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6 CONCRETE

6.1 SCOPE OF WORK


- i) The Specification described herein under cover all labour, materials, equipment and services related to the concrete work to be carried out by the Civil Contractor under this Contract.
- ii) The concrete Work shall be performed to the dimensions as shown on the drawings or as otherwise directed by the Project Manager.
- iii) The Contractor shall co-operate with all other Contractors and Employer related to the construction of Permanent Works where the material or equipment is to be fixed to, or embedded in, the concrete structures.
- iv) The approval given by the Project Manager to the Contractor's plants and equipment or their operation, or of any construction methods shall not relieve the Contractor of his full and sole responsibility for the proper and safe execution of concrete Work or any obligations under this Contract.


6.2 STANDARDS


- i) The concrete materials, production, methods, testing and admixtures shall conform to the latest revisions of the following Indian Standards or, where not covered by these standards, to the equivalent International Standards:


IS: 269	33 grade ordinary Portland cement.
IS: 8112	43 grade ordinary Portland cement.
IS: 12269	53 grade ordinary Portland cement.
IS: 383	Coarse and fine aggregates from natural sources for aggregates.
IS: 456	Code of practice for plain and reinforced concrete.
IS: 457	Code of practice for general construction of plain and reinforced concrete for dams and other massive structures.
IS: 516	Method of test for strength of concrete.


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<div><div><div>IS: 875</div><div>Code of practice for design loads (other than earthquake) for buildings and structures.</div></div><div><div>IS: 1199</div><div>Methods of sampling and analysis of concrete.</div></div><div><div>IS: 1489</div><div>Portland Pozzolanaa cement.</div></div><div><div>IS: 2386</div><div>Methods of test for aggregates for concrete.</div></div><div><div>IS: 2505</div><div>Concrete vibrators – immersion type – general.</div></div><div><div>IS: 2506</div><div>General requirements for screed board concrete vibrators.</div></div><div><div>IS: 4082</div><div>Stacking and storage of construction materials and components at site– recommendations.</div></div><div><div>IS: 5878</div><div>Code of practice for construction of tunnels conveying water.</div></div><div><div>IS: 7861</div><div>Code of practice for extreme weather concreting.</div></div><div><div>IS: 9103</div><div>Admixtures for concrete.</div></div><div><div>IS: 10262</div><div>Recommended guidelines for concrete mix design.</div></div><div><div>ii)</div><div>In cases of conflict between the above standards and the specifications given herein, the decision of Project Manager should prevail.</div></div></div> <div><div>6.3</div><div><u>SUBMITTALS</u></div></div> <div><div><div>i)</div><div>Submittals listed herein are related to the items, which require the consent of the Project Manager and are to be made by the Contractor before the appropriate work proceeds.</div></div><div><div>ii)</div><div>Within 28 days from the date of issue of the Letter of Acceptance, but before procuring or mobilizing to the site, the Contractor shall submit to the Project Manager, updated and detailed plans and descriptions, consistent with those submitted with his bid and any subsequent amendments and additions agreed to by the Project Manager and the contractor, of the following:</div><div><div>a)</div><div>Aggregate Processing Plant:</div><div>Description, flow diagrams and drawings in sufficient details to indicate layout, type and capacity of crushing, screening, washing,</div></div></div></div> <div><div>ISSUE</div><div>P0</div></div>		

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	<p>conveying and other aggregates processing and handling equipment.</p> <p>b) Batching and Mixing Plants:</p> <p>Description, flow diagrams and drawings of the plants, capacity, and details of the equipment, the Contractor intends to use to determine and control the amount of each separate concrete ingredient and mixing thereof into uniform mixture.</p> <p>c) Cooling Plant:</p> <p>Details of the cooling plant and methods, which the Contractor proposes to use to comply with hot weather concrete temperature requirements.</p> <p>d) Transport and Placing of Concrete:</p> <p>Full details of the equipment and methods for transporting the concrete from the concrete plant to the final point of placing, including numbers, type and capacity of transport vehicles, concrete pumps, vibrators and details of standby units to be used.</p> <p>iii) Before any concrete work being carried out on the site, the Contractor shall submit to the Project Manager following information:</p> <p>a) Details of any admixture and Pozzolana, which the Contractor proposes to use, name of manufacturers thereof, and information about the chemical names of the principal admixtures, or additives and the likely effect of under or over dosage. Should the contractor intend to use an accelerator in any concrete work for his own convenience he shall give full details of the type, dosage, influence on construction, and the cost saving involved,</p> <p>b) Details of all surface finishes, treatment of construction joints, and construction techniques which the contractor proposes to use in order to achieve the required concrete surfaces and allowable tolerances,</p> <p>c) Mode and methodology of concrete curing,</p>	<div data-bbox="1396 2033 1485 2123" style="border: 1px solid black; padding: 5px; text-align: center;"> ISSUE P0 </div>

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<div> <div>d)</div> <div>Sampling and Testing of Materials, listing and giving details of equipment for sampling and testing, detailed program for quality control of concrete work, and qualification and experience of the proposed controlling personnel.</div> </div> <div> <div>iv)</div> <div> At least 56 days in advance of any permanent concrete work at Site, or as instructed by the Project Manager prior to procuring or despatching to the Site of the particular item of work to which the submittal relates, the Contractor shall submit to the Project Manager, the following: <div> <div>a)</div> <div>Details of curing compounds,</div> </div> <div> <div>b)</div> <div>Details of epoxy mortar for concrete repair,</div> </div> <div> <div>c)</div> <div>Notification of the source, analysis, method of delivery, and storage of water for concrete manufacture,</div> </div> <div> <div>d)</div> <div>Details of the material for formwork, and for shoring and reshoring.</div> </div> </div> </div> <div> <div>v)</div> <div>Drawings showing the location of construction joints proposed by the Contractor which differ from those on the drawings, including formwork and reinforcement details, shall be submitted to the Project Manager at least 30 days prior to the commencement of work on that particular structure.</div> </div> <div> <div>vi)</div> <div>Before commencement of the concrete placement the Contractor shall prepare a checklist regarding all preparations for the specified work such as rock surfaces and foundations, cleaning, formwork, reinforcement, embedding, and submit this list to the Project Manager, who after his satisfaction about the work preparations will permit the contractor in writing to commence concrete placement.</div> </div> <div> <div>vii)</div> <div> During the performance of the concrete work, the Contractor shall keep a diary where he shall record the construction procedures related to concreting. This diary shall be made available to the Project Manager, upon request. The records shall contain at least the following: <div> <div>a)</div> <div>Commencement and termination of concreting of various parts of the structures,</div> </div> <div> <div>b)</div> <div>Quantities and quality of aggregates and cement provided and the storage from which they were drawn,</div> </div> </div> </div>		
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<div> <div> c) Temperature of air, water, cement, aggregates and concrete, d) Meteorological conditions and humidity of air, e) Personnel employed during various stages of the concreting operation and name of the responsible inspector or foreman, f) Equipment used, g) Directives received from the Project Manager, h) Any special material or procedures employed. </div> <div> viii) The Project Manager reserves the right to require any additional information deemed necessary to be included in the submitted documents. </div> </div> <div> 6.4 <u>CONSTITUENTS OF CONCRETE</u> </div> <div> 6.4.1 <u>GENERAL</u> </div> <div> i) Concrete shall be composed of cement, fine aggregate, coarse aggregate, water and permitted admixtures, as specified herein and as required by the Project Manager. ii) Concrete and concrete constituents and all materials and operations relating to concrete shall meet the requirements of the Indian Standards Code of Practice for Plain and Reinforced Concrete IS: 456, and as required by the Project Manager. iii) Concrete constituents shall be batched and mixed at site using suitable equipment to determine and control accurately the amount of each ingredient entering the mix. The amount of each ingredient shall be batched correctly with sufficient accuracy to obtain concrete of the quality specified in these specifications. iv) Facilities for storage of concrete constituents and batching and mixing of concrete shall be available for inspection by the Project Manager at all times. v) The use of a water reducing admixture to improve workability without reducing the strength or durability of the mix will be considered by the Project Manager. If acceptable to the Project Manager, it shall be used in </div>		
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strict conformance with manufacturer's instructions and will be supplied by the contractor at no additional cost.

- vi) Air content will be determined in accordance with IS: 9103.
- vii) No other admixtures shall be permitted without written acceptance of the Project Manager.
- viii) Wherever required, from the point of view of the Project Manager, the Contractor shall supply and use an accelerator/retarder/plastisizer whereby the type and dosage shall be subject to the approval of the Project Manager.
- ix) The moisture content of coarse and fine aggregate shall be checked every day and necessary corrections for water cement ratio shall be made.

