TENDER DOCUMENT

FOR

Distribution Network for Nabinagar Division of Right Main Canal (RMC), Bihar Portion under North Koel Reservoir Project, Jharkhand and Bihar

Estimated Cost (Rs. 47.85 Crores)

TENDER NO: WAP/NK/RMC/DIST/NABINAGAR/2025

VOLUME -3

TECHNICAL SPECIFICATIONS- Part I
(Canal work)

Issued to M/s_____

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WAPCOS

(भारत सरकार का उपक्रम–जल शक्ति मंत्रालय)

(A Government of India Undertaking-Ministry of Jal Shakti)

Technical Specification

All works shall be carried out in accordance with relevant Indian Standard Code (s) of practice, technical specifications of Irrigation Department or as directed by Engineer-in-charge where necessary.

1 General

These specifications are intended for general description of quality and workmanship of materials and finished work. They are not intended to cover minute details. The work shall be executed in accordance with sound Engineering practice where reference is made to any standard specification of Indian Standards Institution or any other similar body, information and provisions of the latest revised edition of the specifications at the date of submission of the tender shall be applicable. If the provisions of such standard specifications are in conflict with the provisions stated in these specifications, the latter provisions shall have precedence.

a) The intending tenderer is deemed to have visited the work site and acquainted himself of the nature of the sub-soil to be executed. No claim or extra will be allowed as a result of any misunderstanding or incorrect assessment or misinformation or ignorance of the contractor on the prevailing site conditions or soil strata.

b) All the materials to be used on the works are required to be of the best quality as specified and described and all the materials to be used on work are required to be tested at no extra cost to the employer for their respective strength and quality. Tested samples of materials are not paid for and are non-returnable to the contractor. Testing labs to be established for testing concrete etc. Equipment for control concreting should be used for preparing concrete as per specifications at the cost of the contractor.

c) Contractor shall submit to the employer samples of all materials for prior approval and no work shall commence before such samples are approved by the Engineer-in-charge.

d) All material and methods shall conform to the latest specifications of Bureau of Indian Standards (BIS) and relevant codes. All measurements will be taken in accordance with latest specifications of Bureau of Indian Standards (BIS) and relevant codes.

e) All works shall be carried out strictly according to the drawings and instructions of Engineer-in-charge if, in the opinion of the Employer / Architects / Engineer-in-charge any portions of the work is found to be defective or unsound the same shall be pulled down and reconstructed at no extra cost to the employer. Defective materials shall not be brought to the work site by the contractor.

f) A site order Book shall be maintained by the contractor's authorized agent at work site, and the instructions issued by the Employer/ Engineer-in-charge during periodical inspection visits shall be duly entered therein.

g) No standing tree shall be cut by the contractor without the permission of Engineer-in-charge.

h) The site shall be cleared of all rubbish shrubs, vegetational roots, loose boundary materials and got levelled up by filling hollows before starting construction.

i) Before starting the work, the Contractor or his duly authorized agent shall be present while taking ground levels/ pre levels along and across the alignment of the various works, etc., and shall have to sign the field book and also working plans showing working longitudinal and cross sections of their alignment in token of having accepted the ground levels without which they will not be allowed to start the work.

j) Accurate marking and recording levels of earth work and structure of the different portions of canal using the total station instrument is the responsibility of the contractor. Permanent Bench Mark pillars of masonry shall be constructed by the contractor .These Bench marks are required to be maintained by the contractor for checking the elevation at various stages of work by total station.

k) Lifts, Hoists, elevators, ramps and ladders of proper strength and rigidity shall be provided by the contractor not only for conveyance of construction materials to various heights, but also for the safe reaching of workmen and inspection parties to reach all spots of construction, the cost of which are deemed to have been included in the rates.

l) Deep trenches of excavation, newly placed concrete work are required to be properly protected from rain, bad-weather and accidents by adequate means at no extra cost to the employer.

Bailing out water or De-watering:

The rates for various items quoted by the contractor, should include the cost of dewatering. Separate payment will not be made on this account.

i) Should the contractor desire to substitute/ deviate any material or workmanship for any reason whatsoever during construction, prior written approval of the Engineer-in-charge must be obtained, or else such portion of works will be rejected.

ii) All preliminary and enabling construction at site, like site office (for himself & client) , store, cement shed, labour/ watchmen quarters and temporary water storage tank shall be constructed and removed after completion of works by the contractor at no extra cost to the employer.

2 Earth Work in canals/Distributaries

2.1 Setting Out

- Before start of work center line of the canal shall be marked by suitable and firm pegs each at about 30 m interval in straight reaches. In the curved reaches of the canal the curve shall be laid out and top and bottom edges of excavation and toe of embankment shall be suitably peg marked. The center line in such reaches shall be marked by pegs at an interval of 5 m to ensure smooth curve profile during excavation/filling. Distance pegs/muttams shall be constructed at 200 m interval at canal boundary for proper alignment.
- All levels of canal profiles shall be referred to a specified and established firm bench mark not subject to subsidence/interference or disturbance. Temporary bench mark pillars shall be constructed at suitable locations for reference of levels during construction.
- Kuccha Namunas of canal section in fill and cut reaches shall be marked at intervals of 25m at curves and 50 m in the straight reaches or as directed by Engineer-in-charge before start of earth work in the reach.

2.2 Clearing of Land

Before beginning the construction/repair of embankment, the land over which excavations or embankment is to be done/placed shall be cleared of all trees, bushes, vegetation, rubbish, roots, ant hills and any other objectionable material before excavation or placing earth for embankment. The cleared material shall be the property of the Government and its disposal shall be done in a manner as approved by the Engineer-in-charge. The land so cleared shall be maintained free from any growth and vegetation during progress of construction.

In filling reaches, all holes and hollows whether originally existing or produced by digging up roots shall be filled with suitable earth well rammed and leveled off. The depth to which top soil is removed shall be adequate to remove all perishable material and any soil which may become unstable on saturation or may interfere with the development of proper bond between the existing surface and new embankment. As per IS 4701, the depth of stripping as guide for containing light grass cover shall be 5 to 7.5cm. It shall be 20cm for soil containing thick vegetation/agricultural land.

2.3 Drawings

All works shall be carried out in accordance with the Construction drawings to be supplied by the Contractor after obtaining approval from the Engineer-in-charge. Construction drawings will be approved in stages, by the Employer before the start of actual construction at site. After careful study of the drawings approved by the Employer, contractor shall prepare, where necessary supplementary construction/ fabrication drawings with field/construction information and shall submit the same to the Employer for approval prior to construction.

2.4 Excavation

- Before commencement of the excavation in any reach the contractor shall inform and obtain in writing from the Engineer-in-charge, necessary instructions.
- The contractor shall excavate whatever material may be encountered up to the depth of excavation shown on the Cross-section of the channels. Extra payment shall however be admissible for rock and block Kankar excavation, if any. All material, thus excavated, shall be the property of the Government.
- Excavation to be carried out shall strictly conform to the plans and levels shown on the profile of excavation in the Cross-sections. The bed of the canal will have a longitudinal gradient as given in L-section and will be kept level transversely. The side slopes shall also conform to those given in the drawings and shall be neatly finished. Any excavation below the prescribed bed level shall not be paid.
- Excavation of internal section in main canal shall be carried out by suitable earthmoving equipment's/tractors.

2.5 Drainage during execution

- Suitable arrangements of drainage shall be provided to take surface water clear of the excavation during the progress of work. Sumps may be constructed at suitable places and water collected may be pumped out. When cutting on cross sloping ground, it is advisable to cut a catch water drain on the higher side to prevent water from flowing down.
- Wherever ground water is met during excavation, adequate arrangements shall be made for dewatering. The choice of method to be adopted and type of equipment to be used would depend on the volume of water.
- If there is a continuous flow of water, a sub-drain with sumps at suitable intervals may be provided. Excavation from downstream to upstream side will be helpful to drain away all water from the working face.
- All operations for proper drainage and to make the work area suitable for excavation shall be carried out by the contractor at his own costs i.e. no payment for dewatering shall be made extra.

2.6 Embankment

- For the embankment construction /rehabilitation the toe of the slope on each sides of the bank shall be Dag-Belled and marked by pegs firmly driven in the ground at interval of 20m. Profiles made by bamboos, earth and strings shall be setup for the guidance of workmen at 50m interval over straight reaches and about 25m. Apart for curved reaches, a suitable allowance for settlement shall be made in setting up the profile for embankment.
- Surface Preparation: The base of the extension portion of embankment shall be stripped and roots & other vegetation's shall be removed. The stripping operation is to be done up to the bottom of root zone of vegetation so that all roots are removed out of the surface. The stripping depth may vary at places depending upon type of vegetation growing on the area/slopes. The cost of all such stripping up to bottom of roots shall be deemed to be included in the unit rates of the excavations.
- The slope of existing banks shall be benched. Benching of slopes shall be done with a little slope towards the inside of benches so as to give a good grip/bond to the embankment soil with the sub-grade. Unless otherwise specified, the benches shall be 0.3x0.6m on the front and rear slope of the embankment. Before benching, canal slopes shall be cleared of all

roots, vegetation, rubbish etc. No separate payment shall be made for these and the rates quoted for raising the embankment is inclusive of these operations. The areas shall be pre-wet by sprinkling water before the construction of embankment commences. Unless otherwise specified, the water applied for pre-wetting the areas shall not be paid being considered included in the unit price per cubic meter bid in the bill of quantities for compacting the embankment.

- Before laying soil on existing embankment, the slopes shall be properly cut and benched in steps not steeper than 2: 1.
- The earth to be used in banks shall be thoroughly broken before laying. The embankment shall be built to the height and slope shown on the drawings. All the edges of the embankment shall be neatly aligned symmetrical to the centre line of the channel.

2.7 Borrow Pits

- Suitable excavated material available from canals cutting, foundation excavation, structures, any other associated excavations within economic leads shall be used for embankment. Where canal excavation does not furnish sufficient suitable material for embankments, additional material required shall be procured from the borrow pits for which land shall be arrange by the contractor and approved by Engineer-in-charge.
- No borrow pits shall be dug within 5m of the toe of embankment, if their depth is less than 0.5m, and 10m, if their depth is more than 0.5 m; or within such a distance from the toe of the bank where a 4:1 hydraulic gradient line cuts the ground surface whichever is more. Borrow pits shall not be more than 1 m in depth and 25m in length. A clear distance of 1 m shall be left between the pits. The bed of borrow pits shall be left reasonably smooth and even.
- The borrow area shall be clearly demarcated by the contractor with the approval of the Engineer-in-charge. Borrow pits in sodic/ usar areas or in areas having expansive and dispersive clay shall be prohibited.
- The Contractor shall be responsible for the rehabilitation of the borrow area and shall ensure the consent of the farmers.
- Suitability of borrowed earth shall be decided by the Engineer-in-charge after proper examination of the soil based on laboratory tests to be submitted by the contractor.

2.8 Construction/Rehabilitation of Embankments and Disposal of Excavated Earth

- Embankment shall be built in layers not exceeding 20cm to 25cm loose. Each layer will be laid horizontally in 30cm more than full width of the section and the banks and berms shall then be dressed after compaction in full width and to the required slope. The top of embankment shall be leveled and finished so as to be suitable for roadway. Where provided, a cross slope of 1 in 80, outward to drain away rain waters may be given.
- All material of excavation in excess of requirement for rehabilitation of banks shall be disposed outside the embankment at designated disposal sites on either side of canal.
- The surplus earth will be disposed off to approved disposal sites. The contractor will have to take and communicate to the Engineer-in-charge, the formal consent of land owners, tenant and /or cultivators of plots selected for silt disposal. Where canal excavation does not furnish sufficient suitable material, additional quantity of earth required may be procured from approved borrow pits. The bidder/contractor has to arrange suitable borrow areas for borrowing of the earth. Before start of excavation, the contractor will finalize and get borrow areas approved from the Engineer-in-charge.

- Contractor shall be responsible that no unwanted disposal is being made in the work area. Any such disposal shall be removed at his own cost to the satisfaction of Engineer-in-charge. Similarly the contractor shall ensure that there is no blockage of drains or damage to the canal and to the existing outlets of canal due to disposal of material. If anything found contrary, the contractor shall arrange to rectify at his own cost within the prevalent environmental regulations.
- Where the embankment is constructed by taking material from borrow pits, care shall be exercised that large clods are broken and no clod bigger than human fist, say 8 to 10 cm, grass and other rubbish are buried in the earth used for rehabilitation of banks. Before procuring materials from borrow pits, all perishable material shall be stripped off from the top surface as specified or as directed by the Engineer-in-charge. In areas Where gravel and stone is mixed with earth, these should be removed as for as possible. But the areas where all gravel material cannot be economically removed, cobbles, stones of size greater than 40 mm should be removed to ensure proper compaction. The existence of nest of cobbles may result in more seepage and piping. In view of this, measure to remove cobbles of larger size should be taken at the excavation area itself.
- All surplus earth lying on embankments above designed bank level shall be removed by the contactor.

2.9 Compaction Requirement

Embankments shall be compacted, as shown on the drawings, to achieve the requirements laid down as under:-

Laying of earth on embankment:

The fill material shall be deposited in horizontal layers. The thickness of each horizontal layer before compaction shall normally be not more than 25 centimeters (loose layer), or as determined by the Engineer-in-charge and the layer shall be laid to full width of embankment. The thickness of layer shall be governed by the type of compaction equipment to be deployed based on the space available for compaction. The excavating and placing operation shall be such that the material when compacted will be blended sufficiently to secure minimum DBD of 95%. If the surface or any compacted layer of earth fill is too dry or too smooth to bond properly with the layer of material to be placed thereon, it shall be moistened and/or sacrificed in an approved manner to provide a satisfactory bonding surface before the next succeeding layer is placed.

Compaction of earth (Cohesive Material):

Prior to and during compaction, the embankment materials shall possess optimum moisture content as required in IS 4701(Latest addition). The embankment materials shall have optimum moisture content required for the purpose of compaction and this moisture content shall be fairly uniform throughout the layer. Optimum moisture content is the moisture content that corresponds to the laboratory maximum dry density determined in accordance with IS: 2720 (Part-VII). In so far as practicable the moistening of the material shall be performed at the site of excavation but such moistening shall be supplemented as required by sprinkling water at the site of compaction, if necessary. If the moisture content is greater than optimum for compaction, the compaction operations shall be delayed until such time as the material has dried to the optimum moisture content or to the level directed by Engineer-in-charge. The moisture content of soils shall be determined in accordance with IS 2720 (Part-II).

Compaction shall be done by 8-10 T power rollers/sheep foot rollers/vibratory power rollers/mechanical compactors (fuel or pneumatic operated)/mechanical tampers depending upon the extent of space available. Manual compaction through wooden rammers shall not be allowed.

Density tests shall be made after rolling every layer. The dry bulk density of the soil in compacted embankment materials shall not be less than 95% of the maximum dry bulk density at optimum moisture content (proctor density) obtained in accordance with IS 2720 (Part-VII).

The dry density of soil in field shall be determined in accordance with IS 2720 (Part-XXVIII), "Indian code of practice for determination of dry density of soil in place by sand replacement or by IS 2720 (Part-XXIX) Indian code or practice for determination of dry density of soils in place by the core cutter method."

