, are not detrimental to the stability of the construction, the Contractor at his own expense shall grout the cracks with neat cement grout or with other composition as directed by Engineer (IRC:SP -40) and also at his own expense and risk shall make good to the satisfaction of the Engineer all other works such as plaster, moulding, surface finish, which in the opinion of the Engineer have suffered damage either in appearance or stability owing to such cracks. The Engineer's decision as to the extent of the liability of the Contractor in the above matter shall be final and binding.

External crack width shall be restricted to 0.2 mm on all viaduct structures, if cracks width is more than 0.2 mm or in the opinion of Engineer may be detrimental to concrete construction, the contractor at his own expenses should test the structure.

**3.14 Defective Concrete:**

Should any concrete be found honeycombed or in any way defective, such concrete shall be cut out partially or wholly by the Contractor and made good at his own expense. If Engineer feels that repaired structure will not be having same strength or shape or uniformity with other exposed surface as original desired structure / original structure, the same shall be rejected by Engineer and required to be dismantled and disposed by contractor at his own cost as instructed by Engineer. Decision of the Engineer shall be final and binding in this regard.

**3.15 Exposed Faces, Holes and Fixtures:**

On no account shall concrete surfaces be patched or covered up or damaged concrete rectified or replaced until the Engineer or his representative has inspected the works and issued written instructions for rectification. Failure to observe this procedure will render that portion of the works liable to rejection.

Holes for foundation or other bolts or for any other purposes shall be moulded and steel angles, holdfasts or other fixtures shall be embedded, according to the drawing or as instructed by the Engineer.

**3.16 Finishes:**

Unless otherwise instructed the face of exposed concrete placed against formwork shall be rubbed down immediately on removal of the formwork to remove irregularities. The face of concrete for which formwork is not provided other than slabs shall be smoothed with a float to give a finish equal to that of the rubbed down face, where formwork is provided. The top face of a slab which is not intended to be covered with other materials shall be levelled and floated to a smooth finish at the levels or falls shown on the drawings or as directed. The floating shall be done so as not to bring an excess of mortar to the surface of the concrete. The top face of a slab intended to be surfaced with other material shall be left with a spaded finish. Faces of concrete intended to be plastered shall be roughened by approved means to form key.

**3.17 Concrete for flooring on grade:**

Concrete for flooring on grade shall be placed in alternate bays not exceeding more than 4m x 6m or as specified in the drawings including forming the joints or adjacent bays. The stiff mix shall be thoroughly vibrated and finished to receive the floor finish.

**3.18 Grouting of base plates & bolt holes:**

**i. Mixing:**

Dry grout should be mixed in a mechanical mixer: the conventional 200/400-litre capacity concrete mixer can be used to mix four bags of dry grout; alternatively, paddle type mortar mixers can be used. The quantity of grout to be mixed at one time should not exceed that amount which can be placed in approximately 10 to 15 minutes.

**ii. Batching :**

Batching of grout by fraction of a bag is not allowed. The quantity of mixing water should be the minimum commensurate with workability, compaction, and filling of the grout in all corners and crevices. Mixing should be done for a minimum of three minutes to obtain a fluid grout of uniform consistency.

**iii. Cleaning and preparation of the surface:**

The base concrete should be clean and strong, and its surface should be properly hacked; all dust should be removed by suction or compressed air. The surface should be thoroughly wetted with water for several hours. Before the grout is poured, all free water should be removed and the flat surfaces coated with a thin cement slurry.

**iv. Restraint:**

Heavy back-up blocks of timber or concrete should be fixed on all sides of the base plate to prevent escape of the grout, when poured through the openings provided in the base plate. Adequate restraint must be ensured on all the sides for a period of 7 days to obtain effective expansion and shrinkage compensation.

**v. Curing:**

The grout should not dry out where external restraint is provided in the form of formwork, the top opening and all stray openings should be covered with wet sack for at least 7 days.

**vi. Placing and Compaction:**

The grout should be placed quickly and continuously either through the holes in the base plates or from one side only to ensure complete filling without entrapment of air. Grout should be properly spread and compacted by rodding. Excessive vibration should be avoided. Below the bed plates the grout should be compacted using long pieces of doubled- over flexible steel strapping or chains. The forward and backward movement of the strap or chain will assist in the flow of the grout into place. Steps must be taken to keep the grout in full contact with the underside of the bedplate until the grout sets; maintaining a small head of fresh grout in the forms.

**vii. Shrinkage Compensated Grout:**

Shrinkage compensated grout or non-shrinkable grout of Associated Cement Companies Limited or any other approved manufacturer (Fosroc, Sika) should be used. The batching shall be as per the manufacturer's specifications, other procedures being as above.