6.4.2 CEMENT

- i) Cement shall be ordinary Portland cement or Portland Pozzolana Cement or slag cement conforming to the requirements of IS: 269 & IS: 1489 as specified by the Project Manager.
- ii) All bulk carriers of cement shall be clean and dry prior to filling/loading with cement. All carriers for both bulk and bagged cement shall be equipped with weatherproof closures on all openings.
- iii) Sufficient storage facilities shall be provided at the batch plant to enable each new shipment of cement to be stored separately from the cement stored from earlier shipments.
- iv) Cement shall be stored above ground, adequately protected against rain, sun and moisture. Bulk storage bins and silos shall be emptied completely and cleaned of all cement accumulations after every 3 months.
- v) Arrangements shall be made such that stocks of approved cement are adequate to meet the program of work at all times. The program shall allow time for testing and approval of each shipment before such cement is incorporated in the works.
- vi) Cement shall be used in the order of lots in which it is received at site. Cement stored by the contractor and found unfit for use shall not be allowed to be used and must be removed from site immediately

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- vii) The bidder shall price his bid on the basis of the following cement contents for various grades of concrete.

Grade of Concrete As per IS: 456	28th day characteristic strength (MPa) As per IS: 456	Preliminary avg. strength of 3 samples (MPa) As per IS: 516	Cement content (kg / m ³)
M – 10	10	13.5	150
M – 15	15	20	270
M – 20	20	26	310
M – 25	25	32	400
M – 30	30	38	500


Note that the value "30" in M – 30 represents a specified 28th day characteristic strength of 30 MPa for 15 cm cubes as per Indian Standard IS: 456. In order to guarantee this strength the average of 3 samples at 28 days shall have a preliminary minimum strength of 38 MPa as per IS: 516.

- viii) Since the strength of concrete is mainly dependent on the quality of the aggregate used, and this is still to be determined, the cement quantity is therefore indicative only and actual cement quantity shall be dependent on the Mix design.

6.4.3 AGGREGATES


- i) General:
- Unless otherwise specified concrete aggregates shall conform to the requirements of IS: 456 and IS: 383. They shall be tested in accordance with the provisions of IS: 2386,
 - Aggregates shall be supplied only from sources/quarries approved by the Project Manager. Approval of a source shall not be construed as constituting acceptance of all materials to be taken from that source,

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- c) The quality of all aggregates used in the work, including processing such as washing, classifying, screening, re-screening, crushing and blending, necessary to meet the required specifications, shall all be subject to acceptance of the Project Manager.
- ii) Fine Aggregates:
 - a) Sand or fine aggregates shall be used for mortar in stone masonry and as fine aggregates in concrete work,
 - b) It shall be either natural river sand or manufactured, sand crushed from rock/stones or mixture of both in specified proportions. The sand shall be hard, clean and gritty and of a quality approved by the Project Manager. It shall be free from injurious amount of clay, soft and flaky particles, vegetable or organic matter, loam, mica and other deleterious substances and shall not contain any salts,
 - c) The fine aggregates shall conform to the requirements of IS: 383. Varying amount of moisture in fine aggregates contributes to lack of uniformity in concrete consistency. The fine aggregates shall therefore have uniform and stable moisture contents. Dry sand shall be preferred. Hence sand stockpiles shall be protected from rainfall,
 - d) The percentage of deleterious substances in the fine aggregates shall conform to relevant Standards except that the fine aggregates shall contain not more than 0.10 percent by weight of deleterious (reactive) ferrous sulphides. The total percentage of deleterious substances must not exceed 5 percent of the weight,


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Deleterious substance	Maximum permissible Limit by weight
Materials finer than IS sieve no.8	3%
Shale	1%
Coal and lignite	1%
Clay lumps	1%
Cinders and clinkers	0.50%
Alkali, mica and coated grain (deleterious)	2%

- e) Fine aggregates having a specific gravity of less than 2.50 are liable to be rejected. Fine aggregates when subjected to a soundness test with a solution of sodium sulphate, after 5 cycles of tests, shall not suffer a loss of weight in excess of 10%,
- f) The sand shall be well graded and, when tested by standard sieves, shall conform to the prescribed limits of gradation. The best gradation shall be determined by the Project Manager, after experiments and tests and the Contractor shall follow the same,
- g) The sand, as delivered to the batching plant shall have a fineness modulus of 2.6 to 3,
- h) The grading of fine aggregates shall be so controlled that the fineness moduli of at least 9 out of 10 samples of the fine aggregates delivered to the batching plant shall not vary more than 0.20 from the average of 10 samples tested. All classifying, batching or other operations on the fine aggregates shall be done by the Contractor and the cost thereof shall be taken as included in the Unit Rates for the concrete or masonry item as the case may be,
- i) For improving workability of pumped concrete mixes, the Contractor may consider a combination of natural and manufactured sand. Proposed proportions shall be submitted for approval of the Project Manager,

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- j) Maximum amount of material finer than 75 micron shall not exceed 1% by weight,
- k) The gradations shown in the following chart are indicative only. (As per IS: 515-1959)

Sieve size IS	Percentage Passing	
	Natural Sand	Manufactured Sand
480 (4.75 mm)	95 to 100	95 to 100
240 (2.36 mm)	80 to 95	75 to 90
120 (1.18 mm)	45 to 80	50 to 70
60 (600 micron)	30 to 45	30 to 50
30 (300 micron)	5 to 30	15 to 30
15 (150 micron)	1 to 5	8 to 13
8 (75 micron)	0 to 1	0 to 1

- iii) Coarse Aggregates:
- a) Coarse aggregate shall consist of screened natural gravel or crushed rock and shall conform to the requirements of IS: 383,
- b) The term coarse aggregate is used to designate aggregate that is reasonably well graded and ranging in size of particles from 4.75 mm to 150 mm or any size or range of sizes within such limits. The coarse aggregate shall conform to relevant specifications of IS: 515 (for natural and all manufactured aggregate), or IS: 383-1970 (for natural aggregate as revised from time to time),
- c) Coarse aggregate shall have a loss not more than 30% as determined by Los Angeles Abrasion test as specified in IS: 2386 Part IV,
- d) When subject to the sodium sulphate soundness test, coarse aggregate shall not suffer more than 10 percent loss of weight after five cycles,
- e) Natural coarse aggregates shall consist of uncoated hard, strong, dense and durable pieces and shall be free from injurious amounts

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of disintegrated stones, soft flaky or elongated particles, salt, alkali, vegetable matter and other deleterious substances,

- f) Coarse aggregate shall be hard, dense, durable, uncoated rock fragments. Rock having an absorption greater than 3% or specific gravity less than 2.5 shall not be used. Aggregate delivered to the batching plant shall have an uniform and stable moisture content,
- g) Manufactured coarse aggregates shall consist of "very large", "large", "medium", and "small" aggregates and shall be of hard, strong, dense and durable pieces and shall be free from injurious amounts of soft or flaky particles salt, alkali, and vegetable matter and other deleterious substances (IS: 515),
- h) Permissible deleterious substances in manufactured coarse aggregates shall not exceed the following limits:

Deleterious substance	Maximum permissible Limit (by weight)
Materials finer than IS sieve no.8	1%
Coal and lignite	1%
Clay lumps	1%
Total soft, friable elongated or laminated pieces	3%
Other deleterious materials.	As per note given below

- i) Permissible deleterious substances in natural coarse aggregate: Total of all deleterious substances shall not exceed 5% by weight and the coarse aggregate shall not contain more than 0.3% by weight of deleterious (reactive) ferrous sulphide,
- j) The aggregate shall be resistant to chemical or physical change such as cracking, swelling, softening, leeching, or other chemical alteration after its incorporation in concrete,

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- k) The aggregate should be crushed and the different sizes of the coarse aggregate shall be separated into nominal sizes as follows:

Designation	Nominal size range
Small	5 mm to 20mm
Medium	20 mm to 40 mm
Large	40 mm to 75mm
Very large	75mm to 150 mm


- l) Coarse aggregate shall be washed at the aggregate source, however, further washing at the batching plant may be required if the aggregate is found to be unacceptable to the Project Manager,
- m) As far as possible, coarse aggregates shall be of regular shape and free of flat or elongated particles. The volumetric coefficient C, which defines the ratio of the total volume of number of particles at random and the volume of spheres having a diameter equal to the greatest dimension of each element, shall be greater than or equal to the following values:

Aggregate Size	Ratio
6.7/26.5 mm	C = 0.15
26.5/150.0 mm	C = 0.11

- iv) Aggregate Storage:

The coarse aggregate shall, if possible, be stored in a shed or covered storage and arrangements made for sprinkling of water to ensure wetting of the aggregate, great care shall be taken in screening and stacking of the coarse aggregate so as to avoid intermixture of different grade materials and inclusion of any foreign materials. The stockpile should be built in layers of uniform thickness. A hard base should be provided to prevent contamination from underlying materials in storage areas in continual use. Overlap of different materials should be prevented with suitable walls or by an ample distance between storage piles. Sufficient storage of all grades shall be maintained so as to permit continuous placing of concrete.