Moisture content of soil shall be determined in accordance with IS 2720 (Part-II) Indian code of practice for determination of moisture content.

The above compaction tests will be conducted by contractor in the presence of the Engineer-in-charge or his representative at his cost and the contractor shall ensure specified compaction, till the Engineer-in-charge or his authorized representative is satisfied that the specified dry density at optimum moisture content is obtained, and permits the laying of next layer.

Compaction of cohesion less materials: behind the lining where ever applicable

Where compaction of cohesion less, free draining materials, such as sands and gravels is required, the materials shall be deposited in horizontal layers and compacted to the specified relative density. The excavating and placing operation shall be such that the materials when compacted will be blended sufficiently to secure specified relative density. Water shall be added to the materials as may be required to obtain the specified density by method of compaction being used.

As envisaged in clause 6.6.2.1 of IS 4701, the thickness of the embankment layer shall not exceed 25 centimeters (loose layer) before compaction, or as determined by the Engineer-in-charge, and it shall be spread over the full width of the embankment and compaction shall be done by tracks of crawler tractors or vibratory rollers or vibro compactors. Thickness of layer shall be suitably adjusted in accordance with the type of compaction equipment used, to achieve the specified density. **No manual compaction shall be allowed.**

As envisaged in clause 6.6.3.1 of IS 4701 the relative density of the compacted material shall not be less than 70% when tested in accordance with IS 2720 (Part-XIV), "Indian code of practice for determination of density index (relative density) of cohesion less soils."

2.10 Testing:

Density tests shall be carried out after rolling to ascertain the state of compaction, which should be measured in term of dry density. Standard proctor density tests shall be carried out at regular intervals to account for variations in the borrow area material.

Density test shall be conducted from time to time at site to ascertain whether compaction is attained as specified. For every 300 cubic meter of compacted earth fill, at least one field density test using core utter or sand replacement method shall be conducted. The Engineer-in-charge may also deploy 'Portable Electronic Testing Device' for quick on site determination of moisture content, in place density, and compaction efficiency. However, minimum four density tests shall be made per day irrespective of quantity of earth work. In case the tests show that the specified densities are not attained,

suitable action shall be taken either by moisture correction or by additional rolling, so as to obtain the specified density, which shall be checked again by taking fresh tests at the same locations. The test locations should be so chosen as to represent the whole layer under test. Each layer should be tested for proper compaction before a fresh layer is allowed over it.

2.11 Important Points for Rehabilitation of Existing Canal Embankments

For rehabilitation of old canal embankments the following care shall be taken for proper bonding of the freshly laid soil with the old embankment.

i) All trees, bushes, roots and other vegetation growth from the existing embankment shall be removed.

ii) The base of the extension portion of embankment shall be stripped and roots & other vegetation shall be removed. The stripping operation is to be done up to the bottom of root zone of vegetation so that all roots are removed out of the surface. The stripping depth may vary at places depending upon type of vegetation growing on the area/slopes, the cost of all such stripping up to bottom of roots shall be deemed to be included in the unit rates of the excavations.

iii) The slope of existing banks shall be benched to depth of 15 cm. to 30 cm. as per requirement at site for proper bonding of the freshly laid soil with the old embankment. The cost on this account shall be deemed to be included in the unit rates of the excavations.

iv) Earthwork shall be done in layers of specified thickness. Clods must be broken.

v) Under no circumstances, the embankment shall be widened by material dumped from the top of the existing embankment.

vi) Adequate quantity of moistening/watering shall be done at the junction of the freshly laid soil with the old embankment for proper bonding.

vii) If initial moisture content in the soil is less than the optimum moisture content (OMC) water shall be sprinkled over the freshly laid layer before compaction. A tolerance of + 1% of OMC moisture content shall be permitted.

viii) Where the width is sufficient/adequate, compaction shall be done mechanically by 8-10 tones power roller/vibratory power roller so as to achieve at least 95% of Procter density for cohesive soils and relative density of 70% for non-cohesive soil. Where space is not sufficient for the deployment of 8-10 Tones Power Rollers, the earth work shall be compacted by deploying appropriate smaller dimensioned vibratory power rollers (of the same compacting effort as of the 8-10 Tones plain power rollers) or using mechanical compacters/pneumatic compacters (by reducing the thickness of layers to $\pm$ 10-15cm) to achieve 95% proctor density.

ix) In case of minors manual compaction may be done with permission of Engineer-in-charge.

2.12 Tests and their frequencies for embankment construction

S.No.	Test	Frequency of test	Purpose	Test designation
1	Grain size analysis for classification	One test per day or periodically as directed by Engineer-in-charge	To know the classification of soil actually put in embankment	IS : 2720- IV
2	Specific gravity	One test per day	To know the classification of soil actually put in embankment	IS : 2720-V
3	Field density and moisture content	One test in 300m^3 of earth work or in each layer laid on embankment	To determine the placement density and moisture content	
4	Standard Proctor test	One test per day for individual borrow area	To determine MDD (maximum dry density) and OMC (optimum moisture content) of the soil and compare the results with laboratory value	IS : 2720-VII
5	Moisture content	One test in each sample	To know the moisture content in the sample	IS : 2720-II
6	Relative density test	One test in 300m^3 of earth work placement	To know the relative density of cohesion less soil	IS : 2720-XIV

2.13 Measurements

The measurements shall be taken correct to a cm. Before commencement of earthwork in each canal, initial cross sections at every 50m interval in straight reach and at every 25 m interval in curved reaches shall be taken jointly by the department and authorized representative of the contractor, which shall be recorded in M.B./ level book. Contractor/his authorized representative shall have to record his acceptance of levels and measurements on the M.B./level book before start of work. The contractor shall submit the detail programme for carrying out the joint measurements. A notice for recording the measurements shall be issued to the contractor and even then, if the contractor or his authorized representative does not turn up on the desired date, time & place, the work of taking measurements will continue and it will be deemed as acceptable to the contractor.

If the earth from cutting internal section is not sufficient to achieve designed section after compaction, then cross section shall be taken before placing the borrowed earth to achieve designed section wherever required. Similarly after completion of work as per design/drawing, final cross sections shall be taken at the same locations. During the execution of work, cross-section at intermediate state shall also be taken if required. These cross sections shall be prepared in Auto-Cad

by the contractor. All such cross sections shall be utilized to derive quantities of earthwork mentioned under different items in Bill of Quantities. Only joint measurement shall be the basis of the payment. It will be the duty and sole responsibility of the contractor to get the joint measurements done as and when required before commencing any new activity. Quantity of borrowed earth shall be derived on the basis of cross sections as described above. Quantity of earthwork in cutting shall be derived on the basis of initial & final cross section. This earth (only suitable quantity) shall be used for the rehabilitation of banks and surplus earth shall be disposed off as per Disposal plan. Settlement allowance as and where required shall be deducted in accordance with relevant IS Code/ID Specifications.

2.14 Rates

Rate for earthwork shall include and take in to account the following –

1. Making Profiles (Kaccha Namunas).
2. Setting out works, cost of land for haul roads, disposal area/borrows area etc.
3. Disposal of the surplus excavated material including arranging disposal area as per disposal plan or as per direction of Engineer-in-charge taking into consideration environmental & social aspects.
4. Borrowing earth from approved borrow area and rehabilitation of banks.
5. Preparation of cross sections in Auto-Cad.
6. All leads, lifts and dressing of earth.
7. Labour charges, providing all surveying and leveling instruments and material needed for measurements, checking of works and taking initial/final cross sections of canal.
8. Cost of maintenances of works during contract period.
9. Spreading in layers, watering & compaction as per specification.

3 Earthwork in Excavation of foundation:

Foundation trenches for laying of PVC pipes shall be dug to exact length and width as per drawing. The sides shall be left plumb where the nature of the soil permits it, but the sides must be sloped back or shored up carefully when the soil appears likely to fall in or the depth of trench exceeds 1.5m. The disposal of excavated material shall be as per direction of Engineer-in-charge. The earth obtained from excavation of foundation shall be used for back filling and surplus earth shall be utilized for rehabilitation of banks.

The foundation bed for pipes shall be excavated true to lines and grades shown on drawings or as directed by Engineer-in-charge. The minimum width of trench on either side of the pipe shall be 150 mm or one-fourth of the diameter of pipe whichever is more and shall not be more than one-third of diameter of the pipe. The sides of the trenches shall be as nearly vertical as possible. The pipe shall be placed where ground for the foundation is reasonably firm. When during excavation the material encountered is soft, spongy or other unsuitable soil, such material shall be removed to such depth, width &length as directed by Engineer-in-charge and shall be filled with learn concrete at his own cost.

The bottom of the foundation trenches must be perfectly leveled both longitudinally and transversely. The bottom of the trenches shall be slightly watered and well rammed. If excavation is done deeper than shown in the drawing, the contractor shall fill the extra depth with appropriate material at his own expense. Roots of all trees and plants encountered in digging trenches shall be removed carefully if possible, otherwise they shall be cut up to a distance of 30cm on sides and bottom of trench and shall then be burnt and smeared with boiling coal tar at the expense of contractor. If boulders are found in bed they shall be removed at contractor's own cost. The extra depth caused

by removal of roots of trees or removal of boulders from the trench, shall be filled with appropriate material at contractor's own cost.

3.1 Measurements

The measurements of excavation shall be taken as the area in plan by the depth of the foundations below designed bed level, notwithstanding that the contractor may find it more convenient to take out the excavations with sloping sides.

3.2 Rate

The measurement of the excavation shall cover back filling, watering and ramming of the excavated earth in the space of the trenches and also the sloping off and dressing of the excavated earth. All such filling shall be done in courses and along with the masonry/concrete. Any dewatering if required and any shoring that is necessary shall be included in the rate of excavations. The superfluous material not required for refilling shall be removed, and disposed off suitably.

4 CEMENT CONCRETE

4.1 Batching and Mixing

A good concrete requires the use of specified qualities and proportions of ingredients, methods of mixing, manner of laying green concrete in position compaction and curing.

4.2 Proportioning of concrete

1. The cement concrete shall be composed of cement, fine aggregate, coarse aggregate, water and admixture if considered necessary by the Engineer-in-charge.

2. The determination of proportion of cement, aggregates and water to attain the required compressive strength shall be made as under:

- By designing the concrete mix (Design mix concrete)
- By adopting nominal concrete mix (Nominal mix concrete). It involves higher cement contents.

3. The design mix shall be done only for specified materials to be procured for works at site as per specifications and shall be approved by Engineer-in-charge.

4. The mix design done earlier, but not prior to one year, may be considered adequate for works provided there is no change in source and quality of materials.

5. The Design mix concrete shall be preferred to nominal mix. If design mix concrete cannot be used or the quantity of concrete is small, nominal mix concrete of grade not higher than M20 may be used with permission of Engineer-in-charge.

6. Temperature control of concrete has to be kept in view in extreme weather conditions, Concreting shall not be done when atmospheric temperature falls below 4.5^{o}C or rises above 40^{o}C.

7. The various ingredients of different nominal concrete mixes for one cement bag of 50 kg shall be as under (For guidance only).

Ingredients of concrete	**Quantity of ingredients required for concrete**					
	Nominal Aggregate Size 20 mm			**Nominal aggregate size 40 mm**		
	M-10 (1:3:6)	**M-15 (1:2:4)**	**M-20 (1:1.5:3)**	**M-10 (1:3:6)**	**M15 (1:2:4)**	**M-20 (1:1.5:3)**
Weight of Coarse Aggregate	320 Kg	220 Kg	165 Kg	345 Kg	235 Kg	180 Kg
Weight of Fine Aggregate	160 Kg	110 Kg	85 Kg	135 Kg	95 Kg	70 Kg
Quantity of Water	34 Lt	32 Lt	30 Lt	34 Lt	32 Lt	30 Lt

8. The cement Contents of above nominal mixes shall be proportionally increased if quantity of water in the mix is to be increased to facilitate placement and compaction of concrete so that specified water cement ratio is maintained.

9. The cement level to be used in various design concrete mixes will be as under:

Grade of Concrete	**Cement Level (Kg/M^3 of concrete) with Coarse Aggregate of nominal size**	
	40 mm (A40)	**20 mm(A20)**
M10	207	221
M15	259	288
M20	329	366
M25	As per actual mix design	

In case of mix design:

- The quantity of cement in M15, M20, M25 & M30 concrete as calculated by Mix Design should not be less as indicated in the bill of quantities or BIS Code.
- If actual cement quantity, as warranted by mix design in any case, is lesser than that given in table, cost of less cement used will be deducted from the bills.

4.3 Batching

1. Smallest practical number of concrete mixers shall be used on a work to avoid error in batching.

2. The contractor shall provide all necessary computerize equipment and plant to determine and control the actual amount of materials entering into each batch.

3. The coarse and fine aggregates, water and cement shall be batched and measured by weight. Specified air entraining agent/water proofing compound, if any, shall be measured by weight and added separately to the mix, as directed by Engineer-in-charge.

4. The weigh batchers should be capable of weighting, controlling and determining accurately the prescribed quantity of various materials for each batch of mix.

4.3.1 Batching plants & equipments

1. Hoppers for weighing cement, mineral admixtures, aggregates and water and chemical admixture (if measured by mass) shall consist of suitable containers freely suspended from a scale or other suitable load measuring device and equipped with a suitable discharging mechanism. The method of control of the loading mechanism shall be such that, as the quantity required in the weighing hopper is approached, the material may be added at a controllable rate and shut off precisely within the weighing tolerances specified in Annex E of **IS 4926:2003**. The weighing hoppers for cement, mineral admixtures aggregate shall be capable of receiving their rated load, without the weighed material coming into contact with the loading mechanism. Where the rated capacity of a batching plant mixing cycle is less than 2.0 m3, additional precautions shall be taken to ensure that the correct numbers of batches are loaded into the transit mixer. The weighing hoppers shall be constructed so as to discharge efficiently and prevent the build up of materials. A tare adjustment, up to 10 percent of the nominal capacity of the weigh scale, shall be provided on the weighing mechanism so that the scale can be adjusted to zero at least once each day. Dust seals shall be provided on cement hoppers between the loading mechanism and the weigh hopper, and shall be fitted so as to prevent the emission of cement dust and not to affect weighing accuracy. The hopper shall be vented to permit escape of air without emission of cement dust.

2. Vibrators or other attachments, where fitted, shall not affect the accuracy of weighing. There shall be sufficient protection to cement and aggregate weigh hoppers and weighing mechanisms to prevent interference with weighing accuracy by weather conditions or external build-up of materials.

3.Where chemical admixture dispensers are used, they shall be capable of measurement within the tolerances in Annex E and a calibrated container or weigh scales shall be provided to check the accuracy of measurement at least once a month.

4. Where a continuous mixer with ribbon loading is used, the batching procedure specified by the manufacturer of the plant shall be followed.

5. Each control on the batching console and weigh-dial or display shall be clearly labelled with its function and where concerned with the batching of materials, the material type.

6. When more than one type or grade of cement is being used, the weighing device and discharge screw or other parts of the transfer system shall be empty before changing from one type of cement to another.