### 3.19

**(a) Precast Concrete:**

The provision in this section shall be considered supplementary to general provisions for reinforced concrete works.

**Handling and Storage:**

The precast units shall be stored as directed by the Engineer. The area intended for the storage of precast units should be surfaced in such a way that no unequal settlement can occur.

To prevent deformation of slender units, they should be provided with supports at fairly close intervals and should also be safeguarded against tilting. Lifting and handling positions should conform to the Engineer's directions and drawings. In addition, location and orientation marks should be put on the members, as and where necessary. During erection the precast units should be protected against damage caused by local crushing and chafing effects of lifting and transport equipment.

**Temporary Supports and Connections:**

Temporary supports provided during erection should take into account all construction loads likely to be encountered during the completion of joints between any combination of precast and in-situ concrete structural elements. The supports should be arranged in a manner that will permit the proper finishing and curing of any in-situ concreting and grouting associated with the precast member being supported when the gaps of joints have to be filled with concrete or mortar. They should first be cleaned and faces of the joints should be wetted. The mixing, placing and compacting of cement and mortar should be done with special care. Mortar of a dry consistency should be in the proportion of 1:1% (1 part of cement to VA parts of sand) and should be placed in stages and packed hard from both sides of the joint.

**Tolerances:**

The following tolerances apply to finished precast products at the time of placement in the structure.

The forms must be constructed to give a casting well within these limits:

- i. Overall dimensions of members should not vary more than  $\pm 6\text{mm}$  per 3m length with a maximum variation of  $\pm 20\text{mm}$ .
- ii. Cross-sectional dimensions should not vary more than the following:
  - $\pm 3\text{mm}$  for sections less than 150mm thick
  - $\pm 4\text{mm}$  for sections over 150mm & less than 450mm  $\pm 6\text{mm}$  for sections over 450mm to 1000mm .
  - $\pm 10\text{mm}$  for sections over 1000mm

Deviation from straight line in long sections should not be more than  $\pm 5\text{mm}$  up to 3m,  $\pm 10\text{mm}$  for 3m to 6m,  $\pm 12\text{mm}$  for 6m to 12m.

For tolerances on precast segments for girders please refer Annexure 11.2.

**(b) Structural steel inserts/bolts for connecting precast concrete elements**

GI Square rods with internal threading and GI base plate/stiffener, shall be firmly fixed in the mould to the true line, level and alignment as shown in drawings. If required by engineer MS template may use for above purpose. The threaded hole/pipe shall be properly protected so as to prevent ingress of mortar etc. (by providing dummy bolts, PVC cover, cotton waste etc.).

**3.20 Ready Mix Concrete and Pumping:**

- i. Ready-mixed concrete may be manufactured in a central automatic weigh Batching plant and transported to the place of work in agitating transit mixers shall conform to IS:4926.

The maximum size of coarse aggregate shall be limited to one-third of the smallest inside diameter of the hose or pipe used for pumping. Provision shall be made for elimination of over-sized particles by screening or by careful selection of aggregates. To obtain proper gradation it may be necessary to combine and blend certain fractional sizes of aggregates. Uniformity of gradation throughout the entire job shall be maintained.

The quantity of coarse aggregate shall be such that the concrete can be pumped, compacted and finished without difficulty.

- ii. Fine aggregates:
 

The gradation of fine aggregate shall be such that 15 to 30 percent should pass the 0.30 mm screen and 5 to 10 percent should pass 0.15 mm screen so as to obtain pump able concrete. Sands, which are deficient in either of these two sizes, should be blended with selected finer sands to produce these desired percentages. With this gradation, sands having a fineness modulus between 2.4 and 2.8 are generally satisfactory. However, for uniformity, the fineness modulus of the sand should not vary more than 0.2 from the average value used in proportioning.
- iii. Water, Admixtures and Slump:
 

The amount of water required for proper concrete consistency shall take into account the rate of mixing, length of haul, time of unloading, and ambient temperature conditions.

Additions of water to compensate for slump loss should not be resorted to nor should the design maximum water-cement ratio be exceeded. Additional dose of retarder be used to compensate the

loss of slump at contractor's cost, when permitted by Engineer. Re-tempering water shall not be allowed to be added to mixed batches to obtain desired slump.

iv. Transportation:

The method of transportation used should efficiently deliver the concrete to the point of placement without significantly altering its desired properties with regard to water- cement ratio, slump, and homogeneity.