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6.4.4 ADMIXTURES

- i) The Contractor shall furnish suitable plasticizers and chemical admixtures for use in concrete as provided herein. The admixtures shall be of uniform consistency and quality, and shall be maintained at the job site at uniform strength of solution. Admixtures shall be batched separately in liquid form in dispensers capable of measuring at one time the full quantity of each admixture required for each batch. Admixture dispensers shall be constructed and located such that the plant operator can observe the full batch quantity of each admixture in a visual gauge. Each admixture shall be discharged into the batched mixing water so that water is being discharged into the mixer as the admixture is added.
- ii) Admixture will be accepted on manufacturer's certifications. However, the Project Manager reserves the right to require submission of and to perform tests on samples of any admixture either prior to shipment to the job site or after delivery.
- iii) When requested by the Project Manager the Contractor shall submit test data by the manufacturer confirming total compliance of the admixture to these specifications.
- iv) The contractor shall be responsible for any difficulties arising as a result of the selection and use of admixtures, such as difficulty in concrete placing and delay in concrete finishing and form removal. The Contractor shall be entitled to no additional compensation by reason of such difficulties. Chemical admixtures containing calcium chloride shall not be used in concrete.
- v) Accelerating admixtures, wherever required, shall be used after prior approval of the Project Manager.
- vi) Water reducing, set controlling:
 - a) The contractor shall use a water reducing, set controlling admixtures in all concrete. The admixture shall conform to IS specification or equivalent standard,

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b) The amount of water reducing Admixtures used shall be that amount necessary to effect the requirements of Indian Standard specifications or equivalent and as directed by the Project Manager. The Project Manager reserves the right to adjust the quantities of water reducing Admixtures or eliminate its use and the contractor shall be entitled to no additional compensation for such adjustments.

vii) The cost of the admixtures and all costs incidental to their use shall be included in the price bid in the Bill of Quantities for concrete in which the admixture are used.


6.4.5 WATER

- i) A reliable water supply shall be installed and maintained for washing of aggregates and the manufacture and curing of concrete.
- ii) Water to be used in washing of aggregates and manufacturing and curing shall conform to the following specifications. Water shall be clean and free from injurious amounts of oil, acids, alkalis, sugar, salt and organic matter and shall conform to IS: 456.
- iii) Water for manufacturing of concrete shall be approved by the Project Manager.
- iv) Adequate water storage facilities shall be provided at the batching plant to ensure that no part of concreting operations shall be hindered by a temporary break down in the main supply system.

6.5 CONCRETE MIX DESIGN

- i) Mix proportions for the designated Classes of concrete to be used in the work shall be determined by trial mix design from strength tests on 15 cm cube samples and shall be related to the nominal cube compressive strength at 28th day in accordance with IS: 456 and, maximum aggregate size.

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- ii) The water/cement ratio shall be kept to a minimum and not exceed 0.55 unless approved by the Project Manager.
- iii) The following table shows, in general, the anticipated Classes of concrete required in various sections of the Work. The specific class of concrete to be used in each area will be shown on the Construction Drawings or specified by the Project Manager:

Concrete Designation	Class of concrete	Max. size of aggregate mm	Nominal OPC content kg/m ³	Max. slump mm	28-day strength N/mm ²	Location
M25-20	M25	20	400	100	25	Block-out concrete for equipment embedding
M20-20	M20	20	310	80	20	Powerhouse superstructure, Lining for tunnels
M20-40	M20	40	310	80	20	Around galleries, sluices, elevator shaft and adits in dam, Tunnel intake structure, lining for tunnels, Powerhouse substructure, Spillway (ogee)
M20-75	M20	75	310	80	20	Upstream face of dam, spillway crest, glacis, bucket, pier, training wall
M15-40	M15	40	270	80	15	Foundation of dam & bucket
M15-150	M15	150	270	80	15	Mass concrete in dam
M10-40	M10	40	150	80	10	Backfill concrete

- iv) At least 4 months prior to commencement of permanent concrete work, trial mixes shall be prepared by the Contractor for each class of concrete listed above. The trial mixes shall be prepared with the batching and mixing plant to be used for the work and using cement and aggregates, etc., which have

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been approved by Project Manager. The ordinary Portland cement content listed in the table above is to be used for the preliminary testing of trial mix as per IS: 516. The actual cement content shall depend on the result of these tests and further tests as the work progresses. The Contractor cannot receive any extra payment should the required cement content be greater than that as listed.

6.6 QUALITY CONTROL AND TESTING

6.6.1 GENERAL

- i) Immediately after the Aggregate Processing Plant and Batching and Mixing Plants are established by the Contractor but at least 2 months prior to the Contractor's programme to commence any concreting of permanent works, the Contractor shall start the testing of materials, propose the composition of concrete mixes and prepare trial mix of each of the proposed concrete class. The contractor will prepare the trial mixes using the cement, water, aggregates and admixtures intended for the work. Such material shall conform to the requirements specified in this chapter and Indian Standards.
- ii) This preliminary test programme will include the determination of the following parameters:
 - a) Characteristics of aggregates,
 - b) Mix water properties,
 - c) Admixture properties,
 - d) Proportion of aggregate ranges in the mix,
 - e) Proportion of uncrushed to crushed aggregates,
 - f) Cement dosage,
 - g) Water-Cement ratio (W/C),
 - h) Workability of concrete mixes,
 - i) Compressive and tensile strength,
 - j) Density,

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- k) Water tightness.
- iii) These tests will be carried out until the concrete mixes show appropriate strength, workability, density, and water tightness without the use of excessive cement.
- iv) IS: 10262 shall be followed as general guidance for mix design.
- a) Preliminary tests/trial mix, as specified or as required by the Project Manager, shall be carried out sufficiently ahead of the actual commencement of the work with different grades of concrete made from representative samples of aggregates and cement expected to be used on the works. These tests are to be conducted to arrive at the grading of aggregates, water-cement ratio, workability and the quantity of cement required to give Preliminary (target) compressive strengths as specified in the table:

Grade/ Designation of concrete	Compressive strength of a 15 cm cube at 28 days (N/ mm ²)	
	Preliminary test strength (target strength of trial mix)	Characteristic strength of works cubes
M15	19	15
M20	26	20
M25	32	25
M30	38	30

- b) At least three trial mixes are to be made and a minimum of nine test cubes taken for each trial mix noting the slump for each type of mix. The cubes shall then be properly cured. One cube shall be tested at 3 days, 14 days, and 21 days, and three cubes for each mix shall be tested at 7 days and 28 days for obtaining the compressive strength. The test reports shall be submitted to the Project Manager. The design mix particulars shall indicate, with the help of graphs and curves etc. the extent of variation in the grading of aggregates, which can be allowed. While designing mixes, over wet mixes shall be avoided,

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- c) The Contractor shall submit the test reports of mix design to the Project Manager for his view, indicating design criteria, analysis and proportioning of materials, etc. On the basis of the above test reports, a mix proportion by mass and the water-cement ratio, shall be determined by the Project Manager such that concrete prepared with this mix will yield the desired characteristic strength and shall have suitable workability. The proportions, once decided for different grades of concrete, shall be adhered to, during all concreting operations as long as the quality of the materials does not change. If, however, at any time, the quality of materials being used has changed either in the required strength of concrete, or water-cement ratio or workability, the Contractor shall have to make similar trial mixes and Preliminary tests to ascertain the revised mix proportions and water-cement ratio to be used for obtaining the desired strength and consistency.
- v) The mixes for different grades of concrete will be selected by the Project Manager and conveyed to the Contractor.
- vi) During the progress of the work, the mixes may be changed whenever, in the opinion of the Project Manager, such change is necessary or desirable to obtain the required strength, workability, water tightness, density, economy, or to limit shrinkage.
- vii) Employer will render necessary help to the contractor in conduction of various tests, as mentioned above along with preparation of mix design. Employer will charge necessary amount from the Contractor as cost for conduction of tests, which are done by Employer. The Project Manager's decision in this regard will be final & binding to the Contractor.

6.6.2 ADMIXTURES

- i) Admixtures to be used will be tested for their suitability with the cement and materials to be used on the works and under proposed construction conditions.

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- ii) Admixtures will be sampled and tested as set out in IS: 9103.

6.6.3 CONCRETE

- i) Concrete test cubes shall be prepared, and cured in accordance with IS: 456. Nine test cubes shall be made from the each mix proposed for the different classes of concrete. One cube each for compressive strength of concrete will be tested at 3, 14 and 21 days and three cubes at 7 and 28 days. Note that the 3rd day, 14th day, and 21 day test are important to determine the influence of time on the strength of concrete.
- ii) The consistency of the proposed mixes will be tested by means of slump test. Specimen for slump tests will be taken from each batch of concrete used to make the test cubes.
- iii) Air content will be determined in accordance with IS: 9103.