7. When pulverized fuel ash and other mineral admixture are batched through the cement weigh system, the weighing device and discharge screw or other parts of the transfer system shall be empty when the weighing system has returned to zero reading or completed the batch.

8. Where a back weigh system is utilized to weigh materials a system shall be in place so as to prevent materials being loaded during the process of weighing.

4.4 Water Cement Ratio

1. The strength of concrete is inversely proportional to water cement ratio. More water cement ratio will reduce the strength and durability of concrete.
2. Water cement ratio determines the porosity of concrete. More water cement ratio will mean more porous concrete.
3. For proper chemical Actions, the quantity of water required is only 25% of the weight of cement used. Additional water is added only to increase the workability of concrete.
4. The water cement ration in concrete is kept between 0.4 to 0.6 depending upon adequate workability for placement of concrete and for adequate compaction.

5. The quantum of moisture present is fine and coarse aggregate is adjusted while adding extra water for concrete mix.

4.5 Mixing

4.5.1 Stationary Mixer

1. Mixing shall be done in Mechanical mixer. Mixing by hand shall not be allowed.

2. Fine and coarse aggregate, before use, shall be washed with water to remove dirt, dust or any other material.

3. Suitable mixers, 'preferably tilting type with hopper' and of adequate capacity to handle desired quantity of ingredients should be used to mix uniformly and discharging the prepared mix without segregation.

4. The mixer drum shall be flushed clean with water. Measured quantity of dry coarse and fine aggregates shall be placed first in the rotating drum of mixer and mixed through. This shall be followed by mixing of measured quantity of cement (This process is to be followed only in case hopper type mixer is not available & that too with specific approval of Engineer-in-charge).

5. The dry material shall be mixed for at least 4 turns of the drum after which measured quantity of water shall be added gradually while the drum is in motion to ensure even distribution with dry materials. The total quantity of water to be mixed for achieving the specified water cement ratio shall be added before ¼ mixing time has elapsed.

6. The material shall be mixed for a period not less than 2 minutes (about 25 turns of drum) and until a uniform color and consistency of concrete are obtained. The time shall be counted from the moments all the materials have been put into the drum.

7. The complete contents of the mixed concrete shall be emptied before recharging. When the mixer is closed down for the day or for any interval longer than 20 minutes, the drum shall be flushed clean.

4.5.2 Transit mixer

1. When a transit mixer is used for the partial or complete mixing of concrete, mixing shall be considered to commence from the moment when all the materials required for the batch, including water, are in the rotating drum of the mixer.

2. Transit mixers or agitators shall not be loaded in excess of the manufacturer's rated capacity. In

order to produce a satisfactory mix, and where there is no data available to establish different period and speed of revolutions, mixing shall continue for not less than 60 revolutions of the transit mixer drum at a rate of not less than 7 revolutions/min. All completely truck mixed concrete shall be visually inspected for uniformity prior to leaving the plant.

3. When a transit mixer or agitator is used for transporting concrete which has been mixed before leaving the plant, the concrete shall be agitated during transit and re-mixed at the site for at least 2 min so that the concrete is of the required uniformity.

4. Where water is added to the concrete in the transit mixer through the transit mixer water meter and when such water is being accounted for in the total water within the mix, it shall be ensured that the transit mixer water meter is in operational condition and properly calibrated. Where a water meter is not available, water must be measured in a suitable container before being added to the transit mixer.

4.6 Workability

1. For workability, minimum slump required for concrete to be compacted by vibrator shall be 25-75 mm depending upon size of aggregate, thickness of member, quantum and spacing of reinforcement etc.

2. For profile bed bars, slump of concrete shall be 25 mm.

4.7 Preparation of surface

1. In concreting over previously laid concrete, old surface shall be roughened by thoroughly cleaning it of all the loose material, unsound concrete and cement slurry etc. using a wire brush or air/water jet and then slightly wetting the surface. To top surface of aggregate must be exposed.

2. In case of foundation concrete, the prepared earth surface at the bottom, a 2 cm layer of 1:4 cement/sand mortar or a polythene sheet of appropriate thickness or tar paper may be placed to avoid loss of moisture of concrete by underneath earth bed.

4.8 Concrete placement

1. The concrete shall be deposited as near as practicable to its location of placement to avoid any re-handling.

2. Before depositing the concrete, mortar of same ratio of concrete shall be laid on the forms, old foundation or old concrete surface.

3. The entire concrete to be used in work shall be laid gently (not thrown) to avoid segregation. Generally the maximum permissible freefall of concrete may be restricted to 1.5 m. The chutes may be used for more heights.

4. The concrete shall be placed and compacted before initial setting of concrete commences and not be disturbed subsequently.

5. The whole quantity of prepared concrete shall be used preferably within 30 minutes of its mixing but not later than initial setting time.

6. Placement shall be done in layers not exceeding 50 cm in thickness. This thickness may vary (lower) as per direction of Engineer-in-charge and type of vibrator used.

7. In slabs, the concrete shall be placed in direction of Span.

8. The concreting shall be discontinued when the temperatures fall below 4.5^{o}C or rise above 40^{o}C.

4.9 Compaction

1. The concrete shall be thoroughly compacted by using mechanical vibrators till a dense concrete is obtained. Concrete shall be fully worked by vibrators around reinforcement, any embedded fixtures and into the corners of the form work.

2. Fresh Concrete shall be vibrated near all construction joints so that mortar of fresh concrete flows between large aggregates and develop proper bond with old concrete.

3. Care should be taken, while placing and vibrating concrete to avoid any displacement of reinforcement or movement of form work or fixtures.

4. Over or under vibration of concrete are harmful and should be avoided over vibration causes segregation of cement slurry resulting in its deposition on concrete surface. Under vibration causes honey combing.

6. Suitable type of mechanical or electrical vibrators shall be used for compaction. Plate type vibrators will be used for small thickness of concrete such as in wearing coat over deck slab. Needle vibrators will be used where depth of concretes is more than 20 cm.

7. At the end of compaction the needle vibrators shall be withdrawn out of compacted concrete gradually and not suddenly so that no hollow is left in concrete.

8. One spare vibrator and two spare needles shall be placed at site while concreting is in progress.

4.10 Curing

1. Curing is the process of preventing the loss of moisture from concrete and promoting the hydration of cement while preventing high temperature gradient within concrete.

2. The concrete is kept saturated or as nearly saturated as possible until the originally water filled space in fresh cement paste has been occupied by the products of hydration of cement.

3. Hydration of cement can take place only in presence of water. Thus loss of water by evaporation shall be prevented. Permeability is reduced and durability and strength of concrete is increased by curing.

4. After 6 hours of laying of concrete, the surface shall be suitable protected with moist gunny bags or by any other methodology against quick drying for 24 hours. The surface shall then be cured by flooding it with water in a minimum depth of 25 mm. The curing shall be done for a minimum period of 14 days.

5. Curing is best done with water. In case of any difficulty due to water availability, curing compounds may be used with approval of Engineer-in-charge. Curing by curing compounds may be suitable particularly for section profiles. Cost of curing compound shall be borne by the contractor.

4.11 Joints

1. When concreting is to be done in lifts, proper shear keys should be provided while concreting in the top surface of previous lift to ensure proper bond.

2. Concreting shall be done continuously in a slab or a footing. In case the concrete has to be discontinued due to some reason for some time, a construction joint shall be provided as directed by Engineer-in-charge. Such joints shall be minimum as far as possible.

3. Construction joints shall be provided at accessible location to permit cleaning of laitance, cement slurry and unsound concrete by using wire brush on the surface of joint. This shall be done immediately after initial setting of concrete.

4. In case of construction joints at locations where previous concrete has been cast against shattering, the concrete surface is roughened by exposing the aggregate with a high pressure water jet.

5. Fresh concrete shall be brushed and air water jet shall be applied to expose the top surface of aggregate so that bonding with fresh concrete shall be good and leak proof.

4.12 SAMPLING & TESTING

1. The samples of fresh concrete shall be taken, cubes are made, cured and tested at 28 days (IS.516)

2. In order to get a relativity quicker idea of the quality of concrete, compressive strength tests at 7 days may be carried out in addition to 28 days compressive strength test.

3. In all cases, the 28 days compressive strength shall alone be the criterion for acceptance/rejection of the concrete.

4. The sampling should be spread over the entire period of concreting and cover all mixes.

The minimum frequency of sampling of concrete of each grade shall be

Quantity of concrete in work (M^3)	Number of samples
1-5	1
5-15	2
15-30	3
30-50	4
51 and above	4 plus one additional sample for each additional $50m^3$ or part there of

Three test specimens shall be made for each sample for testing at 28 days.

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

4.12.1 CASTING OF CUBES

The concrete cubes are to be cast in the following manner:

1. The cube moulds should be cleaned and well-oiled/or greasing from all sides.
2. The cube moulds should be placed on smooth surface before casting and should be free from vibration.
3. The cube moulds shall be filled in three layers, each layer tamped with 25 strokes of standard tampers.
4. After filling and rodding of final layer the excess concrete should be removed by tamping bar by applying rubbing.
5. The cubes will be finished by trowel after 30 minutes from casting.
6. After 20 hours of casting of cubes, identification marks, dates etc. be written on the upper portion of cubes.
7. The cubes shall be de-moulded within 22-24 hours from the time of mixing water in the ingredients.

4.12.2 CURING OF CUBES

1. After demoulding of cubes from cube moulds, the cubes shall be transferred in the curing tank for curing at various ages.
2. The water for curing shall be potable. The curing temperature of water shall be $27\pm2^{o}C$.
3. The water of curing tank should be changed once in a week.

4.12.3 TESTING OF CUBES

As soon as the curing of cubes is complete, the testing of cubes will be done in the following manner
1. Cubes should be tested in a moist condition.
2. Cubes shall be tested at right angle to the direction in which they are filled.
3. The rate of application of load is usually $14N/mm^2/min$.

4.13 Acceptance Criteria (I.S. 456 - 2000)

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

(a). The mean strength determined from any group of four consecutive test results complies with the appropriate limit in column 2 of Table below.
(b). Any individual test result complies with the appropriate limit in col 3 of Table below.

Characteristics Compressive Strength Compliance Requirement

Specified Grade	Mean of the Group of 4 Non-Overlapping Consecutive Test Results in N/mm^2	Individual Test Results in N/mm^2
M 15	f_{ck} + 0.825 x established standard deviation (rounded of to nearest 0.5 N/mm^2) or f_{ck}+ 3 N/mm^2 . which is greater	f_{ck} – 3 N/mm^2 Where f_{ck} – characteristic cube compressive strength of concrete
M 20 or	f_{ck} + 0.825 x established standard deviation (rounded of to nearest 0.5	f_{ck} – 4 N/mm^2 Where f_{ck} - characteristic cube

above	N/mm^2) or f_{ck} + 4 N/mm^2 which is greater	compressive strength of concrete
NOTE – In the absence of the established value of standard deviation, the values given in IS: 456 may be assumed, and attempt should be made to obtain results of 30 samples as early as possible to establish the value of standard deviation.		

Grade of concrete	Assumed standard Deviation
M 10	3.5N/mm^2
M 15	
M 20	4.0 N/mm^2

4.14 Test and their frequency:

The various tests and their frequencies for concrete work shall be carried out as per following Table

S. No.	Name of test	Frequency	Purpose	Indian Standard
1.	**Coarse Aggregates :**			
	Sieve analysis	One test for every 150m^3 or less	To know the gradation	IS 2386-Part I
	Specific gravity, bulk density, moisture content and absorption	- do -	To assess the suitability of aggregate and to utilized data for mix design	IS 2386-Part III
	Soundness (Sodium sulphate method)	- do -	To assess the quality of materials	IS 2386-Part V
	Abrasion, impact & crushing method	- do -	- do -	IS 2386-Part IV
	Organic impurities	- do -	- do -	IS 2386-Part II
	Petrographic properties	Twice in one season	To know the extent of deleterious material & silt content	IS 2386-Part VIII
2.	**Fine Aggregate :**			
	Sieve analysis	One test for every 150 m^3 of sand used in concrete	To know grain size and fineness modulus of sand	IS 2386-Part I
	Unit weight and bulkage	- do -	To know suitability of sand and to utilize data for mix design	IS 2386-Part III
	Organic impurities	- do -	To assess the quality	IS 2386-Part II
	Specific gravity, moisture content	- do -	To utilize data for mix design	IS 2386-Part III
3.	**Cement :**			
	Fineness test	One test for each	To know the quality of	IS 4031

		brand of cement used during the working season preferably at 3 months interval	cementused in construction	
	Normal consistency	- do -	- do -	IS 4031
	Setting time	- do -	- do -	IS 4031
	Soundness	- do -	- do -	IS 4031
	Compressive strength	- do -	- do -	IS 4031
	Chemical analysis	- do -	- do -	IS 4032
4.	**Finished concrete :**			
	Slump test	One test in each shift or at frequent intervals to check workability	To check workability of Concrete/watercement ratio.	IS 1199
	Compressive strength	Refer sampling & strength or designed mix	To know the strength of Concrete.	IS 516

4.14.1 Measurement and Payments:

Measurement of concrete will be made only to the neat lines of the structures as indicated on the drawing or as established by the Engineer-in-charge. Dimensions shall be measured nearest to 1 cm. The areas shall be worked out to nearest 0.01 square meter. The cubic contents shall be worked out to nearest 0.01 cubic meter. The rate shall include the cost of all materials, labour, necessary tools & plants involved in above operations. This shall also include laying, compaction and curing but excluding centering & shuttering.

5. FORM WORK

Forms shall be used wherever necessary to confine the concrete and to shape it to the required lines. Normally all exposed concrete surfaces having a slope steeper than 2H: 1V shall be formed. The condition of forms influences appearance as well as quality of the concrete in the structure. Form work shall be designed and constructed to the shape, lines and dimensions shown in the drawing with following tolerances. The tolerances shall apply to concrete dimensions only.

S. No.	Description	Tolerance (mm)
1.	Linear outline	
	In 6m of length	±12
	In 12m of length	±18
2.	Plumb, specified slope or curved surface of structures.	
	In 3m of height	±12
	In 6m of height	±18
	In 12m of height	±30

3.	Dimensions of cross sections of structures	+12 - 6
4.	Dimensions of footing	
	Dimensions of plan	+50 -12
	Eccentricity	0.02 times the width of footing in the direction of deviation but not more than 50mm
	Thickness	±0.05 times the specified thickness

5.1 Workmanship, cleanliness and strength of form work

1. The form work and its supports shall be of steel. Timber forms shall not be allowed. Contractor shall provide details of proposed formwork to Engineer-in-charge for his approval before its use.

2. All rubbish particularly chippings, shavings, cement mortar and grout etc. shall be removed from the interior faces of the forms. Cleaned faces will be checked before use. Inner faces of forms in contact with concrete shall be oiled / greased to provide a thin uniform coating to the forms, without coating reinforcement, before concreting.

3. Forms shall have sufficient strength to withstand all pressures during placement and vibration of concrete including all dead and live loads in construction without any deflection from the prescribed lines. Forms shall be made sufficiently rigid by use of adequate supports.

4. The joints in the formwork shall be made water tight to prevent loss of slurry from the concrete.

5. The forms required to be used more than once shall be maintained in a good condition, thoroughly cleaned & repaired if required before re-use. All forms shall be checked for proper shape, cleanliness and strength before re-use.