The revolving-drum truck bodies of approved make shall be used for transporting the concrete. The numbers of revolutions at mixing speed, during transportation, and prior to discharge shall be specified and agreed upon. Reliable counters shall be used on revolving drum truck units. Standard mixer uniformity tests, conforming to ASTM standards C 94-69 "Standard Specifications for Ready Mix Concrete", shall be carried out to determine whether mixing is being accomplished satisfactorily.

v. Pumping of concrete:

Only approved pumping equipment, in good working condition, shall be used for pumping of concrete. Concrete shall be pumped through a combination of rigid pipe and heavy duty flexible hose of approved size and make. The couplings used to connect both rigid and flexible pipe sections shall be adequate in strength to withstand handling loads during erection of pipe system, misalignment, and poor support along the lines. They should be nominally rated for at least 3.5 MPa pressure and greater for rising runs over 30 m. Couplings should be designed to allow replacement of any section without moving other pipe sections, and should provide full cross section with no construction or crevices to disrupt the smooth flow of concrete.

All necessary accessories such as curved sections of rigid pipe, swivel joints and rotary distributors, pin and gate valves to prevent backflow in the pipe line, switch valves to direct the flow into another pipe line, connection devices to fill forms from the bottom up, extra strong couplings for vertical runs, transitions for connecting different sizes of pipe, air vents for downhill pumping, clean-out equipment etc, shall be provided as and where required. Suitable power controlled booms or specialized crane shall be used for supporting the pipe line.

vi. Field control:

Sampling at both truck discharge and point of final placement shall be employed to determine if any changes in the slump and other significant mix characteristics occur. However, for determining strength of concrete, cubes shall be taken from the placement end of line.

vii. Planning:

Proper planning of concrete supply, pump locations, line layout, placing sequence, and the entire pumping operation shall be made and got approved. The pump should be as near the placing area as practicable, and the entire surrounding area shall have adequate bearing strength to support concrete delivery pipes. Lines from pump to the placing area should be laid out with a minimum of bends. For large placing areas, alternate lines should be installed for rapid connection when required. Standby power and pumping equipment should be provided to replace initial equipment, should breakdown occur. The placing rate should be estimated so that concrete can be ordered at an appropriate delivery rate.

As a final check, the pump should be started and operated without concrete to be certain that all moving parts are operating properly. A grout mortar should be pumped into the lines to provide lubrication for the concrete, but this mortar shall not be used in the placement. When the form is

nearly full, and there is enough concrete in the line to complete the placement the pump shall be stopped and a go-devil inserted and shall be forced through the line by water under pressure to clean it out. The go-devil should be stopped at a safe distance from the end of the line so that the water in the line will not spill into the placement area. At the end of placing operation, the line shall be cleaned in the reverse direction.

### 3.21 Additional Specifications for Concrete M60 and above

- (a) Mineral admixture in the form of micro silica or condensed silica fume shall be permitted in the design mix. It shall comply with IS 15388 (2003) and ASTM C 1240 "Specifications for Fume for use in Hydraulic Cement Concrete and Mortar". It shall be obtained from proven and reliable manufacturer/supplier to the satisfaction of the Engineer.
- (b) Adequate and complete dispersal of the micro silica during the concrete mixing shall be ensured.
- (c) When micro silica is used in powder form the contractor shall take all precautions against potential health hazards during handling of the material.
- (d) Chilled water and/ or ice shall be used in the concrete mix depending on the ambient temperature, dimensions of the concrete element, rate of pouring and design mix constituents.
- (e) Special profuse curing arrangements shall be made for dissipation of the heat of hydration. The water curing shall be continued for a period of 14 days.
- (f) The concrete design mix and arrangement for mixing, transportation, and curing of concrete shall be subject to the approval of the Engineer.

### 3.22 Measurement (Not applicable for Viaduct Lumpsum portion (Schedule B)):

Concrete and reinforcement shall be paid separately unless otherwise "specified. Measurement shall be made for the finished volume of reinforced cement concrete (excluding lean concrete) only. All linear dimensions shall be measured correct to 1cm & restricted to design dimensions, and the volume calculation will be correct to two decimal places in cubic metres. The volume of concrete measured shall include that occupied by:

1. Reinforcement and other metal sections.
2. Cast in components each less than 0.01 cum in volume.
3. Rebates fillets or internal splays each less than 0.005 Sq.m in cross sectional area.
4. Pockets and holes not exceeding 0.01 m<sup>3</sup> in volume.

Rates for precast concrete shall include remoulding, handling, storing, transporting and erecting at site, including all clamping, bracing that may be required during erection including erection equipment.