6.6.4 TESTS DURING EXECUTION OF WORKS

- i) Samples from the concrete being used for the Permanent Works, shall be taken either at the batching and mixing plant or the placing point, and shall be cured and tested.
- ii) In addition to the 28 days strength tests, the Project Manager, may require, ninety-days strength test and also at other ages.
- iii) Concrete for test specimens for compressive strengths will be collected at random as it comes out of the mixer or at placing point once every shift or more often as the Project Manager may require, and in quantity sufficient to prepare necessary number of test pieces from each sample, and at least at every 120 m³ produced or 400 m² of wall or slab surface placed. In calculating surface area, only one side of the slab or the wall should be considered. The concrete so collected shall be a representative sample.

6.6.5 MEASURING AND TOLERANCES

- i) Water, cement, admixtures, fine aggregate and coarse aggregate shall be weighed separately and not cumulatively. The accuracy of the measuring

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devices shall be maintained so that the indicated measure does not vary by more than 1 percent from true measure throughout their range of use. The devices shall be capable of being operated to control the delivery of materials so that the combined inaccuracies in feeding and measuring do not exceed the following limits:

Material	Percent (by weight)
Cement	2
Water	1.5
Aggregates	3
Admixture	1

- ii) At the batch plant, standard certified test weights shall be provided and such other auxiliary equipment as may be necessary to check the operating performance of each scale or other measuring device. Unless otherwise directed by Project Manager, check tests of equipment used for measuring water, cement and admixtures shall be made at least once in every 2 weeks and of equipment used for measuring fine and coarse aggregates at least once in every month. After completion of each check test, operator shall report the results to Project Manager and make such adjustment, repairs, or replacement as Project Manager deems necessary to secure satisfactory performance before further use of the measuring devices shall be allowed.

6.6.6 ACCEPTANCE CRITERIA FOR CONCRETE


For concrete to be accepted for in-situ concreting works it must satisfy all the relevant acceptance criterion of IS: 456 (Latest edition), as interpreted by the Project Manager. Any Concrete not satisfying the criterion shall be made good at no extra cost to Employer.

6.7 BATCHING AND MIXING

6.7.1 BATCHING AND MIXING EQUIPMENT

- i) All aggregates shall be batched by weight.

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- ii) The Batching and Mixing Plant shall be of the requisite capacity to maintain the required progress on different items of work.
- iii) The Plant shall be capable of determining accurately, by direct weighing, the prescribed amount of the various ingredients including water, cement, admixtures and Pozzolana etc., and each individual size of aggregate entering the concrete and combining them to give a uniform mix within the prescribed time and discharging the mix without segregation.

6.7.2 MIXING


- i) All concrete shall be thoroughly mixed in the Batching and Mixing Plant of an approved type, size and design so as to positively ensure uniform distribution of the components throughout the mass during the mixing operations.
- ii) Mixing shall be continued until there is a uniform distribution of the materials and the mass is uniform in colour and consistency. If there is segregation after unloading from the mixer, the concrete shall be remixed.
- iii) Separation of coarse aggregate from mortar shall be avoided by proper arrangement of the discharge so that the concrete falls vertically and not diagonally into whatever container is to receive it.
- iv) Should the last fraction of the batch contain an excessive amount of coarse aggregate, this portion shall be retained and mixed with the succeeding batch.
- v) Discharge pipes of all water batches shall be of such a size and so arranged that the flow into the mixer is completed within the first 25% of the mixing time and delivered well inside the mixer where it is mixed quickly with the entire batch.
- vi) On no account shall any addition be made to any component of a concrete batch once that batch has been mixed and discharged from the mixer, whether for the purpose of retempering or any other reason, without the prior approval of the Project Manager.

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- vii) The mixers shall not be charged in a manner that some water will enter in advance of cement and aggregate and all materials shall continue to flow in as rapidly as possible. The construction of the mixers shall prevent loss of materials during charging.
- viii) The mixers shall not be charged beyond their rated capacities and the entire contents of the mixer shall be discharged before recharging.
- ix) Unless otherwise authorized by Project Manager for mixers of 1 m³ capacity or less, the mixing of each batching shall continue for 1.5 to 2 minutes after all materials, except the full amount of water, are in the mixer. For mixers of larger capacity, the minimum mixing time will be increased by 15 seconds for each additional 0.5 m³.
- x) The mixing time shall be increased when, in the opinion of Project Manager the charging and mixing operations fail to result in the required uniformity of composition and consistency within the batch and from batch to batch.
- xi) Mixers shall be rotated at the rate recommended by the manufacturer of the mixer.
- xii) The arrangement for controlling, measuring and mixing operations shall be such that the operator, or an assistant in communication with the operator, may observe the concrete discharging from the mixer.
- xiii) Each mixer shall be cleaned after each period of continuous operation and shall be maintained in such a condition that the mixing action will not be impaired.
- xiv) Where the distance between the batching plant and a concrete pour is such as would in the opinion of Project Manager cause deterioration of mixed concrete in transit, dry batching may be permitted using transit mix trucks in accordance with IS: 457. Water shall be added not later than 30 minutes after batching.
- xv) On no account shall any addition be made to any component of a concrete batch once that batch has been mixed and discharged from the mixer, whether for the purpose of re-tempering or for any other reason, without the prior approval of Project Manager.

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- xvi) The decision of the mode of mixing i.e. by concrete mixers or batching plant shall finally be made by the Project Manager.

6.8 HOT AND COLD WEATHER CONCRETING

- i) When deposited in the forms, concrete shall have a temperature of not more than the maximum values as determined by concrete cooling studies, and appropriate measures as approved by the Project Manager shall be taken to attain this requirement. Concrete operations shall be temporarily suspended during excessively hot weather when the ambient temperature exceeds 35°C. or when conditions are such that the concrete cannot be placed at the required temperature. Wherever necessary, exposed surfaces of fresh or green concrete shall be adequately shaded from the direct rays of the sun and protected against premature drying by curing under continuous fine spray of water. In case the concreted surface gets washed, the damaged portion shall be removed before the next lift is placed.
- ii) Every effort shall be made to minimize the temperature of concrete during manufacture, placement and curing.
- iii) Any or all of the following means and any other method as deemed fit by the Project Manager shall be adopted, to produce concrete of minimum temperature.
- a) Protect all freshly placed concrete and forms from exposure to direct sunlight,
 - b) Use of Ice for pre-cooling of Water,
 - c) Employ continuous moist curing as soon as possible,
 - d) Moisten forms and reinforcement with water,
 - e) Pre-Cooling of aggregate piles,
 - f) Keep mixing time and time required to convey to point of placement to a minimum,
 - g) Shade batching, mixing and conveying equipment. Paint pipes, storage bins and tanks white,

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- h) Use spray nozzles that create fogging of the area to be concreted so that a mist forms over the mass concrete,
- i) Any other suitable measure as directed but the Project Manager.

6.9 CONVEYING

- i) Concrete shall be conveyed from mixer to forms as rapidly as practicable by methods, which shall prevent segregation and/or loss of ingredients. In case such separation occurs, concrete shall be remixed before being laid in place.
- ii) The distance between the mixer and the place of concreting as also the mode of transport of concrete shall be subject to the prior approval of the Project Manager.
- iii) Concrete shall be deposited in the final position as early as practicable but always before initial set of the concrete starts (this occurs after a period of at least 45 minutes but usually before 60 minutes after mixing unless retarders are used). Hence, using a small safety margin, the limit for depositing concrete shall be 45 minutes unless tests indicate that the Project Manager can relax this limit. The limit may be modified by the Project Manager to suit working or weather conditions such as temperature, humidity, and wind.
- iv) Plant, such as buckets, cars, conveyors, and pumping equipment, which may be used for conveying concrete shall be of such size, design and condition as to ensure an even and adequate supply of concrete at the placement area.
- v) Particular attention shall be paid to prevent segregation at the ends of chutes, at hopper gates and at all other points of discharge.
- vi) Methods of conveying concrete to any part of the structure wherein the concrete is loaded into chutes, belt conveyor or other similar equipment and carried in a thin continuously exposed flow to the forms shall not be permitted except for very limited or isolated sections of the work, and only when approved in writing by the Project Manager.

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- vii) Where chutes are used, they shall be so constructed and arranged as to permit continuous flow of the concrete without separation of the ingredients. Chutes shall not have a slope steeper than 2 H : 1 V.
- viii) There shall be no vertical drop greater than 1.5 m except where equipment satisfactory to the Project Manager is used to confine and control the falling concrete.
- ix) Concrete may be dropped through flexible elephant-trunk chutes, provided some method is used at the lower end to retard the speed of the falling concrete and prevent it from segregating.
- x) Buckets for transporting concrete shall be manufactured as low-slump concrete buckets.
- xi) The conveying plant shall be kept free from hardened concrete and foreign materials and shall be cleaned at frequent intervals.
- xii) All conveying plant shall be supported independently of the forms, except as specifically permitted by the Project Manager.