6. The contractor shall inform Engineer-in-charge well in time before starting placement of concrete in the forms to enable him to inspect the formwork for its adequacy, alignment, strength & overall fitness.

7. The holes / recesses in the concrete resulting from removal of the end of the she-bolts, ties in the forms and any damage to concrete surface caused by removal of forms shall be filled / repaired in accordance with the provisions for Repair of Concrete and shall be finished flush with concrete surface by contractor at his own cost.

8. Forms shall not be released until the concrete has achieved adequate strength. In normal circumstances, where ambient temperature does not fall below 15^0C, ordinary Portland cement is used and adequate curing is done, following striking period of forms will be adopted.

S. No.	Type of formwork	Minimum period before striking formwork
1.	Vertical formwork to columns, walls & beams	16-24 hours

2.	Soffit formwork to slabs (props to be re-fixed just after removal of formwork)	3 days
3.	Soffit formwork to beams (props to be re-fixed just after removal of formwork)	7 days
4.	Props to slabs	
	• Spanning up to 4.5m	7 days
	• Spanning over 4.5m	14 days
5.	Props to beams and arches	
	• Spanning up to 6m	14 days
	• Spanning over 6m	21 days

9. Care shall be taken that the forms are stripped off without any injury to the concrete surface.
10. The contractor shall ensure that the number of props left-under, their sizes and disposition shall be such as to be able to safely carry full dead load of slab, beam or arch together with any live load likely to occur during curing or further construction.
11. If the inspection of forms reveals that forms are not strong enough to hold the concrete or are not braced sufficiently to stay in alignment, Engineer-in-charge shall immediately notify the contractor to set right the deficiencies and concrete shall not be placed before the forms are re-inspected and found ok.
12. A very common blemish on formed concrete surfaces is the off-set found at horizontal construction joints at the bottom of new lift. Such off-sets shall be prevented by setting the forms to fit snugly against the top of concrete in previous lift and securing them so as to remain in tight contact during the placement of the concrete to prevent any leakage of cement slurry / mortar.
13. The anchoring of forms shall be done by using ample number of ties and bolts above and near the construction joints.
14. Forms shall overlap the hardened concrete in the previous lift by not more than 50mm.
15. Occasionally, spalling may occur from the face of the concrete when forms are struck. This is often caused by rough spots on the inner faces of the form where mortar adheres strongly to overcome tensile strength of green concrete.
16. Such areas on the faces of the form shall be cleaned, polished and then covered with a thin layer of suitable form oil.
17. The following common deficiencies resulting in failure of form work shall be inspected and addressed.

a) Inadequate cross / horizontal bracings.
b) Unequal horizontal filling of forms with concrete
c) Abnormal displacement in the forms during and after placement of concrete.
d) Lack of adequate inspection of form work.

5.1.1 Measurement and Payments:

Measurement of the form work (centering and shuttering) will be made only to the neat lines of the structures as indicated on the drawing or as established by the Engineer-in-charge. Dimensions shall be measured nearest to 1 cm. The areas shall be worked out to nearest 0.01 square meter. The rate shall include the cost of all materials, labour, necessary tools & plants involved in above operations.

6 CEMENT

- Cement for use in works shall be ordinary Port land Cement (OPC) 43 grade conforming to IS: 8112.

- Pozzolana port land cement (PPC) conforming to IS 1489 may be used in specific locations, components of the work subject to permission of Engineer-in-charge. However difference between the market rates of OPC and PPC at the time of execution of such work shall be deducted for the quantity of PPC actually used.

6.1 Properties

1. The compressive strength of cement shall be as under.

S.No.	Time	Compression strength	
		OPC (IS: 8112)	PPC (IS: 1489 II)
1	72 ± 1 hours (3 days)	230 kg/cm^2	160 kg/cm^2
2	168 ± 2 hours (7 days)	330 kg/cm^2	220 kg/cm^2
3	672 ± 4 hours (28 days)	430 kg/cm^2	330 kg/cm^2

2. Unit weight of cement shall be 1.44 T/m^3. Average net mass of cement per bag shall be 50 kg.
3. The Pozzolana cement requires curing for a longer period.
4. The cement shall have normal setting time. The initial setting time shall not be less than 30 minutes and final setting time shall not be more than 600 minutes.
5. The consistency of cement should conform to IS: 4031.

6.2 Tests

1. Manufacturer of cement shall furnish, on demand, a certificate to indicate that cement conforms to the requirements of IS: 8112 or IS: 1489 regarding chemical constituents, fineness, soundness, setting time and compressive strength.

2. Average weight of cement Bag shall be as per IS: 8112.

The number of bags in a sample for calculating the average net mass of a cement bag shall be –

S.No.	Batch Nos.	Size	Sample nos.
1	A	100 – 150	20
2	B	151 – 280	30
3	C	281 – 500	50
4	D	501 – 1200	80
5	E	1201-1200	125
6	F	3201 and above	200

The bags in a sample shall be selected at random.

Number of bags showing minus error greater than 2% of standard mass of 50 kg shall not be more than 5% of sample. Also the minus error in no such bag shall exceed 4% of standard mass of 50 kg.

6.2.1 Compressive strength (IS: 4031 – VII)

The average compressive strength at 7 days and 28 days per source of cement shall be tested on 2 sets of at least 3 mortar cubes of size 7.06 × 7.06 × 7.06 cm (face area 50 cm^2). Material for each cube shall be mixed separately with following quantities.

Cement 200 gm, standard sand 600 gms and potable water. Standard sand shall be of quartz with grains of spherical shape and shall be free from silt. The sand shall pass 100% through 2 mm IS sieve and shall be retained 100% on 90 micron IS sieve.

Cement and sand are mixed dry and the water is added to prepare a uniform mix of mortar. Mixing time shall not be less than 3 minutes and more than 4 minutes. Mortar is then filled in cube mould and prodded 20 times in 8 seconds to ensure elimination of entrapped air/honey combing. The mortar in the mould is compacted by placing the mould on the table of vibration machine and given vibration for 2 minutes. Top surface of cube is finished with trowel. Filled mould is kept in moist closet for 24±1 hours. Moulds are then removed and cubes are cured for 14 days.

Cubes are tested on their sides without any packing between cubes and steel plates of testing machine. One of the platters shall be carried on the base and load is uniformly increased @ 350 N/mm^2 per minute starting from zero. Compressive strength is calculated by dividing maximum load with cube surface area. Specimen giving variation of more than 10% is rejected. At least two strength values are considered for determining compressive strength.

6.2.2 Consistency (IS: 4031 IV)

This test is conducted at source of cement. A paste of weighed quantity (about 500 gms) of dry cement with weighed quantity of potable water is prepared. Mixing time shall not be less than 3 minutes and more than 5 minutes which shall be counted from time of adding water to the time of starting to fill the paste in the vicat mould. The mould is placed over non-porous plate and slightly shaken to expel the entrapped air while mixing. Top of paste surface is finished with a trowel.

The test block in mould together with non porous plate is placed under the rod bearing the vicat plunger. The plunger is gently lowered to touch the surface of the test block and is quickly released allowing it to sink into the paste just after filling the mould. Trial pastes with varying %age of water are prepared and tested until the amount of water for allowing the plunger to penetrate to a point 5mm from bottom of vicat mould is found. This amount of water in percentage gives the standard consistency of cement.

6.2.3 Setting time (IS: 4031 – V)

Initial setting Time – Procedure for preparing cement paste and testing it are similar to those described for consistency test. A neat cement paste is prepared with 85% of amount of water required to procedure a paste of standard consistency. The needle of vicat plunger is gently lowered to just touch the surface of test block and is quickly released to penetrate test cube. Initially needle will completely pierce the block. Process is repeated until needle fails to penetrate the cube beyond 5 ± 05 mm measured from bottom of cube. The time elapsed from this moment to the moment of adding water to cement to prepare paste shall be the initial setting time of cement.

6.2.4 Final Setting Time:

The needle of vicat apparatus is replaced by a needle with annular attachments. The cement is considered as finally set when upon applying the needle gently to surface of test cube, the needle makes an impression there on while the attachment fails to do so. The time elapsed from these moments to the moment of adding water to cement shall be the final setting time of cement.

6.3 Storage

1. The cement shall be stored in such a manner so as to prevent deterioration due to dampness or water.

2. It shall be stored in water proof building and on wooden floor which will prevent the absorption of moisture from ground.

3. The cement shall be staked in rows having two bags in width and 8 bags in height. Bags shall be arranged length wise and cross wise in alternate layers.

4. The rows shall be separated by sufficient space to provide easy access for inspections.

5. Cement shall be used on 'first in first out' basis i.e. cement received first shall be used first.

6. Cement loses strength with storage period. Cement older than 90 days shall be used only after testing its properties.

6.4 Delivery

The cement shall be packed in bags bearing manufacturing name or his registered trademarks. The words 43 grade, 53 grade as the case may be (or the trade mark of other type of cement), nominal average net mass of cement, date of manufacture and Batch No. shall be legibly marked on each bag. The bags shall be in good condition at the time of inspection.

7 FINE AGGREGATE (SAND)

The fine aggregate to be used in preparation of plain concrete, reinforced concrete, cement sand mortar etc shall conform to IS: 383. It should consist of clean, hard, durable and strong form of crushed stone, gravel or some suitable combination of natural sand, crushed rock/grand. The fine aggregate shall not contain dust, lumps, soft or flaky materials, mica, silt, organic impurities or any other type of deleterious materials. Presence of mica (Muscouite & Biotite) in sand will reduce, considerably, the durability and compressive strength. The sand/fine aggregate shall be washed off all the mixed earth before use. Fine aggregate having positive alkali-silica reactions, shall not be used.

Quick color test shall be conducted in the field to determine the presence of any harmful organic impurities in sand with 3% solution of sodium hydroxide, as under :-

1. A colour less liquid indicate clean sand free from organic matter

2. A Straw color liquid indicates some organic matter but not enough to be seriously objectionable.

3. A dark color will mean unsafe limits of organic matter.

7.1 Grading

The grading of fine aggregate has been divided in following four zones.

IS Sieve size	Zone I	Zone II	Zone III	Zone IV
	%age passing by weight			
10 mm	100	100	100	100
4.75 mm	90-100	90-100	90-100	95-100
2.38 mm	60-95	75-100	85-100	95-100
1.18 mm	30-70	55-90	75-100	90-100
600 micron	15-34	34-59	60-79	80-100
300 micron	5-20	8-30	12-40	15-50
150 micron	0-10	0-10	0-10	0-15

Sand conforming to zone I & II shall be used for concrete works. Sand conforming to zone III & IV can also be used for concrete work but concrete mix shall be properly designed. The sand conforming to zone IV shall not be used in reinforced concrete works.

If grading falls outside the limits of particular zone of sieves, except 600 micron sieve, by a total amount not more than 5%, it shall be taken as conforming to that zone.
Percentage (by weight) passing through 600 micron sieve as specified in the table gives the grading zone of the sand.

The amount of deleterious substances shall not exceed the percentage given below:

Deleterious substances	**Percentage more than**
Shale	1.00
Coal and ignite	1.00
Cinders and clinkers	1.00
Material passing 75-micron sieve	0.50
Alkali, mica and coated grain	3.00

The sum of the percentages of all deleterious substances shall not exceed 5% by weight. The sand shall also be sound and free from any amounts of organic impurities.

7.2 Tests

1. One test per each consignment of sand shall be conducted.
2. The supplier, on demand, shall supply a certificate to indicate that material as per the requirement of IS 383.
3. The weight of the samples for gradation shall not be less than that shown below.

Maximum size (mm) present in Substantial proportion	**Minimum weight of sample for sieving (kg.)**
4.75	0.2
2.36	0.1

The sample for sieving shall be prepared from larger sample either by quartering or by means of a sample divider. The sample shall be brought to an air dry condition by drying it at room temperature before sieving. Air dry sample is weighed and sieved successively on the appropriate sized sieves,

starting with the largest sieve. Each sieve shall be shaken separately over a clean tray until not more than a trace passes but for a period of not less than two minutes. If sieving is done with a nest of sieves on a machine, not less than 10 minutes sieving shall be continued.

To prevent blinding of sieve apertures by overloading, quantum of sand placed on each sieve shall be such that the weight of sand retained on the sieve at the completion of the operation is not greater than as under-

IS: Sieve	Maximum weight (for 20 cm dia sieve) gm
2.36 mm	200
1.18 mm	100
600 micron	75
300 micron	50
150 micron	40
75 micron	25

After completion of sieving, material retained on each sieve together with any material cleaned from mesh shall be weighed. The result shall be reported as –

1. The cumulative percentage, by weight, of the total sample passing each sieve to the nearest whole number.
2. Percentage, by weight, of the total sample passing one sieve and retained on the next smaller sieve to the nearest 0.1%.
3. Specific gravity of sand shall be minimum 2.6

7.3 Bulking of Sand

Sand may contain an amount of moisture which will cause it, when loosely filled in a container, to occupy a larger volume than it would occupy if dry. If the sand is measured by loose volume, it becomes necessary to increase the measured volume of sand put into concrete or mortar to compensate for this bulking. In ordinary sand, the bulking varies from 10 – 30%. The bulking is more in fine sand. If sand is measured by weight, no allowance/ increase for bulking are needed.

For estimation of bulking, a graduated cylinder is filled with sand to approximately 2/3 height. The cylinder is shaken and sand is leveled. The height of sand (H_1) is noted. The cylinder is then filled with water and is shaken well. The cylinder is kept undisturbed so that the sand settles down. The height of settled sand (H_2) is noted.

The percentage bulking of sand = (H1 -H2/H2)*100 Therefore, when sand is measured by volume.

2.

8 COARSE AGGREGATE

Coarse aggregate shall conform to IS: 383. It shall consist of clean, hard, strong, dense, non-porous and durable pieces of crushed stone, crushed gravel, natural gravel or a combination there of or other approved inert material. The coarse aggregate shall not contain disintegrated stones, soft, flaky elongated particles, vegetative matter or others deleterious materials. The aggregate should either be rounded or cubical in shape. The unloading and stacking of coarse aggregate shall be done in a manner to avoid any segregation. The course aggregate shall be washed of all the mixed earth before use. The minimum specific gravity shall be 2.2 to 2.5.

8.1 Properties

a) Gradations – The coarse aggregate for use in concrete shall be well graded and should conform to the specified gradation.