### 3.23 Inspection, Tests and Standards of Acceptance

- a. The Contractor shall submit test certificates from the manufacturer or supplier of materials along with each batch of material(s) delivered to site.
- b. The Contractor shall set up a field laboratory with necessary equipment for testing of all materials, finished products to be used in the construction.
- c. The testing of all the materials shall be carried out by the Contractor at the field laboratory or from the laboratory approved by the Engineer and in the presence of the Engineer. The Contractor shall make all the necessary arrangements and bear the entire cost for the same.
- d. Tests which cannot be carried out in the field laboratory shall be done at the Contractor's cost at any recognised laboratory or testing establishments having NABL certification and duly approved by the Engineer.
- e. If materials are brought from abroad, the cost of sampling or testing, whether in India or abroad, shall be borne by the Contractor.



- f. The Contractor shall provide and maintain on site, until the works are completed, at all times the equipment and staff required for carrying out these tests. The Contractor shall grant the Engineer or his representative full access to his laboratory at all times and shall, on demand, produce complete records of all tests carried out on the Site.

### 3.24 Quality Control of Concrete

- a. The Contractor shall carry out the following tests for concrete, at his own cost, at the site of placing and ensure that they comply with appropriate provisions of Indian and/or other standards, as may be applicable:
  - i. Slump test for concrete: The frequency of slump test shall be conducted once in each delivery of transit mixer as per IS: 1199 & IS: 7320. Tolerance for slump shall conform to IS 4926 (CL. 6.2.1).
  - ii. Compressive and Flexural strength of concrete: Sampling, Strength tests and Acceptance criteria of concrete shall conform to IS: 456 & IS 1199. according to the type of concrete grade. For the purpose of precast segment lifting and pre-stressing of segments, additional concrete cube samples shall be casted as directed by the Engineer-In-Charge.
  - iii. Chloride ion content test: It shall be conducted once a week. Test method shall be as per manufacturer's instructions and conforming to IS 456.
  - iv. Relative Density and pH value of plasticizer (if used): The test shall conform to IS 9103 and the tolerances shall be as specified in IS:9103.
  - v. Temperature of concrete shall be verified once in each slump test.
  - vi. The concrete shall be verified for permeability and the test procedure along with tolerances shall conform to the provisions given in these specifications. The frequency of test shall depend upon the change in design mix or change in source of material used in the work. However, the Engineer shall select random batches of concrete for examination at his discretion, and any time during concreting. Sampling shall generally be done at the point of discharge from the mixer and at placing point. The concrete shall pass the permeability test if it is properly compacted and the water penetration depth in the broken core is less than 25 mm.
- b. It is the complete responsibility of the Contractor to redesign the concrete mixes as per the standard methods that have been approved and to produce the reinforced concrete conforming to the specifications. The Contractor shall have competent staff to carry out this work.
- c. After the completion of the quality control checks of concrete, the Contractor shall immediately report the test results to the Engineer by submitting quality control records of the concrete.

### 3.25 Failure to meet specified Requirements:

- i. If from the cube test results, it appears that some portion of the Works has not attained the required strength, the Engineer may order that portion of the structure be subjected to further testing of any kind whatsoever as desired by the Engineer, including, if so desired by him, full load testing of the suspected as well as adjacent portions of the structure as specified in the Conditions of Contract. Such testing shall be at the Contractor's own cost. The Engineer may also reject the work and order its demolition and reconstruction at the Contractor's cost.
- ii. If the strength of concrete in any portion of the structure is lower than the required strength, but is considered nevertheless adequate by the Engineer so that demolition is not necessary, the Contractor shall be paid a lower rate for such lower strength concrete as determined by the Engineer.

### 3.26 Inspection of Concrete

- a. Inspection shall be carried out by the Contractor, after the removal of formwork. Also, additional inspection shall be carried out if instructed by the Engineer.
- b. Inspection shall be carried out as per approval of the Engineer and in accordance with approved Method Statement.
- c. Additional non-destructive tests (NDT) on the hardened concrete in the structure as a whole or any finished part of the structure where necessary, or directed by the Engineer.
- d. The Contractor shall report the inspection results along with the location to the Engineer immediately after the inspection.
- e. If defects such as deleterious cracking, deformation, and finishing defects are noticed from the results of the inspection, no repair work shall be commenced without prior permission taken from the Engineer. Countermeasures against the defects shall be subjected to approval of the Engineer. In this case, "repair work" refers to all actions which make alterations to the surface of concrete after the removal of formwork (including plastering etc.). If repair work is required, the Contractor shall submit Method Statement on the repair work and shall obtain approval of the Engineer for the same, prior to the commencement of repair work. During the repair work, the Contractor shall record about the work, and shall report to the Engineer on the results of the work immediately after the repair work has finished.
- f. If cracks develop in concrete construction, provisions given elsewhere in these specifications shall be followed.