6.10 PLACING

6.10.1 GENERAL


- i) No mortar or concrete shall be placed except in the presence of the Project Manager.
- ii) Concrete shall be placed only in locations where authorised and no concrete or mortar shall be placed until formwork, installation of reinforcing steel, steel ribs, piping and other embedded parts, preparation of surface and necessary clean up have been done and checked and certified by the Project Manager, as being in conformity with specifications and drawings.
- iii) Concrete placed without prior knowledge and approval of the Project Manager, may be required to be removed and replaced.
- iv) Earth foundations on which concrete is to be laid shall be firm dry soil, free from any soft mud or other objectionable material.

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- v) Whenever concrete is to be placed on earth, a layer of lean concrete shall first be placed before placing concrete of the specified grade. The thickness of such layer of lean concrete shall be as shown on the drawings or as directed by the Project Manager.
- vi) No concrete shall be placed in running water. Water shall, generally, not be allowed to flow over freshly poured concrete until final set has been achieved.
- vii) Immediately, before placing concrete, all such surfaces upon which concrete is to be placed shall be thoroughly cleaned by the use of high velocity air and water jets or sand blasting, steel brooms, picks or other effective means, satisfactory to the Project Manager.
- viii) Any pool of water from the surface on which concrete is to be placed shall be cleaned to ensure proper bonding of fresh concrete with the rock surface or previously poured concrete surface. The method of disposal of water at the work site shall be subject to the approval of the Project Manager.
- ix) Sufficient mixing and placing capacity shall be provided so that the work may be kept active and free from cold joints. Formed concrete shall be placed in horizontal layers, avoiding inclined layers and construction joints.
- x) To get a monolithic placement, it is important that each layer be shallow enough so that the previous layer is still soft and the two layers are vibrated together.
- xi) Concrete shall not be allowed or caused to flow horizontally or on slopes in the forms.
- xii) Concrete placing on slope shall begin at the lower end of the slope and progress upward, thereby increasing compaction of concrete.
- xiii) In pneumatic placement of concrete, usual high velocity discharge shall be reduced to a point where no separation and scattering of the concrete occurs.
- xiv) In order to reduce bleeding, slump shall not be more than necessary to achieve proper placement and consolidation.

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- xv) All care shall be taken to avoid separation of coarse aggregate from the concrete. Obvious groups and clusters of separated coarse aggregates shall not be permitted. They shall be removed before the concrete is placed over them, otherwise they may cause serious imperfections in the finished work. Hence particular attention shall be paid to the tendency for objectionable separation to occur at the points of discharge so that uniformity and homogeneity of concrete in placement and good workmanship is assured.
- xvi) The concrete shall drop vertically into the centre of whatever container receives it. To protect the rods, spacers, and embedded features from damage and to prevent displacement of reinforcement, concrete falling in forms shall be confined in a suitable drop chute.

6.10.2 PREPARATION FOR PLACING OF CONCRETE

- i) All surfaces on which or against which concrete is to be placed, including surfaces of construction joints between successive concrete placement, reinforcing steel and embedded parts, shall be thoroughly cleaned of dirt, mud, debris, grease, oil, dried mortar or grout, laitance, loose particles or other deleterious matter.
- ii) Surface seepage and other water shall be so controlled, to the satisfaction of the Project Manager, that at no time during the placement or hardening of the concrete will it wash, mix with, or seep into the concrete.
- iii) Wind barriers shall be erected, should wind cause a too rapid evaporation of water at the concrete surface. When curing of concrete is done with water using continuous sprinkling or hoses with holes and the rate of water evaporation losses could exceed 1.0 kg/m²/hr wind barriers should be erected. If it is not possible to measure evaporation losses (as per Figure 1 of ACI 308-92) and no special curing cover is used; then wind barriers should be placed, if practicable, when wind velocity are expected to exceed 15 km/hr. Otherwise heavy moist burlaps or similar curing covers should be used. The Contractor shall submit his wind barrier scheme to the Project Manager for approval.


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6.10.3 CONCRETE PLACEMENT

- i) The method and equipment used for placing concrete shall be such that it will permit the delivery of concrete of the required consistency into the Work without objectionable delay, segregation, porosity or loss of workability.
- ii) All surfaces of forms and metal work, including reinforcement bars, that have become encrusted with dried mortar or grout from concrete previously placed, shall be cleaned of all such matter before the surrounding or adjacent concrete is placed.
- iii) Concrete shall be placed in lifts as shown on the drawings or as directed by the Project Manager.
- iv) In reinforced concrete works, which have congested parts, care shall be taken to see that all the bars are properly embedded and that no voids are left. On flat, horizontal surfaces, where a congestion of steel near the forms makes placing difficult, a mortar of the same cement sand ratio as is used in the concrete shall be first deposited to cover the forms.
- v) No concrete shall be placed in running water or during rain, high winds, dust storms, excessive heat or cold and similar conditions without prior approval of the Project Manager.
- vi) In all cases, concrete shall be deposited as nearly as practicable directly in its final position.
- vii) The maximum time interval between placing successive layers within a lift shall not exceed 30 minutes. However, depending upon job requirements and climatic conditions, the Project Manager can allow an increase of this time interval using appropriate methods of vibration/agitation or the use of retardants.
- viii) Concrete shall not be piled up in the forms in a manner that causes movement of the unconsolidated concrete, or permits mortar to escape from the coarse aggregate.

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6.10.4 RATE OF PLACING OF CONCRETE


- i) Concreting shall be done as a continuous operation until the structure or section is completed or until a satisfactory construction joint can be made. The Contractor shall make all arrangements necessary to maintain continuity of concrete placing in any particular pour during meal periods, shift changes, or any other such interruptions.
- ii) Concrete shall not be placed faster than the placing crew can compact it properly.
- iii) In placing thin members and columns, precaution shall be taken against a too rapid placement, which may result in movement or failure of the form due to excessive lateral pressure. An interval of at least 24 hours, unless otherwise approved or directed by the Project Manager, shall elapse between the completion of columns and walls and the placing of slabs, beams or girders supported by them.
- iv) The rate of placing shall be such as to have no objectionable effect on placement of concrete, particularly near the forms and in and around embedded equipment where the rate shall not exceed the limit placed by the Project Manager.


6.10.5 CONSOLIDATION OF CONCRETE

- i) Consolidation of newly placed concrete shall ordinarily be done with internal vibrator of an approved design. The equipment for vibration shall have adequate power and shall be of high frequency, rugged and reliable.
- ii) Operators of vibrators shall be experienced and competent in handling these devices.
- iii) Ample stand-by-units and parts, as well as, systematic servicing shall be provided.
- iv) Vibrators shall not be used to cause concrete to move more than a short distance laterally, otherwise fine wet material may run ahead and separate from the coarse aggregate.

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<div> <div>v)</div> <div>Inadvertent or unintended re-vibration of concrete may be beneficial provided the concrete become momentarily plastic again during re-vibration. Re-vibration shall be resorted to only after specific instructions are given by the Project Manager.</div> </div> <div> <div>vi)</div> <div>Where vibration is used to full advantage for consolidation of newly placed concrete, no supplementary rodding or other working of the concrete is necessary.</div> </div> <div> <div>vii)</div> <div>Concrete shall be compacted and worked into all corners and angles of forms, obstructions, block-outs, locations with congested reinforcement, and around embedded items. Special care shall be taken to attend to these places with ample, properly applied additional vibration or rodding as the case may be, without permitting the concrete materials to segregate.</div> </div> <div> <div>viii)</div> <div>External, i.e. form vibrators of an approved type shall be used only in inaccessible locations and where it is impracticable to use immersion type vibrators; and only after their use has been specifically authorised by the Project Manager. The form vibrators shall be designed to receive vibrations without losing shape and causing leakage of mortar.</div> </div> <div> <div>ix)</div> <div>The immersion type mechanical vibrators, complying with IS: 2505, electric, air driven or diesel, shall generally be inserted vertically and the vibrating head shall be allowed to penetrate under the action of its own weight. In very shallow concrete, some consolidation can be obtained by using vibrators in horizontal position.</div> </div> <div> <div>x)</div> <div>Internal vibrators, when used, shall be inserted at regular intervals and vibration, with the vibrator fully into the layer being compacted, shall be continued until an acceptable degree of compaction has been achieved, and by taking care to avoid excessive vibration which may result in the top containing excessive paste and laitance.</div> </div> <div> <div>xi)</div> <div>The entire depth of a new layer of concrete shall be vibrated and ordinarily the vibrators should penetrate the layer below (which has not yet become rigid) for approximately 10 cm to ensure thorough bond between the layers.</div> </div>		
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<div> <div> xii) Under ordinary job conditions, there is little likelihood of damage from direct re-vibration of lower layer as long as the lower layer is still plastic and not reached its final set. Vibrators shall not, however, be inserted into lower courses that have commenced final set nor shall they be directly applied to or allowed to disturb reinforcement extending into hardened or partially hardened concrete. Vibration shall not be transmitted by means of the embedded steel. </div> <div> xiii) Systematic spacing of points of vibrators shall be established to ensure that no portions of the concrete are missed. It shall be ensured that zones of influence overlap and the concrete is properly consolidated. </div> <div> xiv) In compacting the surface of a concrete lift, the coarser particles of the aggregate in the surface shall be embedded while the concrete is being vibrated, but the surface left with the desired degree of roughness. </div> <div> xv) Disturbance of the surface concrete at construction joints during early stage of hardening shall be avoided. Necessary traffic on new concrete shall be on timber walkways constructed so as not to cause injury to the concrete. </div> <div> xvi) When smooth surfaces are required, for all surfaces that shall be permanently exposed to the weather and for all surfaces next to embedded metal work around which it is desired to prevent leakage, the adjacent concrete shall be properly vibrated, spaded or tamped. </div> <div> xvii) To ensure even and dense surfaces which are free from aggregate pockets, honey combing, or air holes, it may be necessary to supplement internal vibration with hand spading or tamping all along the boundaries of the concrete and around embedded parts, while the concrete is plastic under vibrating action. </div> <div> xviii) Equipment and methods for the production, transportation placing, consolidating, curing and finishing of concrete shall be subject to acceptance by Project Manager. </div> <div> xix) Specifications for placing, measurement and payment of shotcrete are covered separately under heading "Shotcrete". </div> </div>		
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6.10.6 CONCRETE IN R.C.C. FRAMES/WALLS/SLABS