IS sieve size	Percentage passing by weight for graded aggregate of nominal size

	40 mm	20 mm
80 mm	100	-
40 mm	95 – 100	100
20 mm	30 – 70	95 – 100
10 mm	10 – 35	25 – 55
4.75 mm	0.5	0.10

b) Aggregate Impact Value – This is a relative measure of the resistance of an aggregate to sudden shock or impact. This shall not exceed 45% by weight for general concrete and 30% of weight for concrete in wearing surfaces.

c) Aggregate crushing value – This is a relative measure of resistance of an aggregate to crushing under a gradually applied compressive load. This value shall not exceed 45% by weight for general concrete and 30% by weight for concrete in wearing surfaces.

d) Water absorption – The water absorption of aggregate value submerged for 24 hours in water shall not exceed 2% Water absorption is an indication of porosity of the aggregate.

e) Flakiness Index – This is the percentage (by weight) of particles in the aggregates passing through various thickness gauges or sieves whose least dimension (thickness) is less than 3/5 of their mean dimension. The index shall not exceed 25% by weight (IRC-SP 23).

f) Deleterious materials – These shall not exceed the limits as under (IS : 383)

Deleterious material	Method of test	Percentage of weight maximum
Coal & Lignite	IS:2386 (Part II)	1%
Clay lumps	- Do -	1%
Soft fragments	- Do -	-
Material timer than 75 it is sieve	IS : 2386 (Part I)	3%
Shale	- Do -	-
Total of percentage of all deleterious material (except mica)	-	5%

8.2 TESTS

1. One test for each consignment of course aggregate shall be conducted.
2. The supplier, on demand, shall supply certificate to indicate that the material complies the requirements of IS: 383.

8.2.1 GRADATION (IS: 2386-I).

The weight of the samples for gradation shall not be less than that shown below –

Maximum size present in substantial proportions (mm)	Minimum weight of sample for sieving (kg)
40	15.0
20	2.0
10	0.5
6.3	0.2
4.75	0.2

The sample for sieving shall be prepared from larger sample by quartering. The sample shall be brought to an air dry condition by drying it at room temperature before sieving. The air dry sample is weighed and sieved successively on appropriate sized sieves starting with largest sieve. Each sieve shall be shaken separately over a clean tray until not more than a trace passes but for a minimum period of two minutes. The material shall not be forced through the sieve openings by hand pressure. If sieving is carried out with a set of sieves on machine, minimum period of sieving shall be ten minutes.

To prevent blinding of sieve operations by overloading, the quantum of aggregates placed on each sieve shall be such that the weight of aggregate retained on the sieve at the end of operation is not more than the value as under –

IS sieve	Maximum weight for 30 cm dia sieve (kg)
50 mm	4.5
40 mm	3.5
31.5 mm or 25 mm	2.5
20 mm	2.0
16 mm or 12.5 mm	1.5
10 mm	1.0
6.3 mm	0.75
4.76 mm	0.5
3.35 mm	0.3

The material retained on each sieve shall be weighed. The result shall be reported as-

1. The cumulative percentage, by weight, of total sample passing each sieve to the nearest whole numbers.

2. Percentage, by weight, of the total sample passing one sieve and retained on next smaller sieve to the nearest 0.1%.

The material retained on each sieve shall be weighed and percentage passing through each sieve is calculated to determine the gradation of the aggregate.

8.2.2 Flakiness Index (IS: 2386 -Part I)

Sample shall consist of sufficient quantity of aggregate to provide minimum number of 200 pieces of any fraction to be tested. Sample shall be sieved in the manner described for gradation of aggregate with sieve sizes specified below. Each fraction shall be gauged in turn for thickness on sieves having elongated slots. Width of slots used in sieve shall be of the dimensions shown here under.

Size of aggregate		Thickness gauge (mm)	Length gauge (mm)
Passing through IS sieve (mm)	Retained on IS sieve (mm)		
63	50	33.90	-
50	40	27.00	81.00
40	25	19.50	58.50
31.5	25	16.95	-
25	20	13.50	40.50
20	16	10.80	32.40
16	12.5	8.55	25.50

2.50	10	6.75	20.20
10	6.3	4.89	14.70

Total amount passing the gauge shall be weighed to an accuracy of 0.1% of the weight of test sample. The flakiness index is the total weight of the aggregate passing the various sieves expressed as a percentage of total weight of the sample gauged.

8.2.3 Aggregate Impact Value (IS: 2386 – IV)

The test sample shall consist of aggregate, the whole of which passes a 12.5 mm IS sieve and is retained on 10 mm IS sieve. The sample shall be dried in an oven for a period of four hours at temperature of 100 – 110ºC and cooled.

A cylindrical metal mould of 75 mm diameter and depth of 50 mm shall be filled about 1/3 full with the aggregate and tamped with 25 strokes of round tamping rod. The mould shall be filled up to top in stages in same manner. Net weight of aggregate in the mould shall be determined (A).

The impact machine shall rest without any packing on a level platform. Cylindrical steel cup in the machine shall be fixed firmly in position on the base of machine and the whole of the test sample is placed in it and compacted by a single tamping of 25 strokes. Hammer of the machine shall be raised until its lower face is 38 mm above the upper surface of aggregate in the cup. The hammer is allowed to fall freely on the aggregates. The test sample shall be subjected to a total of 15 such blows, each at an interval of one second or more. The crushed aggregate shall then be removed from the cup and whole of it sieved on 2.36 mm IS sieve until no further amount passes through it in one minute. The weight of fractions passing the sieve (B) and retained on it (C) shall be determined to an accuracy of 0.1 gm. In case weight (B+C) is less than (A) by more than one gram, result shall be discarded and a fresh test is made. Two tests shall be made.

Aggregate impact value (AlV) = B/A×100 The mean of two results

shall be reported to the nearest whole number.

8.2.4 Water Absorption (IS: 2386-III)

A sample of not less than 2000 gm of aggregate shall be tested. Two tests shall be made. Two samples should not be tested concurrently.

The sample shall be washed to remove all fine particles and dust, drained and then placed in a wire basket and immersed in distilled water at a temperature 22 – 32ºC with a cover of at least 5 cms of water over top of basket. The entrapped air shall be removed from the sample by lifting the basket containing it 25 mm above the base of the tank and allowing it drop 25 times at a rate one drop per second. The basket and aggregate shall remain completely immersed during the operation and for a period of 24 ± 0.5 hours after words. The basket and the sample shall then be lifted and weighed in water (A1). Basket and the aggregate shall then be removed from water, drained and the aggregate shall be gently emptied from the basket on a dry cloth. Empty basket shall be returned to water and weight (A2). The aggregate placed on dry cloth shall be gently surface drained and spread out not more than 1 stone deep on a dry cloth. The aggregate is completely surface dried by keeping it in sunlight for 10 minutes and is weighed (B). The aggregate shall then be placed in oven in a shallow tray at a temperature of 100 – 110ºC for 24 ± 05 hours. It will then be removed from oven, cooled in a air tight container and weighed (C).

Water absorption (% of dry weight) = 100(B-C)

The individual and mean results, along with size of aggregate shall be reported.

8.3 Storage:

The aggregate shall be stacked in such a way as to prevent intrusion of any foreign materials such as soil, rubbish, vegetation etc. Heaps of fine and coarse aggregates shall be kept separate. When different sizes of fine and coarse aggregates are procured separately, they shall be stored in stock piles so that they do not get intermixed. The aggregates shall be stock piled near to mixer site/B & M plant to minimize re-handling. The aggregate shall be placed on a dry hard patch of ground if available otherwise a plat- form or plane galvanized iron sheet or a floor of dry bricks shall be prepared. If the coarse aggregate is stored on normal ground, it is advisable not to use the bottom 20cm layer of the aggregate.

9 WATER AND ADMIXTURES

Water for mixing

The water used for mixing of concrete and cement/sand mortar shall be free from any injurious amounts of deleterious materials. The waters containing any sugar, excess of acid, alkali or salt shall not be used. The pH value of water should be between 6 and 8. The tests for determination of solid contents shall be conducted as per IS: 3025.

Limits of permissible impurities

Type of Impurity	Permissible Limits (By weight)
Organic	0.02%
Inorganic	0.30%
Sulphates	0.05%
Alkali Chlorides	0.10%

Potable water is generally considered fit for mixing concrete and preparation of mortar.

Curing Water

The use of water in curing is intended to penetrate the concrete/ mortar. The water should not produce any unsightly deposit or objectionable stain on the surface. Even very low concentration of iron and organic matter can cause staining on the surface. As per IS: 456-2000, the presence of tannic acid or iron compounds are objectionable in curing water. In case of doubt about the suitability of water particularly in remote areas or where water is taken from sources, not normally utilized for domestic purposes, water should be tested before use.

9.1 Admixtures

Admixture is added to the concrete mix immediately before or during mixing to modify some specific properties of concrete in fresh or hardened state. It shall be batched by means of mechanical batcher in such a manner as will ensure uniform distribution of the admixture throughout the batch during the specified mixing period. The properties commonly modified are

1. Rate of hydration

2. Setting times
3. Workability
4. Dispersion/ Air entrainment

In general construction activities, admixtures are added to improve the workability of concrete and are a substitute for high water contents. The air entraining agents (AEA) are used as admixture in such a case. The quantity to be added depends upon the desired percentage of air entrainment which shall be fixed by the Engineer-in-charge. The quantity can be changed whenever necessary to satisfy varying conditions encountered during construction. The air entrainment agent should conform to IS: 9103.

10 Hessian cloth

10.1 General requirements:

The hessian shall be woven with jute yarn in plain weave, with two single yarns drawn through each split of reed. The hessian shall be generally of uniform construction. Selvedges shall be firm, straight and may contain cotton yarn.

10.2.1 Cut (Full Cut):

A length of continuously woven jute fabric measuring 82 **m** or **more.**

10.2.2 Short Piece

A length of continuously woven jute fabric measuring 18 m or more but less than 82 m.

10.2.3 Lot

The quantity of hessian of one definite type, quality, packed in bales or rolls containing one definite length and delivered to buyer against one dispatch note.

10.2.4 Roll

The cylindrical rigid package containing one type of hessian wrapped on suitable core and covered with roll covering with outer layer stitched properly in conformity with IS 4744: 1968.

10.3 Sampling, Testing and Inspection

Unless otherwise agreed to between the buyer and the seller, the procedure for sampling shall be as given in Annex B and the procedure for testing and inspection shall be as given in Annex Cof **IS Code 2818 (Part 1)** : 1990.

10.4 Criteria for Conformity

The lot shall be considered as conforming to the requirements of this standard, if the following conditions are satisfied.

10.4.1 For Hessian Packed in Bales:

a) The total of the corrected net mass of the bales under test is not less than the total contract mass of the bales.

b) The total length of hessian (cuts) in each bale shall conform to the specified requirement.

c) The number of short pieces (cuts) in each bale under test does not exceed the specified numbers.

d) The average moisture content percent of the test samples does not exceed the specified percentage.

e) The average oil content percent of the test samples does not exceed the specified percentage.

f) The average warp way and weft way breaking strength values of the test samples either by travelled trip test method or grab test method are not less than the corresponding breaking strength specified.

g) The average value of (i) mass per square metre, (ii) ends per decimeter, and (iii) picks per decimeter for the test samples are in accordance with the requirements specified.

h) (i) Construction above (38 X 31) or (9 X 8) (see Note)

Note - 38 X 31 stands for 38 ends/dm and 3 I picks/ 9 X 8 stands for 9 porters and 8 shots.

Not more than 20 percent of the width readings of the cuts under test are outside the specified tolerances and not more than half of these readings (10 percent) are below the specified nominal value. However, no individual reading shall fall below the specified nominal value by more than 0.5 percent subject to a minimum of 0.5 cm.

10.4.2 For Hessian Packed in Rolls:

a) The total of the corrected net mass of the rolls under test is within +8 to -2% percent of the contract mass.

b) Observed length of the rolls is within +/-1 percent of the marked length of the rolls.

c) For moisture regain, oil content, breaking strength, mass, ends and picks, and width conditions given in **9.4.1(d), (e), (f), (g)** and **(h)** respectively are satisfied.

10.5 Sampling

Sampling should be done as per Annex B Clause 6.1 of Annex B of IS Code **2818 (Part 1):** 1990.

10.6 Testing and Inspection

Testing and Inspection should be done as per Annex C Clause 6.1 of Annex Cof IS **Code 2818 (Part 1):** 1990.

10.7 Measurements

The measurements shall be taken correct to the nearest millimetre. The circumference of the Bale or roll shall be measured in millimetres, and the length shall be multiplied to calculate the quantity (IS 2818 (part 1): 1990), which will be recorded to the nearest 0.01 square metres, as specified in the Bill of Quantities. The rate for payment includes the cost of materials, 50% extra for hessian cloth wrapping, wastage, labour, contractor's profit, necessary tools and equipment, all applicable taxes, labour cess, etc.

11 PVC Perforated Pipe

11.1 Each PVC pipe shall be clearly and indelibly marked in colour using ink/paint as given in IS Code 4985, at intervals of not more than 3 meters. Alternatively, inkjet printing in any contrasting colour can also be used for marking at intervals of not more than 3 metres. The markings shall show the following:

a) Manufacturer's name or trade-mark,
b) Outside diameter,
c) Class of pipe and pressure rating,
d) Batch or lot number, and
e) The word plumbing in the case of plumbing pipes.

Class of Pipe	**Colour**
Class 1	Red
Class 2	Blue
Class 3	Green
Class 4	Brown
Class 5	Yellow
Class 6	Black
Plumbing pipes	Pink

11.2 The section of the drain should be as per drawing supplied by the Engineer-in-charge . The drain should be carefully filled up to the bottom of the lining with graded filter with pipe as shown in Drawing and properly compacted so as to form even bedding for lining. The pipe should be perforated PVC150 mm/ 250mm Dia pipe as shown in drawing .The Work should be done as per IS Code 4558.

11.3 Perforations shall conform to the following requirements unless otherwise specified or shown on the drawings:

a. Perforations shall be either circular or slots.

b. Circular perforations shall be 1/4 ± 1/16-inch diameter holes arranged in rows parallel to the axis of the pipe. Perforations shall be evenly spaced along each row such that the center to-center distance between perforations is not less than eight times the perforation diameter. Perforations may appear at the ends of short and random lengths. The minimum perforation opening per foot of pipe shall be as shown in table below.

Material Specification PVC Pipe				
S.no.	Nominal pipe size (inches)	Minimum number of rows		Minimum opening Per foot (Sq. inch)
		circular	slot	
1	4	2	2	0.22
2	6	4	2	0.44
3	8	4	2	o.44
4	10	4	2	0.44
5	12	6	2	0.66

c. Slot perforations shall be symmetrically located in two rows, one on each side of the pipe centerline.

Slot perforations shall be located within the lower quadrants of the pipe with slots no wider than 1/8 inch and spaced not to exceed 11 times the perforation width. Minimum perforation opening per lineal foot of pipe shall be as shown in above table.

d. On both the inside and outside of the pipe, perforations shall be free of cuttings or frayed edges and of any material that would reduce the effective opening.

11.4 Measurement and Payment

Measurement shall be made in running meter after proper completion of work and payment shall be made accordingly.

12 Reinforcement

12.1 General

1. All reinforcement shall be procured from genuine manufacturers. Re- rolled steel shall not be used in any component of work.
2. The contractor shall make his own arrangement to procure high yield strength deformed bars of grade Fe – 415 in accordance with IS: 1786 and in quantity/ size as shown in the drawing.
3. Tested quality of steel reinforcement bars shall be used. Requisite IS test certificates from manufacturers are to be provided by contractor to the Engineer-in-charge before use of reinforcement steel on the work.
4. Steel bars shall be stored in such a manner as to avoid distortion or deterioration by rusting / corrosion.
5. To protect reinforcement steel from exposure to saline atmosphere, surface of bars shall be treated with cement wash or any other suitable method shall be used.
6. The mass per meter run in Kg of reinforcement steel bars shall be as tabulated below (I.S. 1786).