- i) Concrete shall be placed in lifts of heights as shown on the drawings or as directed by the Project Manager. Within each lift, concrete shall be deposited in approximately horizontal layers about 40 cm to 45 cm thickness unless otherwise directed by the Project Manager.
- ii) At locations where lift heights are not shown on the drawings, the Contractor shall submit to the Project Manager for approval, details of the placing procedure he proposes. No concrete shall be placed at such locations without the prior approval of the Project Manager.
- iii) Slabs shall be placed in one lift unless otherwise indicated or directed by the Project Manager. Beams, girders, drop panels and haunches shall be poured preferably at the same time as the slabs.
- iv) In walls, lifts shall terminate at such levels as will conform to the structural requirements.
- v) The placement of concrete shall be carried out at such a rate and in such a manner that the formation of cold joints is prevented.
- vi) Where slabs and beams are placed continuously with walls and columns, the concrete in walls and columns shall have been in place for at least 2 hours or for as long as that it takes for the already placed concrete to be fully set (i.e. no longer plastic), or for a longer period when so directed by the Project Manager before placing concrete in the slabs and beams.

6.10.7 CONCRETE DEPOSITED IN WATER

- i) Concrete shall be deposited in water only with the prior approval of the Project Manager.
- ii) Concrete placed underwater shall be deposited by a tremie or by a valved tremie.
- iii) The methods and equipment used shall be subject to the prior approval of the Project Manager.

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- iv) Concrete buckets shall not be permitted for underwater placement of concrete.
- v) The tremie seal shall be done in a manner that will not produce undue turbulence in the water around the pipe. The discharge end shall be kept submerged continuously in the concrete and the concrete pumped in without interruption until the concrete has been brought to the required height.
- vi) The tremie shall not be moved horizontally during a placing operation and a sufficient number of tremies shall be provided so that concrete does not have to flow horizontally, a distance of more than 3 metres.

6.10.8 CHIPPING AND ROUGHENING OF CONCRETE SURFACES


- i) Surface upon or against which additional concrete is to be placed shall be chipped and roughened to a depth of not greater than 40% of the maximum aggregate size nor greater than 25 mm, whichever is smaller.
- ii) The roughening shall be performed by chipping, sand blasting or other satisfactory methods and in such manner as not to loosen, crack or shatter any part of the concrete beyond the roughened surface.
- iii) After being roughened, the surface of the concrete shall be cleaned thoroughly of the loose fragments, dirt and other objectionable substances and shall be sound and hard and in such condition as to assure good mechanical bond between old and new concrete.
- iv) Concrete that is not hard, dense and durable shall be removed to the depth required to secure a satisfactory surface.

6.11 FINISHING OF CONCRETE

6.11.1 FINISHING OF FORMED SURFACES

- i) Except as otherwise specified or directed, all permanently exposed concrete surfaces and other waterway surfaces requiring durability shall be finished in the following manner:

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- ii) Any damage to finished concrete resulting from the action of removing formwork or from any other cause shall be repaired to the satisfaction of the Project Manager. Immediately on removal of the form, the surface shall be examined and all porous honeycombed or defective concrete removed and repaired as specified herein.
- iii) All imperfections or ridges due to joints in the formwork, shall be removed by light chipping or grinding down if necessary, to produce a smooth surface.
- iv) When the treatment of a surface has been completed, the surface shall be cured.
- v) All patches and mortar filled pits on exposed surfaces shall be neat and have the same colour and texture as the adjoining concrete.
- vi) The finished surfaces of concrete shall be true, sound, smooth and free from fins, offsets, pits, depressions, voids, blemishes and other defective concrete and surface irregularities and shall be in accordance with the requirements for the particular class of finish specified herein or as shown on the drawings.
- vii) Finishing work shall be done only by skilled workman in the presence of the Project Manager or his mandated representative and shall be performed as soon as possible and within one day after formwork removal.
- viii) Before final acceptance of the Work, Contractor shall clean all exposed concrete surfaces of all encrustations of cement, mortar or grout, to the satisfaction of the Project Manager. Concrete shall not be considered finished until all required repair work and finishing have been completed.

6.11.2 FINISHING OF UNFORMED SURFACES

- i) Unformed surfaces shall be finished by one or more methods of screeding, floating and trowelling and working of the surfaces shall be done at the proper time, employing experienced men and shall be just sufficient to produce the desired finish.
- ii) Screeding:

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<div> <div>a)</div> <div>It gives the surface its approximate shape by striking off surplus concrete immediately after completion and shall be accomplished by moving a straight edge or template with a swing motion across wood or metal strips that have been established as guides,</div> </div> <div> <div>b)</div> <div>Where the surface is curved, a special screed shall be used.</div> </div> <div> <div>iii)</div> <div> <div>Floating:</div> <div> <p>Shortly after the concrete is screeded, the surfaces shall be brought true to form and grade by working it sparingly with a wooden float. If a coarse textured finish is specified or if the surface is to be steel trowelled, a second or final floating shall be performed after some stiffening has occurred and the surface moisture film or shine has disappeared.</p> </div> </div> </div> <div> <div>iv)</div> <div> <div>Trowelling:</div> <div> <div>a)</div> <div> <p>If a smooth dense finish is desired, floating shall be followed by steel trowelling some time after the moisture film or shine has disappeared from the floated surfaces and when the concrete has hardened sufficiently to prevent fine material and water from being brought up to the surface. Excessive trowelling at an early stage as would tend to produce cracking or result in a surface that is too hard to finish properly shall be avoided,</p> </div> </div> <div> <div>b)</div> <div> <p>Trowelling shall, therefore, be done at the appropriate time and shall have the surface smooth, even and free of trowel marks and ripples. A fine textured surface that is not slick shall be obtained by trowelling lightly over the surface with a circular motion keeping the trowel flat on the surface of the concrete. Where a hard steel trowelled finish is required, trowelling shall be continued until it no longer produces noticeable compaction and the surface has a glossy appearance, trowelling pressure being increased gradually as the operation progresses.</p> </div> </div> </div> </div> <div> <div>v)</div> <div>The use of any finishing tool in areas where water has accumulated shall be prohibited. Operation on such areas shall be delayed until the water has</div> </div>		
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been absorbed or has evaporated or has been removed by draining, mopping or other means.


- vi) All joints and edges on unformed surfaces, that shall be exposed to view, shall be finished with suitable moulding tools with rounded, bevelled or filleted edge, as directed by the Project Manager. Unless the use of other slopes or level surface is indicated on the drawings as directed, narrow surfaces such as top of walls or tunnel portals shall sloped approximately 9 mm per 300 mm of width. Broader surfaces as walls, roadways, platforms and decks shall be sloped approximately 6 mm per 300 mm.
- vii) Where separate concrete finish for floors or for 2nd stage concreting in gate grooves is specified or directed, the concrete shall be struck off sufficiently below grade to allow for the subsequent placing concrete. The surface of such concrete shall be left rough, by applying air jet or any other means as specified by the Project Manager.
- viii) As soon as the condition of the base permits and before it has hardened fully, all dirt, laitance and loose aggregate shall be removed from the surface, by means of water jets and wire brooms leaving the coarse aggregate slightly exposed and the surface made suitable for taking further concrete.