S. No.	Nominal Size of bar (mm)	Cross sectional area (mm^2)	Mass per meter (kg)
1.	8	50.3	0.395
2.	10	78.6	0.617
3.	12	113.1	0.888
4.	16	201.2	1.58
5.	18	254.7	2.00

6.	20	314.3	2.47
7.	22	380.3	2.98
8.	25	491.1	3.85

12.2 Cutting & Bending of Reinforcement

1. The bars shall be bent by hand or power cold, correctly and accurately to the size and shape as shown in drawings or as directed by Engineer-in-charge.

2. The radii of the bends in the main reinforcement bars shall not be less than 6 times bar diameter. The radii of the bends of stirrups shall not be less than twice the diameter of the bar.

3. Bars bent during transport and handling shall be straightened before being used on work. Bars shall not be heated to facilitate bending.

4. Reinforcement bars from any rejected lot shall not be used.

5. Where reinforcement bars are bent aside at construction joints and after wards bent back into their original position, care shall be taken to ensure that at no time radius of the bend is less than 6 bar diameter. Care shall also be taken when bending back the bars to ensure that concrete around bars is not damaged.

6. Reinforcement bars at the construction joints shall not be bent or re-bent and afterwards straightened without the approval of Engineer-in-charge.

12.3 Placing of Reinforcement

1. Rough handling, prior to placement shall be avoided. Reinforcement shall be secured against displacement beyond the specified limits.

2. Before the reinforcement is placed, surface of bars and the surface of any metal supports shall be cleaned of rust, loose mill scale, dirt or coats of paints, oil or other coatings which may reduce bond with concrete.

3. Reinforcement steel bars shall be placed accurately to the dimensions and shape given in the bar bending schedule shown on the relevant drawings.

4. Reinforcement bars shall not be allowed to sag between supports.

5. Unless otherwise specified by Engineer-in-charge, reinforcement shall be placed with-in the tolerance limit of ±10mm for effective depth of 200 mm or less and ±15mm for effective depth more than 200mm.

6. Reinforcement bars shall be placed in position as shown in drawings. The bars crossing one another shall be tied together at every intersection with annealed mild steel binding wire of 16 SWG by twisting the strands tight to make the skeleton of the steel bars rigid so that the reinforcement is held in position and does not get displaced during the deposition of Concrete.

7. Minimum distance between individual bars will be kept as per drawing. However following guidelines shall be adopted.

   - Horizontal distance between two parallel main bars shall usually be the greater of the twice diameter of the larger bar and 5mm more than nominal size of coarse aggregate.

   - The size of coarse aggregate may be reduced, with the permission of Engineer-in-charge around congested reinforcement to comply with these provisions.

8. All supports used for positioning of bars shall be of non-corrodible material. Metal supports shall not extent to the surface of concrete except where shown in the drawing. Pieces of broken stone or brick or wooden block shall not be used.

9. Special care shall be taken to prevent any displacement of reinforcement embedded in freshly placed concrete.

10. The bars shall be kept in position by using pre-cast cement concrete cover blocks, spacer bars, supporting bars and templates as directed by Engineer-in-charge to provide specified nominal clear cover to the reinforcement. Spacers / chairs shall be placed at a maximum spacing of 1 m. c/c.

11. Cover blocks shall be of same grade as that of main concrete or of PVC.

12.4 Splicing

1. Preferably, bars of full length shall be used. Overlapping length of bars shall be as shown in the drawing. As per IS: 456 the lap length of a bar shall not be less than 30 diameter of bar. The overlapping bars shall be tied with binding wire as per provisions of IS 456.

2. When permitted by Engineer-in-charge or specified in the drawings, welded joints or mechanical connections may be used as per IS: 456 subject to the appropriate tests to prove that the joints are of full strength of bars connected. Costs of all material, equipment and conducting tests, subject to the approval of Engineer-in-charge, shall be borne by contractor.

3. Welding of joints in reinforcement bars shall be done in accordance with IS: 2751-1966, IS 456-2000.

4. Reinforcement bars with diameter of 28mm or greater may be butt welded. These bars will be connected by overlapping, only when it is more practical than butt welding and overlapping does not hinder concrete / reinforcement placement.

5. Reinforcement bars with diameter of 28mm or less may be connected by overlapping or butt welding whichever is considered more practical by Engineer-in-charge.

6. Welding pieces of reinforcement shall be tested at the rate of 0.5% of the total no. of joints welded or as decided by Engineer-in-charge. Specimen shall be taken from the actual site of work. No extra payment shall be made.

12.5 Nominal Cover to Reinforcement

1. Unless specified otherwise, actual concrete cover to the reinforcement shall not deviate from the required nominal cover by (+) 10 mm.

2. The following Table may be referred to for the concrete cover for reinforcement unless otherwise specified.

1	Thin slabs and walls	Not less than diameter of bar minimum 15mm.
	(i) Beam sides	Not less than diameter of bars minimum 25 mm.
2	Beam top and bottom ends	2 times dia of bars ; diameter of bars minimum 25 mm.
3	Columns	Not less than diameter of bars minimum 25 mm up to 200mm sides
4	Footings	Minimum 50 mm
5	Foundations	40mm

12.6 Payment

The rate in the bill of quantities for reinforcement shall include cost of steel, binding wire or welding material, its cutting bending cleaning, placing, binding work and fixing in position as shown on drawings and as directed by the Engineer-in-charge. The unit rate shall also include cost of all devices for keeping reinforcement in approved position, cost of jointing as per approved methods and all wastage, overlaps, dowels, binding wire or welding material and spacers and cost of all incidental operations necessary to complete the work as per specifications.

13 L.D.P.E. Film under Lining

13.1 General:

A plastic membrane of low density polyethylene film of 50 micron or as prescribed by the Engineer-in-charge shall be used below the concrete lining in sides and in beds to prevent absorption of water in sub grade/reduce seepage losses. The use of polyethylene sheet below concrete lining is for achieving better ultimate imperviousness of the lining as a whole,

13.2 Film

The low density polyethylene film made from virgin raw material should conform to IS 2508 - 1984(reaffirmed-2003) and be of nominal thickness of 200 microns and should be black in color. Film manufactured with recycled material will not be allowed to use.

The film shall be uniform in color texture and finish. The material shall be substantially free from pin holes and undispersed raw materials, streaks and particles of foreign matter, there shall be no other visible defects, such as holes, tears or blisters. The edges shall be free from nicks and cuts visible to unaided eye.

The density of the material used in the LDPE film should be in between 0.922 to 0.937 gm/cc. melt flow index in gm/10 minute should be in between 0.1 to 1.0., Percentage of carbon black content must be 2.5+/-0.5. Tensile strength at break must be 188 kg/cm$^{2.}$

The film shall be furnished in the form' of flat, sheet or rolls or in the form of flat tubing or in any other specified form as per direction of the Engineer-in-charge.

13.2 Laying Technique

The film shall be laid over the sub-grade prepared below the designed bed level to the extent of cover thickness in strips perpendicular to water flow depending upon the width of the film, width of the bed & perimeter of the section.

The film shall be spread loosely over the sub-grade so that it shall attain the contours of subgrade and compensate for thermal variation during the day. It is recommended that an extra length of 2.5 percent, over the length of the film required for spreading over bed and side slopes should be provided to take care of thermal variations during the day.

As polyethylene film is likely to be affected by very high temperature about 45°C obtaining in summer days it would be advisable to avoid laying of the film under such high temperature. In case it is necessary to continue the work on hot days as well working should be done carefully and Water should be sprinkled on film to avoid over heating of film.

Adjacent layers of film sheet should be laid in such a manner that the width of an overlap should be adequate and the overlap should point downstream.

The film sheets should be jointed using of the method described below

13.4 Jointing by hot bitumen

The film sheet can be joined by a coat of bitumen. Bitumen the grade 85/25 and 80/100 in the ratio of 2:1 should be heated at a temperature around 100^0C. Heated bitumen can be tested on a small piece of film sheet so that overheated bitumen may not damage the film. After ascertaining the appropriateness of the temperature, apply a thick coat of tested bitumen on a 10 cm area along the width of both the sheets and fold them and cover the same with brick (Dhamalies) at a suitable interval depending upon the width of the film which should come directly over this joint at a regular intervals. Using, damaged fill sheet is not recommended. However, this method has been found convenient for repairing punctures in the film at site itself. In case of big holes, pieces of sheet should be pasted from both sides.

13.5 Jointing by Heat sealing

The overlap joints can be heat sealed with a hot iron. The temperature of the iron should be adjusted and maintained at 150°C and pressed on the film sheet joint overlap for 5 seconds or as recommended for a 200 micron film thickness sheet. For every 50 micron increase in the film sheet thickness the time would be increased by one second. To avoid the risk of film/sheet sticking to iron a poly-tetra-fluoroethylene (PTFE) impregnated glass cloth or Teflon sheet or Cellophane sheet should be placed between the film and the iron. Heat Sealing is the most effective method for jointing the LDPE film.

In all type of joints the overlap should be kept normal to the flow and should point downstream of the canal.

Extra length of film sheet should be placed in trench at embankment top and covered with earth. The embankments may be then raised to designed level.

Connection To Structures - In case of structures in lined channels film should be embedded in the solid structure, i.e. R.C.C/masonry by about 15 cm to provide impermeable layer. This film should be protected by a layer of 50 mm to 100 mm thick cement concrete.

Do's and Don'ts for Geo membrane or LDPE film For Canal Lining.

(1) Keep the rolls in original packing prior to actual use of laying and see at the time of delivery that the rolls are packed properly.

(2) Apply uniform pressure while thermal welding (heat sealing) the film sheet.

(3) Don't leave unpacked rolls exposed to over prolonged periods or preferably store them indoors.

(4) Don't rough-handle or drag rolls, as the film sheet may get damaged in the process.

(5) Don't let workers walk on the film sheet while the lining operation is in progress to avoid puncturing of the film sheet, in case this is unavoidable, they should walk barefoot after taking proper precautions for safety of film.

(6) Don't slide cement concrete on film/sheet to avoid damage and displacement

(7) Don't use hooks for lifting the rolls.

Measurement and Payment

The payment for LDPE film shall be made in Sqm. The rate includes the cost of LDPE film, transportation up to site, laying, jointing etc. complete.

14 Cement Concrete Canal Lining Using Paver Machine

14.1 Preparation of sub grade

The sub grade should be prepared, dressed and rolled true to level and according to the required cross-section of the canal to form a firm compacted sub grade for the lining.

In other than predominantly sandy reaches where the dry bulk density of the natural soil is not less than 1.8 g/cm3 initial excavation should be done up to about 30 cm above the final section and the cutting to final shape should be done immediately before lining.

For checking the uniformity of side slopes, sample profiles at an interval of about 20 m. in straight reaches and 10m in curved, reaches should be made. Concrete templates of suitable size should be laid on the sample profiles. To begin with the top and bottom of the side templates should be fixed with reference to the established centre line of the canal and the corresponding design levels. For verifying the slope of the templates representing the sample profiles the diagonals of the cross-section of canal, between the two opposite side templates are checked. After laying the templates to the correct profile a cord should be stretched over the two templates (representing the

same profiles) and run along the slope till the surface between the two profiles is properly leveled and dressed from top to bottom.

If at any point material of prepared sub grade has been excavated, beyond the neat lines required to receive lining, the excess excavation should be filled with proper filler material compatible with sub grade material and thoroughly compacted.

When partial filling of an existing canal is necessary to adequately reduce the cross-sectional area to that required for lined canal, the fill should be placed and suitably compacted to avoid its settlement and rupture of the lining

To cover up any lapses in the compaction of the inner core of the banks near the edges and to allow sufficient width for a laborers to work conveniently a lip cutting width of not less than 50 cm horizontally should be provided.

Compaction of Sub grade Predominantly Sandy Reaches

Bed

If the bed level is below required line the suitable material must be laid in 25 cm layers laid horizontally and compacted by heavy duty vibro earth compactor or laid in 20 cm layer and compacted. The density of compacted layer must be 70% of relative density. The level of compactor surface must be 10 cm higher than the required level.

Sides

The fill material i.e. Soil or silt brought from the demarcated area must be laid in 20 cm layer compacted to 15 cm. The thickness of layer may increase up to 25 cm if heavy duty vibro earth compactor is used. Filled material must be compacted up to 70% of relative density.

Compaction of Sub grade in Other than Predominantly Sandy Reaches.

All compaction should be done at optimum moisture content in layers not more than 15 cm thick to obtain a dry bulk density of not less than 95% of the density at optimum moisture content obtained in accordance with **IS 2720 (Part 7) 1992(standard proctor density).**

Bed

Where the dry bulk density of the natural soil is less than 1.8 g/cm3 and the subsoil water is near the Subgrade, the compaction should be done by under cutting the bed by 7.5 cm and then ploughing up to 15 cm below the sub grade level, the loosened soil should then be re-compacted with sheep foot rollers or other suitable devices. Where the subsoil water is low, requiring no dewatering and the

dry bulk density of the natural soil is less than 1.8 g/cm3 the compaction should be done by digging the canal up to subgrade level and after loosening the earth below subgrade up to 15 cm by disc harrows, or ploughing and compacting the same. After there, the second layer of 15 cm of earth should be laid over 'the compacted layer by taking earth from lip cutting and compacted. The compacted layer above the subgrade level, should be removed and the subgrade brought to design before laying the lining.

Sides

Compaction on sides should be done, by suitable compactors to a depth of 30 cm to obtain a minimum dry bulk density of not less than 95 percent of the density at optimum moisture content. The fill material i.e. Soil or silt brought from the demarcated area must be laid in 20 cm layer compacted to 15 cm. The thickness of layer may increase up to 25 cm if heavy duty vibro earth compactor is used. Filled material must be compacted up to 95% of standard proctor density.

In present case partial filling of an existing canal is necessary to adequately reduce the cross-sectional area to that required for lined canal, the fill should be placed and suitably compacted to avoid its settlement and rupture of the lining.

14.2 Pride

The problem of effectively compacting the sub grade for side lining on slopes is very important. In sides and bed, in addition to design thickness thirty cm (Perpendicular to side slope) or fifty cm (horizontally) extra pride may be provided and compacted in horizontal layers to the required density. This pride should be removed only just prior to the placement of lining, thus making a fresh and well compacted surface available for lining.

For cutting best method is to leave the cutting 20 cm or so undercut (Perpendicular to the canal slope) and remove this undercut only just prior to the placement of concrete lining.

14.3 Anti - Salt Treatment

Soil in all reaches should be tested for salt content before the lining is started. Where the salt content is over 1.00 percent or sodium sulphate is over 0.36 percent, the subgrade should first be covered with about 2mm thick layer of bitumen obtained by evenly spraying bitumen at a rate of about 2.35 kg/ m^2. To get a good bond between bitumen and soil, crude oil at a rate of 60.5 lit/m^2 should be sprayed over it in advance of spraying bitumen. In case such a situation is encountered only in small pockets the replacement of sub grade up to suitable depth by suitable earth from adjoining reaches should be considered, if economical. Before spraying crude oil, subgrade should be perfectly dry, clean and free from dirt, and crude oil should be allowed to penetrate the subgrade surface. Bitumen should be heated to a temperature of 175°C and applied to the subgrade by a suitable sprayer, immediately following the application of bitumen, dry sand should be uniformly spread. Lining should be started 6-12 hours after spraying.

14.4 Drainage behind lining

The drainage arrangement depending upon the water table and the type of subgrades, the under drainage arrangement with PRV is required to be provided as per IS 4558:1995 and in case of expansive soil as per IS Code 9541:1994. In case the contractor fails to provide a proper drainage arrangement, then the Engineer-in-charge can replace a drainage Geo-composite without any extra

cost to be used for under drainage arrangement consisting of three dimensional net structures which form the core with a layer of thermally bonded, spun bonded, non-woven geotextile bonded to one side and impermeable membrane bonded to the other side by thermal lamination. It shall confirm to EN 13252:2000. The product should have excellent resistance to biological and chemical environments normally found in soil and shall be stable against short term exposure to ultraviolet radiation.

The Core should be Extruded net (Polyethylene) and Membrane should be Extruded impermeable membrane (Low density Polyethylene/EVA).

Hydraulic Properties-Composite (mean value)

Surfaces: Hard/ Hard , machine
Direction in plane water flow EN
ISO 12958
Hydraulic gradient=1.0
20k Pa L/m.s (10^{-3} m^2/s) 0.68
100k Pa L/m.s (10^{-3} m^2/s) 0.58
200k Pa L/m.s (10^{-3} m^2/s) 0.53

Hydraulic Properties-Filter (mean value)

Pore size EN ISO 12956 Mean AOS	mm	0.15
Permeability EN ISO 11058 Velocity L/m^2s (10^{-3} m^2/s)		100
Index h 50		

Physical Properties (Composite typical)

Mass per unit area EN ISO-9864	g.m^2	825
Thickness EN ISO (9863-1 (2k Pa)	mm	5.00
Filter over lap (one side)	mm	100

Mechanical Properties (Composite typical)

Tensile strength EN ISO 10319	MD	kN/m	13.0
CBR Puncture resistance EN ISO		N	2150

14.5 Trimming the canal section

General.

(a) The provisions of this paragraph apply to the preparation of subgrade upon which concrete lining is to be placed.

(b) The work of trimming the canal section up to the underside of concrete lining and preparing sub grade for concrete lining includes excavation, prepares the base for lining shall be carried out by machine (trimmer) of adequate capacity to match with the paving machine used for lining with insertion of PVC strip immediately, but in no case the time interval should exceed 3 days in normal weather and 2 days in adverse weather conditions. Wherever, earth is over excavated the item of trimming and preparation of sub-grade includes, filling the over excavated portion with suitable semi-pervious material, watering, compaction and its trimming up to underside of the concrete lining. Rain cuts on the banks shall be filled up with approved excavated material and shall be compacted

Adequately to required line and level. The material required for filling the over excavation if not available during excavation in soils to be done under this item shall be hauled from stockpile and placed in position. The bed and side slopes shall be trimmed to the required section by using trimmer machine. The canal bed and slopes shall be dressed, watered and compacted by suitable slope compactors.

(c) If at any point material has been excavated beyond the pay line required to receive the concrete lining the excess excavation shall be refilled in horizontal layers with selected material moistened, if required and compacted using rollers and slope compactors. The layers may be placed parallel to the surface of the foundation. If at any point the foundation material is disturbed or loosened during the excavation process or otherwise it shall be moistened, if required and thoroughly compacted by tamping, rolling or other approved methods to form firm foundations for placing the concrete lining.

(d) Immediately prior to placing the first lift of bedding material, the surfaces of the excavation and embankment to receive the material shall be adequately wetted to a depth of 15cm or to impermeable.

(e) After the canal prism has been shaped to a reasonably true and even surface as described above, bedding material shall be placed on adequately wet surfaces in layers of 15cm. maximum thickness to bring the bedding material to a height where it can be trimmed to form a true and even surface upon which the concrete for lining is to be placed. Each layer of bedding material shall be moistened and thoroughly compacted.

(f) Suitable material trimmed from the canal shall be used to complete canal embankments or to construct road embankments or for back fill around structures or to deposit bedding material. Where material suitable for bedding as determined by the Engineer-in-charge is encountered during trimming operations and cannot be placed in one continues operation, such material shall be stockpiled along the right of way where designated by the Engineer-in-charge .

Kankar or any sharp angular material shall be removed to provide reasonable smooth sub-grade. Any weeds roots and vegetation that may damage the film should be removed.

If the reaches are weed infected, suitable anti-weed treatment of the sub-grade May be done to discourage weed growth under the film The weedicides should be selected with utmost care specially where the canal water is used for drinking/bathing purpose and should not be harmful

After completion of the spraying of weedicides and before taking up the next activity a period of 24 hours should be allowed for penetration of chemicals into the soil.

As there is no bond between concrete & LDPE film, the canal profile should not be smoothened (with a layer of sand etc.) as the undulations will form keys& prevent sliding tendency of concrete.

Tolerances:

Excavated profile provides the final base for lining and tolerances i.e. departure from established alignment shall be as indicated.

+ - 20mm on straight section

+ - 50mm on tangents

+ - 100mm on curves

+ - 20mm Departure from established grade.

The above tolerance shall be negotiated gradually through smooth transition in a length of 50M.

14.6 Cement concrete for paver lining

Cement concrete for lining shall be prepared with four ingredients i.e. cement, fine aggregate, coarse aggregate& water.

The M15 mix shall be designed on the basis of a minimum quantity of cement /m3 concrete, 20 mm MSA of graded coarse aggregate, and water cement ratio of 0.350-0.70. Standard deviation of 3.5 N/mm2 (as per IS: 456-2000) shall be assumed initially, if sufficient test results are not available, for designing the concrete mix on the basis of 28 day target average strength. With accepted proportion of low results (1 in 20), a factor of 1.65 shall be taken (as per IS: 10262-1982) to compute the target strength. Established standard deviation shall be used there after upon availability of the requisite test results (normally 30 test results)

Target average 28 day strength- 20 + 1.65 x Standard Deviation

The concrete manufactured shall conform to IS: 3873-1978. The concrete shall be of controlled grade with suitable admixtures of approved air entraining agents, using well graded aggregates with maximum size of aggregate of 20mm.

Batching.

(a) The contractor shall provide such means and equipments as are required to accurately determine and control and relative amounts of the various materials including water, cement admixture, fiber, sand and each specified size of coarse aggregate required for the concrete. Such means and the equipment and its operation shall be subject, at all times, to the approval of the Engineer-in-charge . The quantity of cement fly ash (if required), sand and each size of coarse aggregate entering each batch of concrete shall be determined by weighing and the quantity of water required shall be determined by volumetric measurement.

(b) The measuring and weighing equipment shall operate within the limits of accuracy specified. Standard test weights and other auxiliary equipments required for checking their satisfactory performance shall be provided by the Contractor.

(c) The equipment shall be capable of controlling the delivery of material for weighing or volumetric measurement so that the combined in accuracies in feeding and measuring during normal operation do not exceed 1% for water and 3% for all aggregates, Periodical tests shall be made at least once in every week in the case of equipment for measuring water, cement and admixtures and at least once in every month in case of equipment measuring sand and coarse aggregate. However, this shall not obviate any surprise checking and testing at any time as desired by the Engineer-in-charge. Repairs, replacement, or adjustments of equipment shall be made as necessary in order to secure, satisfactory performance.

(d) The Weighing equipment shall conform to the requirement of **IS: 2722-1964** and the

batching and mixing plant to the requirement of **IS: 4926 -2003.**

Mixing

(a) Concrete shall be mixed in a mechanical mixer and shall be as dense as possible plastic enough to consolidate well and stiff enough to stay in place on the slopes.

(b) Mixing shall be continued until there is a uniform distribution of the materials and the concrete is uniform in colour and consistency. The time of mixing shall be as shown in table 1 of **IS: 457 - 1957**, shall be matched with the lining equipment capability so as not to impede the specified placement rate of each lining operation. The overall equipment deployment shall be such as to ensure the completion of canal lining within the schedule period specified in the contract.

(c) Concrete when deposited shall unless otherwise specified have a placement temperature of not less than 4.5°C and not more than 40°C.

(d) Concrete shall be deposited and spread on the bed and sides of the canal in strips. Concrete may be so laid as to facilitate placing, vibrating, finishing and curing operations. The side lining concrete on sides of canals shall be screened up the slope, while the concrete is being vibrated ahead of the screed. Concrete required for coping, keys, dowels as shown on the drawings shall be laid integrally along with the side lining.

(f) The joints shall be formed by inserting PVC strips in green concrete.

Slump:

A slump range of about 35 mm – 70 mm shall be considered adequate at the placement site from consideration of proper discharge of concrete from the transit mixer/ agitator cars, mechanical mixer, and case of placement and attaining a well consolidated lining with a good finish.

For hand-placing and for placing with the light machines where concrete is screened from bottom to the top of the slope, the consistency shall be such that the concrete will barely stay on the slope. A slump of 35 to 70mm shall be generally allowed. For heavier longitudinally operating slip-form machines, a slump of 50 mm at the laying point shall be permitted. To have a close control of consistency and workability of the concrete the slumps of concrete shall not vary by more than 20 mm which would otherwise interfere with the progress and quality of the work.

Air entraining agent:

AEA, as an admixture, shall be added to the concrete batch in solution in such a manner as will ensure uniform distribution of admixture throughout the batch during the specified mixing period of about 2.5 minutes to 3 minutes. The amount of AEA shall be such as to effect entertainment of about 5% air in the mix having 20 mm maximum size aggregate in order to have good workability and, thus secure a good finish of concrete lining.

Aggregates:

Fine aggregate (sand) and coarse aggregate shall be well graded and proportioned in nominal sizes as per IS: 383-1970 so as to impart good workability and finish. Aggregates shall be duly tested for their gradation, specific gravity, water absorption, abrasion, soundness, petro graphic analysis, deleterious constituents and alkali aggregate reactivity. Sand shall have a fineness modulus between 2.2 to 3.0, and the maximum size shall the limited to 4.75mm. Each grade of material shall be

stacked separately. The exact gradation required to produce a dense concrete of desired workability and durability shall be evolved through laboratory testing and approved by the Engineer-in-charge.

Concrete production and transportation

Concrete shall be produced in a stationary weight batching plant/plants of adequate capacity installed at a suitable place/ places by the contractor and concrete conveyed to the placement site/sties in mobile transit mixer for placement of concrete lining with fully mechanized concrete paver/pavers.

Alternatively, Mobile self-loading, weight batching, mixing and transporting mixer with the mixer drum capacity of 2.8 m3 (or other suitable capacity) shall be deployed by contractor for production of controlled concrete as well as transportation of this concrete to the placement site/sites. Concrete transported by transit mixers or mobile batching mixing and transporting equipment shall be delivered to the hopper of the side discharge conveyer of the Concrete Paver. The Paver shall screed up the concrete and duly compact it (cylinder finishing). Contraction joints shall be cut with groove cutters attached to the Paver machines and PVC water stop seal of 45X44mm shall be inserted in concrete and finish to line as per drawing. Each lining machine and the associate support equipment shall be capable of placing canal lining at an average advancement rate of not less than about 8m/hr so that cutting of contraction joints and placing of PVC water stop seal, is achieved smoothly and efficiently when the concrete is still in a good plastic state. Contraction joints shall be as shown in the drawing or as directed by the Engineer-in-charge.

i) Broadly; mechanized cement concrete lining of bed and side slopes of the canal section through deployment of concrete Paver of adequate capacity shall be done. Concrete shall be transported by transit mixers from the batching and mixing plant.
ii) Concrete shall be placed only in the presence of a duly authorized representative of the Engineer-in-charge .
iii) Concrete shall be mixed in a mechanical mixer. Hand mixing of concrete shall not be permitted.

14.7 Laying of Concrete Lining

Tolerance in Concrete Thickness, Alignment and Grade

a)	Departure from Established alignment	+ 20mm on straight reaches, 50mm on partial curves or tangents
b)	Departure from established grade	+ 20mm on small canals
c)	Variation on concrete lining thickness	+ 10 mm provided average thickness is not less than specified thickness.

Core test

In order to test the effectiveness of vibration, permeability and strength of concrete cores at suitable places from the side as well as from the bed concrete should be taken from the placed concrete i.e. paver placing.

As the concrete lining work progresses and has attained a minimum curing and setting of 28 days period, cores shall be taken at random to evaluate the quality of concrete lining laid in respective reaches. Frequency of coring shall be determined by the Engineer-in-charge, broadly, it could be one core from bed lining or side lining, as directed by the Engineer-in-charge. In no case fewer than 3 cores shall be tested. The cores shall be examined for segregation/honey combing and thickness of lining. The cores shall be tested for compressive strength. The contractor shall allow all facilities and cooperation require for testing of concrete.

In-situ sleepers in case of bed, in sides, should be provided under the joints. The sleepers should be constructed as per drawing provided. The sleepers should be placed centrally below the joint. Concrete used for sleepers should be of M15/ M20 grade as mentioned in contract. Concreting near the joints should be done with utmost care so as to avoid segregation and collection of loose pieces of aggregate along the form work which may later result in honey combing.

Concreting in curvilinear portion should be done such that side and bed both should rest firmly against curvilinear to resist any back-kick from external hydrostatic forces. Procedure for formation of junction of the sides with bed depending upon the sequence of laying.

Construction Joints

Construction joints form a work link in the lining and deterioration is generally noticed at such joints. Besides joints are potential seepage points for the canal water. As such number of joints should be kept to the minimum and great care should be taken to obtain well compacted and smooth concrete surface at joints. To ensure a good surface the shuttering should be smooth, cleaned, well-oiled and rigidly fixed at site. Besides different mechanisms for compaction of concrete in lining, tamping with iron bar near the joint surface gives better results.

To cater for initial shrinkage and cracks, concreting should be done in alternate strips. The strips size shall be 3.0 mtr. The top of LDPE film on sleepers and side of panel should be applied with primer conforming to IS: 3384;1985. This will acts as an intercepts for seepage through the joint. In case lining is laid by mechanical paver, PVC water stops are placed at joints along with the concreting.

Finishing

The surface of concrete finished against forms should be smooth and should be free from projections, honeycombing and other objectionable defects. Immediately on the removal of forms, all unsightly ridges or lips should be removed and undesirable local bulging on exposed surfaces should be remedied by tooling and rubbing. Repairs to concrete surfaces and additions, where required, should be made by cutting regular openings into the concrete and placing fresh concrete to the required lines. The chipped openings should be sharp and should not be less than the thickness of lining i.e. 75 mm in depth. The fresh concrete should be the same grade as already laid concrete. The mortar should be placed in layers not more than 20 mm in thickness after being compacted and each layer should be compacted thoroughly. All exposed concrete surface should be cleaned of impurities, lumps of mortar or grout and unsightly stains.

The concrete should be finished to an even and smooth surface free from pockets, voids or exposed aggregates. This should be obtained by careful use of a long- handled steel trowel. Any remaining roughness or rough spots shall be rendered smooth, without any time interval after laying the concrete, with cement mortar.