6.11.3 TOLERANCE FOR SURFACE FINISHES

- i) Surface finishes shall generally conform to the types and tolerances indicated in the table given below, unless otherwise specified on the drawings or as required by the Project Manager. The classes of finish are designated by F1, F2 and F3 for plane surface respectively by F1C, F2C and F3C for curved surface.
- ii) Positive tolerance shall be measured outside and negative inside the lines and grades defining the structure on the drawings.


Type of Finish	General Area of Application and method of Forming	Tolerance (mm)
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F1, F1C	Formed surfaces of construction joints and other surfaces that shall not be permanently exposed. The surface shall require no treatment after form removal, other than repair of defective concrete and specified curing, or treatment as specified for construction joints.	+ 10 - 10
F2, F2C	All permanently exposed formed surfaces for which type F3/F3C finish is not specified. Form sheathing or lining shall be placed so that joint marks on the concrete surface shall be in general alignment, both horizontally and vertically and conform to a standard pattern. Immediately on the removal of forms, all unsightly ridges of fines shall be removed; all holes left by removal of ends of form rods shall be neatly filled with mortar and surfaces treated to meet the required tolerances by tooling and rubbing.	+ 5 - 5
F3, F3C	Formed surfaces which shall be exposed to flowing water shall be hard, smooth and dense, free from offsets, pits, voids, air holes and irregularities, and shall be chipped, ground and thoroughly cleaned as necessary to conform to the required tolerances.	+ 5 - 5
U1	Unformed, screeded surfaces that shall be covered by fill materials, static water or concrete. Type U1 finish shall be used as the first stage of type U2 and U3 finishes. Finishing shall consist of sufficient levelling then screeded to produce an even, uniform surface meeting the required tolerances.	+ 10 - 5
U2	Unformed surfaces not permanently concealed by fill or concrete or not required to receive type U3 finish. (Type U2 finish shall be used as the second stage of Type U3 finish). Floating by means of hand or power driven equipment shall be started as soon as the screeded surface has stiffened sufficiently and shall be the minimum necessary to produce a surface that is free from screed marks and uniform in texture. If type U3 finish is to be applied, floating shall be continued until a small amount of mortar without excess water is brought to the surface so as to permit effective trowelling.	+5 -5
U3	Unformed, screeded surfaces that shall be exposed to flowing water. This finish shall be applied by steel trowelling after the concrete has hardened enough to prevent excess of fine materials and water from being brought to the surface free from blemishes, ripples and trowel marks. After the surface has nearly hardened, it shall be trowelled once more until the surface is hard and glossy in appearance.	+3 -3

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6.12 TOLERANCE FOR CONCRETE CONSTRUCTION

6.12.1 GENERAL

- i) Permissible surface irregularities for various classes of concrete surface finish as specified above are to be distinguished from tolerances as described herein.
- ii) Deviations from the established lines, grades and dimensions will be permitted to the extent set forth herein. OWNER reserves the right to diminish the tolerances set forth herein if such tolerances impair the structural action or operational function of a structure or portion thereof. Where specific tolerances are not stated in these specifications, or if not shown on the drawings for a structure or portion of a structure, permissible deviations will be interpreted as conforming to the tolerances stated in this Chapter.
- iii) The Contractor shall be responsible for setting and maintaining concrete forms within the tolerance limits necessary to ensure that the completed work will be within the tolerances specified. Concrete work that exceeds the tolerance limits specified in these specifications or shown on the drawings shall be remedied or removed and replaced at the contractor's expense.


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6.12.2 TOLERANCES FOR CONCRETE STRUCTURES

a) Departure from established alignment	- 25 mm, + 10 mm
b) Departure from established grade	- 25mm, + 10 mm
c) Variation from plumb from the specified batter for lines and surfaces of walls and for arises:	
Exposed in any length of 3.0m	±10 mm
Backfilled in any length of 3.0m	±20 mm
d) In any height < 30 m In any height ≥ 30 m	1:1000 but not exceeding ±25 mm 1:1000 but not exceeding ±75 mm
e) Variation from level or from grades indicated on the drawings for slabs: Exposed in any length of 3.0m Backfilled in any length of 3.0m In any length < 30 m In any length ≥ 30 m	±8 mm ±15 mm 1:1000 but not exceeding ±25 mm 1:1000 but not exceeding ±75 mm
f) Variation from plumb and level for sills and side walls for radial gates and similar watertight joints	3 mm in 3 m
g) Variation in cross-sectional dimensions of slabs, walls and similar parts of the structures.	- 5 mm, +10 mm
h) Tolerances for cast-in-place concrete tunnel lining, departure from established alignment or grade.	- 10mm, + 20 mm
i) Tolerance for placing reinforcing steel -	With member size < 60 mm, -5 mm With member size ≥ 60 mm, 10 mm
j) Variation from indicated bar spacing	± 25 mm, but number of bars per metre is maintained
k) Variation of protective cover	when member size is < 300 mm, -8 mm when member size is ≥ 300 mm, -8 mm

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6.12.3 DEFECTIVE AND DAMAGED CONCRETE


Concrete which is damaged from any cause and which is not manufactured, placed and compacted in accordance with these specifications and is found to have lower strength, density etc. than specified, as determined from test samples or core samples, shall be removed and replaced by the Contractor. The Contractor shall seek the approval of the Project Manager for the method and timing of the removal.

6.13 CURING AND PROTECTION OF CONCRETE

6.13.1 CURING WITH WATER

- i) Plant and materials required for curing and protection of concrete shall be available at the location of each concrete placement before concrete placement is started and the water used for curing shall meet the requirements set out as specified in this specifications.
- ii) All concrete shall be protected against damage until final acceptance.
- iii) Exposed finished surfaces of concrete shall be protected from the direct rays of the sun for at least 72 hours after placement.
- iv) Fresh exposed concrete shall also be protected from the action of the rains, flowing water and mechanical injury.
- v) Curing water temperature shall not exceed 25°C or above the expected average ambient temperature (in the shade) of the 28-day curing period. Note that curing water should not be much cooler than the concrete; otherwise it may cause cracking from thermal stresses. Average anticipated ambient temperature (in the shade) shall be based on climatic records and forecasts approved by the Project Manager.
- vi) No fire shall be permitted in direct contact with concrete at any time.
- vii) Concrete in which Portland cement is used shall be kept continuously wet for not less than 14 days, for normal concrete and 21 days for concrete containing Pozzolana or fly ash, by covering with water saturated materials such as jute bags wet burlaps, or a system of perforated pipes, mechanical

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sprinklers or porous hole or by any other approved method. Curing period where special cement may be used shall be specified by the Project Manager.


- viii) Construction joints shall be cured in the same manner as the other concrete and shall also, if practicable, be kept moist until the placing of additional concrete upon the joint or for at least for 72 hours.
- ix) Horizontal surfaces shall be cured preferably by the use of wet quilts or mats and/or by sprinkling water or by covering with damp sand all of which shall have a satisfactory supply of the required curing water. If damp sand or quilt is used for curing, it shall later be completely removed. The time of applying damp sand shall be specified by the Project Manager before which curing shall be carried out by other approved methods.
- x) The method of keeping formed vertical concrete surface moist shall be by covering with a water saturated material and continuous sprinkling or spraying of water as may be necessary to prevent any portion of the surface from drying during the specified period.
- xi) The unformed top surface shall be moistened by covering with a water saturated material such as jute bags, or by other effective means as soon as the concrete has hardened sufficiently to prevent damage by water.
- xii) The water and other methods of curing shall be so handled as not to stain concrete surfaces, which shall be exposed.
- xiii) The actual method of curing adopted shall be subject to the approval of the Project Manager.

6.13.2 CURING WITH CURING COMPOUND

- i) In limited areas and for special purposes, the use of an approved and properly applied compound may be permitted at the discretion of the Project Manager to restrict the evaporation of the mixing water. Such curing compound shall be of the surface membrane type, which will thoroughly seal the surface. Curing compound shall not be used on joints where bonding is required.