All exposed concrete surfaces shall be cleaned of impurities, lumps of mortar or grout and unsightly stains should be removed. The finished surface shall be even, smooth and free from pockets Where the surface produced by lining machines meet the specified requirements, no further finishing operation will be required. Surface irregularities, when tested with a straight edge of 1.5 meter length shall not exceed 6mm in canal bed for bottom slab and 12mm in the laid on side slopes.

14.8 Curing

Subsequent to laying of concrete lining and after a period of 12 hours or as earlier as warranted by site conditions, the lining should be cured for at least 28 days with the help of Gunny Bags.

General

The concrete lining in canal bed & sides shall be cured with water in accordance with the specifications. If water curing of lining in the canal bed is not carried out to the satisfaction of the Engineer-in-charge as per specifications. The contractor shall be directed to switch over to liquid membrane forming curing compound i.e. spraying white pigmented membrane curing compound Type II, Class B confirming to ASTN-C 309 for curing for which no extra payment shall be made to the contractor.

All equipment, material, etc. needed for curing and protection of concrete shall be at hand and ready for installing before actual concreting begins. Detailed plans, methods and procedures whereby the various phases of curing and protection shall be firmly established, shall be settled and got approved in writing from the Engineer-in-charge sufficiently in advance of the actual concreting. The equipment and method proposed to be utilized shall provide for adequate control and avoid interruption of damage to the work.

Bed lining

Twelve hours after laying of concrete, small bunds longitudinal and cross-wise consisting of earth materials or lean mortar (1:15) should be laid for a height of 8 cm for the purpose of curing. Water will be kept always ponded in these bunds for 28 days continuously.

Side Lining

The strips in which concreting is done on the previous day should be covered with burlap or empty cement gunny bags or hessian cloth. For the purpose of curing, water tank of 5000 liters capacity should be placed on a platform at the edge of service road at the rate of one for 500 m length of lining, which should be kept filled with water with arrangement of outlet and flexible hose of at least 500 m length. Water should be continuously sprinkled on the gunny bags or hessian cloth keeping them wet for 28 days. Sprinkling shall be done during night time also. The curing of side slopes may also be done by perforated pipes on the coping at the top of lining or by sprinklers.

14.8 Testing of Concrete and Acceptance of Work

General

Testing of concrete shall be carried out at the cost of the contractor, by the standard testing Laboratory on representative samples taken at the site of laying the concrete in accordance with relevant Standard Specification.

Sample Procedure and Frequency

(a) Sampling Procedure: A random sampling procedure shall be adopted to ensure that each concrete batch has a reasonable chance of being tested, I.e. the sampling should be spread over the entire period of concreting and should coverall mixing units.

(b) Frequency: The minimum frequency of sampling of concrete to each grade shall be in accordance with the following.

Quantity of concrete m^3	**Number of Samples**
1 to 5	1
6 to 15	2
16 to 30	3
31 to 50	4
51 and above	4 Plus one additional sample for each Additional $50m^3$ or part there of

Note: At least one sample shall be taken during each shift.

Test Specimen

Three test specimens shall be made from each sample for testing at 28 days. Additional cubes may be required for various purposes, such as to determine the strength of concrete at 7 days or all the time of taking form Work, or to determine the duration of curing on to check the testing cubes cured by accelerated methods as described in IS : 9018 -1978. The specimen shall be tested as described in IS: 518 -1959.

Test Strength of Sample

(a) The test strength of the sample shall be the average of three specimens; individual variation shall not be more than 15 percent of the average.

(b) Contractor shall provide necessary unskilled labour and facilities for transport for collection of samples, cores etc. and shall remain present at the time when the samples, cores etc. not taken. Testing shall be carried out at the testing laboratories set up at the site or at any other laboratory that the Engineer-in-charge may decide upon and the results given thereby shall be considered as correct and authentic and acceptable to the Contractor. The Contractor shall be given access to all operations and tests that may be carried out as aforesaid. All testing charges are to be borne by the contractor.

Acceptance Criteria

(a) The average strength of the group of cubes cast for each day shall not be less than the specified cube strength for the work. About 20 percent of the cubes cast of each day may have values less than the specified strength provided the lowest value is not less than 85% of

the specified strength.

(b) In case the concrete does not conform to the accepted criteria for strength as specified above, the Engineer-in-charge reserves the right to reject the work proved by him. Whenever necessary for the purpose of obtaining economy, workability, density, impermeability, durability or strength on account of variation in the quality and gradation of aggregates of other materials the Engineer-in-charge , in consultation with Laboratory Division, shall after testing, make necessary changes, and the contractor will not be entitled to any compensation on account for such changes.

Tolerance

(a) The intent of this paragraph is to establish tolerance that are consistent with modem construction practice yet be governed by the effect that permissible deviations will have upon the structural action or operational function of the structure, Deviations from the established, lines, grades and dimensions shall be permitted to the extent set forth herein below provided that the Deptt. reserves the right to diminish the tolerance set forth herein if such tolerance impairs the structural action of operational function of the lining.

(b) Tolerance for lining shall be permitted within the following units :-

(i) Departure from established alignment 20mm on straight reaches 50mm on tangents.

(ii) Departure from established grade 100mm on curves 20mm on straight reaches

(iii) Variation in concrete lining thickness provided average thickness of each day's placement is not less than specified thickness.

Any departure from alignment or grade shall be uniform and no corrections in alignment be made in less than 50m. No overrun in concrete quantity shall be paid to the Contractor:

14.9 Measurement and Payment

Measurement will be on the basis of cubic meter of cement concrete lining and payment will be at the unit rate quoted in Bill of Quantities. Payment for lining will be made for the thickness shown on the drawing multiplied by the surface area in bed and on sides including keys. The thickness of lining shall be determined by setting of paver machine in relation to final sub grade on which lining is to be laid. The thickness shall be cross checked by (i) volume of concrete placed and area covered (ii) use of probe when concrete is green and (iii) coring if required, any over in quantity of concrete in lining shall not be paid to the contractor. The rate of concrete lining includes cost of all ingredients, their transportation up to site, batching, mixing, and production of concrete, transportation of concrete, placing of concrete by Paver machine, compaction of concrete, finishing, sprinkling of 1:3 cement water slurry on LDPE film, curing, testing charges and assistance required in testing.

Adjustment of rate

The rate of the concrete has been worked out with the 395 kg of cement in 1 Cum. of concrete. If due to mix design cement content in 1 Cum. of concrete is reduced or increased, then rate shall be reduced proportionately as per estimation.

14.10 Joints

In canal lining contraction joints shall be provided to accommodate expansion and contraction of the concrete or to provide continuity between the breaks in construction work. Joints shall be provided as shown on the drawings or as directed by Engineer-in-charge.

Construction Joints

To cater for initial shrinkage and cracks, concreting should be done in strips. The strips size shall be 3.0 mtr. The top of LDPE film on sleepers and side of panel should be applied with primer conforming to IS: 3384-1985. This will acts as an intercepts for seepage through the joint. In case lining is laid by mechanical paver, PVC water stops are placed at joints along with the concreting.

Joints with Bitumen sealing compound

Contraction joints shall be provided and treated as show in the drawings or as directed by the Engineer-in-charge. Longitudinal contraction joints shall be provided in center of the bed. The shape, spacing and dimensioning of contraction joints shall be as shown in the drawing, broadly, the joints shall extend to 1/3 of lining thickness (viz 2.5 cm for 7.5 cm thick lining) with a top width of 12mm maximum and tapering to 9mm to join a 45° groove at bottom. The contractor must ensure that the grooves are of specified dimensions, acceptable to the Engineer-in-charge. After casting of strips thermacol sheet shall be placed in the joint to protect the edges and check the filling of joint by waste material. When the joints was to be filled by the filler material these sheets will be removed and joints shall be clean by applying air water jet, air jet etc. Before filling the joint, joint must be well cleaned and dried. So bituminous primer and other filling material stick to the concrete.

Filling of joints

Filling of joints shall be taken up only after a minimum of 28 days setting period of CC lining. The grooves shall be cleaned thoroughly to their full depth and width by brush, air jet, water jet etc. All loose particles and foreign matter shall be removed and the grooves shall be thoroughly clean and dry to the satisfaction of Engineer-in-charge or his representative so as to ensure good adhesion to the sealant. The primer shall then be applied by means of brush or any other suitable applicator to cover the sides completely before the application of sealing compound mix. Primer shall be as per IS code 3384-1986.

Composition of sealant

Unless otherwise specified, the sealant shall be prepared from the following materials:

1. Bitumen 85/25 = 55%
2. Sand (fineness modules 1.0 to 1.5) = 43%
3. Asbestos powder (of white color) = 2%

The sealant shall be prepared by heating the bitumen to 375° F and sand also to the same temperature separately. The sand shall be mixed with $2/3^{rd}$ quantity of bitumen first and then asbestos powder shall be added to it. The remaining $1/3^{rd}$ quantity of bitumen shall then be added to his mix and stirred thoroughly. The grooves shall be covered with wooden strip and held on slopes with the help of clay puddle put along the sides. The wooden strips shall be coated with greases on inner side so that it may not stick to the filled in similar manner. The joint shall be finished with hot trowel and any hole shall be refilled with sealant. Filling of joints shall commence from bottom of slopes.

Measurement and payment

The joint shall be measured in the running meter up to 1 cm. The payment shall be made as per rate quoted in G Schedule. The rate shall be inclusive of cleaning of joint, painting with the bituminous primer, filling of joint with sealant, cost of all material etc. complete.

PVC water stop seal joint

In the transverse joints PVC (Polyvinyl Chloride) strips shall be provided with the shapes conforming to dimensions shown on the drawing and off white 'in color. The finished PVC strips shall be extruded from virgin, pigmented, plasticized polyvinyl chloride (PVC) The PVC strips shall be dense, homogeneous, free from holes and other imperfections. The cross section of the PVC strips shall be uniform along its length and thickness shall be symmetrical transversely. Tolerance for dimensions in overall length and width shall be 5% and in thickness 10%. The finished PVC strips shall meet the following requirements.

Sr. No.	Characteristic	Unit	Values
1.	**Tensile strength**	Kg/cm2	116 Minimum
2.	**Ultimate elongation**	%	300 Minimum
3.	**Tear Resistance**	Kg/cm2	49 Minimum
4.	**Stiffness if flexure**	Kg/cm2	24.6 Minimum
5.	**Accelerated extraction**		
a)	Tensile strength	Kg/cm2	105
b)	Ultimate elongation	%	250
6.	**Effect of alkali at 7 days**		
a)	Weight increase	%	0.10
b)	Weight decrease	%	0.10
c)	Hardness change point	%	± 5
7.	**Effect of alkali at 28 days**		
a)	Weight increase	%	0.4
b)	Weight decrease	%	0.3
c)	Dimension change	%	± 1

The surface finish of PVC strips shall be mat finish, and off white in colour.

Contractor shall arrange for getting the finished PVC strips tested in recognized testing Government Test Houses. The Contractor shall furnish test same of PVC strips in 30 cm length reel and free of cost also shall bear testing cost. Each sample shall remarked with the number of the reel from which sample is obtained and with certification that the samples are from the roots to be furnished

It is mandatory for the manufacturer of the PVC strips, from whom the contractors procure PVC strips, to have a full- fledged testing laboratory in the factory to enable pre-dispatch testing of the products, as in the event of laboratory test reports being received after a few weeks, showing substandard values. It would not be possible to remove the material embedded in concrete. Test reports from Government test houses shall also be binding on the manufacture based on sample drawn by the Engineer-in-charge and sent for testing to Government test house, from consignments received at site. The Contractor will got the sample of PVC strip approved by the Engineer-in-charge. He will furnish the name of manufacture, the details of the in-house testing all arrangements with the manufacturer and will also furnish a test report from the in-house testing facilities along with the sample.

The PVC strips shall be inserted in the concrete lining when concrete is plastic by automatic machines attached with paver. If lining is laid manually than the PVC strips at edges shall be placed in position fixed with longitudinal channels by clips of such other arrangement prior to laying of concrete. The PVC for crack inducing joints shall be inserted in position in concrete lining as shown in the drawing. The insertion of the longitudinal or transverse PVC for crack including joints at the predetermined locations of joints requires special attention to ensure location (depth is especially important), plumb installation and consolidated around the PVC for crack inducing joint. The longitudinal final PVC strips include a cellular upper fin. The manner of installation shall include mechanical vibration that produces thorough consolidation of the concrete around the crack inducing joint and provides a continuous contact between the concrete and all surface of the crack inducing joint.

Measurement and Payment

(a) Measurement will be on the basis of running meter of PVC strip joints provided as per requirements and as directed by the Engineer-in-charge . The payment will be at unit into quoted in Bill of Quantity.

(b) The unit rate for PVC strip joints includes providing and fixing PVC for crack inducing joints to specified depth in panels as directed by the Engineer-in-charge costs of all material inducing wastage, equipments, labour, tools, transport with all leads and lifts, finishing and also dewatering where required.

15 Dewatering

15.1 Where water is met with in excavation due to seepage, springs, rain or other reasons, the contractor shall take adequate measures such as bailing, boring, pumping, construction of diversion channels, drainage channels, bunds, and any other necessary works to keep the working area dry when so required and to keep the green concrete/ masonry protected against damage by or undermine its strength including erosion at the contractors cost and risks. In this regard and other details thereof, it shall be left to the choice of the contractor but subject to the approval of the Engineer-in-charge. Approval of the Engineer-in-charge shall however, not relieve the contractor of his responsibility for the adequacy of dewatering and protection arrangements and the safety of the works. Pumping from inside of working area enclosures shall be done in such a manner as to preclude the possibility for the movement of water through any freshly placed concrete. No surface pumping shall be permitted during the placing of concrete or for any period of at least 24 hours thereafter, unless it is done from a suitable sump separated from the concrete work by a watertight 56 wall or similar means. At the discretion of the contractor and at his cost, approved methods may be used to prevent or to reduce seepage and to protect the excavation area. The contractor shall take all precautions in diverting channels and in discharging the drained water so as not to cause damage to the works or to adjoining property

15.2 The following points should be taken care of while dewatering:

1) After above the water table dewatering of the working area should be commenced by well points/open pumps/deep well pumps and the water table progressively lowered.

2) In sandy soil well point systems may be suitable for dewatering. In silty clay foundations strata open pumps and/or deep well pumps may be suitable. If an impermeable compact shingles & cobble layer is sandwiched between sandy layers in the depth to be excavated, deep-well pumps with

strainer throughout the depth of the tube well will be suitable.

3) The bore hole details indicating the foundation strata, soil characteristic namely, grain sizes, distribution, relative density and permeability should be examined before deciding on the system of dewatering.

4) The preliminary requirements of dewatering pumps should be based on the inflow to the work area, calculated on the basis of permeability of the strata and closeness of the water source/ sources.

5) The designs, installation and operation of dewatering system should be in accordance with **IS 9759: 1981**. Guidelines for Dewatering During Construction. 6) During dewatering care should be taken to ensure that there is no removal of fines from the substrata that may weaken the canal lining.

7) Any seepage from foundation at local points or springs should be taken care of properly so that there is no piping of the foundation material.

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