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<div> <div>ii)</div> <div>Curing compounds shall be applied according to the manufacturer's recommendations to provide a continuous uniform sealant over all areas. Curing compounds shall be applied immediately after finishing operations are complete.</div> </div> <div> <div>iii)</div> <div>A curing compound shall not be used on any unformed surface where, in the opinion of the Project Manager, the irregularities in that surface would prevent the membrane from forming an effective seal, on any surface which has a temperature lower or higher than manufacturer's recommended application temperature, or any surface where a bond is required for additional concrete, or where a curing compound is placed on a surface where a bond is required, it shall be removed by sand blasting or by other means satisfactory to the Project Manager.</div> </div> <div> <div>iv)</div> <div>Surfaces that have received curing compounds shall be protected from damage at all times.</div> </div> <div> <div>v)</div> <div>Curing compounds may consist of a suitable white-segmented compound, which forms a water retaining sealant on the surface of concrete upon application. However, for concrete surfaces, which will be permanently exposed, to view a clear curing compound shall be required. Curing compound shall be applied to the concrete surfaces by spraying on one coat to provide a continuous uniform membrane over all area, with a maximum coverage per litre as prescribed by the manufacturer according to the roughness of the surface to be covered. Mortar encrustation's and fines on surfaces for which finish F3/F3C is specified shall be removed prior to application of curing compound. Curing compound shall be applied to all areas of concrete surfaces except that those parts with surface imperfections shall be omitted until repaired.</div> </div> <div> <div>vi)</div> <div>Curing compound shall be of approved quality. Unless otherwise mentioned by the specifications of the curing compound manufacturer, the concrete surfaces on which curing compound is proposed shall be moistened with light spray of water immediately after the forms are removed, and shall be kept moist until the surfaces do not absorb more moisture. As soon as the surface film of moisture disappears, but while the surface still has a damp</div> </div>		
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appearance, the curing compound shall be applied. There must be ample coverage with the compound at edges, corners and rough spot of formed surfaces. One shall avoid placing curing compound where small repair is required, otherwise special removal of the curing compound in these zones is required. After the application of curing compound has been completed and the coating is dry to the touch, any required repair of concrete surfaces shall be performed. Each repair after being finished shall be moistened and coated with curing compound in accordance with the aforementioned requirements.

6.13.3 PROTECTION OF CONCRETE

- i) Care shall be taken not to disturb the steel reinforcement projecting from any placement for at least 24 hours after the completion of such placement.
- ii) Finished concrete surface shall be protected from stains or abrasion and surface or edges likely to be injured during the construction period shall be kept properly protected by leaving forms in place or erecting protective covering satisfactory to the Project Manager.
- iii) In case, the curing operations are inadequate or unsatisfactory, the Project Manager shall be entitled to take such steps as he may deem necessary to make good the deficiencies and defects.
- iv) Traffic and other construction operations shall be such as to avoid damage to coatings of curing compound for a period of not less than 28 days after application of the curing compound. Where it is impossible because of construction operations to avoid traffic over surfaces coated with curing compound, the membrane shall be protected by a covering of wooden planks at least 25 mm thick or by other effective means. The protective covering shall not be placed until the sealing membrane is completely dry. Any sealing membrane that is damaged or the peels from concrete surfaces within 28 days after application shall be repaired without delay.

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6.14 REPAIR OF CONCRETE

6.14.1 GENERAL

- i) Repair of concrete shall be performed by skilled workmen and in the presence of the Project Manager.
- ii) No repair work shall be carried out until the Project Manager has inspected the location of the proposed repair and accepted the method of repair.
- iii) The Contractor shall correct all imperfections on the concrete surfaces as necessary to produce surface that shall conform to the required standards.
- iv) Stains and discolorations of exposed concrete surfaces shall be repaired. The procedure method shall be submitted by the Contractor and is subject to the approval of the Project Manager.
- v) All materials, procedures and operations used in the repair of concrete shall be subject to approval by the Project Manager.
- vi) Surfaces of concrete finished against forms shall be smooth and free from projections. Immediately upon the removal of forms and within 24 hours thereof, wherever practicable, all unsightly ridges or fins shall be removed and any local bulging on exposed surfaces shall be removed and remedied by tooling and rubbing. All holes left by the removal of fasteners and tie rods shall, after being reamed with a toothed reamer, be neatly filled with dry pack mortar.
- vii) All honeycombed, porous, fractured, or otherwise defective concrete and surface concrete in which, in the opinion of the Project Manager, additions are required to bring it to the prescribed lines, shall be removed by chipping concrete.
- viii) The chipped openings shall be sharp edged and keyed, and shall be filled to the required lines with fresh concrete or as found suitable. Where concrete is used for filling, the chipped openings shall be not less than 100mm in depth and the fresh concrete shall be reinforced and dowelled to the surface of the openings as directed by the Project Manager.

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<div> <div>ix)</div> <div>Dry pack mortar shall consist of one part of cement to two parts of sand by volume and just enough water so that the mortar as used sticks together on being moulded into a ball by slight pressure of the hands and does not free water when so pressed but leaves the hands damp. The mortar shall be fresh when placed and any mortar that is not used within 30 minutes, after preparation shall be wasted with all consequences to the Contractor.</div> </div> <div> <div>x)</div> <div>The mortar shall be placed in layers not more than 25 mm thickness after being compacted and each layer shall be thoroughly tamped to the satisfaction of the Project Manager. Each layer except the last shall be roughened thoroughly to provide effective bond with the succeeding layers. The last or finishing layer shall be smoothed to form a surface continuous with the surrounding concrete. Dry pack mortar shall be used for filling behind reinforcement or for filling holes that extend completely through a concrete section. Shotcrete shall be used for holes too wide for dry pack mortar filling and too shallow for concrete filling and no deeper than the far side of the reinforcement that is nearest to the surfaces.</div> </div> <div> <div>xi)</div> <div>All patches shall be bonded thoroughly to the surface of the chipped holes and shall be sound and free from shrinkage cracks and shoddy areas.</div> </div> <div> <div>xii)</div> <div>Concrete surfaces where high velocity flows may occur and as required by the Project Manager, repair to the surfaces having F3/F3C and U3 finishes shall be bonded with an epoxy adhesive acceptable to the Project Manager.</div> </div> <div> <div>xiii)</div> <div>All repairs to the surface of concrete for flowing water shall be ground smooth to meet the tolerances set out in these specifications.</div> </div> <div> <div>6.14.2</div> <div><u>PROCEDURE FOR REPLACEMENT OF CONCRETE, CURING OF REPAIRS ETC.</u></div> <div> <p>All procedures for replacement of concrete, mortar replacement, use of epoxies and curing of repairs shall be according to the provisions laid down in chapter VII Repair and Maintenance of concrete. Concrete Manual, the United States Bureau of Reclamation, Eighth edition revised in 1988.</p> </div> </div>		
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6.14.3 METHODS OF REPAIR

i) Dry pack method:

- a) This method should be used for holes having a depth nearly equal to or greater than the least surfaces dimensions of the repair area, or for cone bolt, she bolt and grout insert holes and narrow slots cut for the repair of cracks,
- b) Dry pack should not be used for relatively shallow depressions where lateral restraint cannot be obtained; for filling behind considerable lengths of exposed reinforcements, nor for filling holes which extend entirely through the wall, beam, etc.

ii) Concrete replacement method:

Concrete replacement should be used when holes extend entirely through the concrete sections; when holes in un-reinforced concrete have an area of more than 1000 cm² and are 100 cm or more in depth; and in holes in reinforced concrete that have an area of more than 500 cm², and the defects are deeper than the reinforcement steel.


iii) Mortar replacement method:

This method can be used for holes too wide to dry pack and too shallow for concrete replacement, and that have comparatively shallow depressions, large and small, which extend no deeper than the far side of the reinforcement bars that is nearest to the surface. Note large surface dimension will normally requires mortar gun, whereas for small surface dimensions mortar will be placed by hand.

iv) Epoxy method:

- a) A thermosetting plastic known as epoxy can be used as a bonding medium wherever long time curing of conventional concrete cannot be assured. Moreover, epoxy mortars of fine sand, as well as, plain epoxy are suitable for concrete repair work, and should be used whenever very thin patches are to be placed for immediate reuse of the area is required or where moisture curing cannot be effectively

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accomplished. Furthermore epoxies should be used to bond new concrete or mortar to old concrete whenever the depth of the defect is between 40 mm and 150 mm. Epoxies should also be used where the depth of the repair is less than 40 mm and has a perimeter with a very thin sharp edge (i.e. a featheredge),


- b) Epoxy repairs shall be carried out by trained personnel only.

6.14.4 PREPARATION OF CONCRETE FOR REPAIRS

- i) All concrete of questionable quality should be removed. Moistening, surface cleaning, removal of free surface water before applying the repair filler and complete curing are of utmost importance when making repairs that must be thoroughly bonded, water tight and permanent. Surface between trimmed holes should be kept continuously wet for several hours, preferably overnight prior to placing new concrete or mortar. Immediately before placement of the filler, the holes should be cleaned so as to leave a surface completely free of chipping dust, dried grout, and all other foreign materials. A preliminary washing, as soon as, the chipping and trimming are completed is desirable to remove loose materials.
- ii) Final cleaning of the surface to which the new filler is to be bonded should be done by wet sand blasting followed by washing with air-water jet for thorough cleaning and drying with an air jet. Care should be taken to remove any loose material embedded in the surface using chisels during the trimming and eliminating all shiny spots, which will indicate free surface moisture. Cleaning of the steel reinforcement, if necessary, should be accomplished by sand blasting or using a steel brush if the area is relatively small. The surface of old concrete should be kept moist for at least 24 hours. The period the old concrete must be kept moist before applying the filler may be shorter or longer depending on the type of epoxy to be used and manufacturer specification.
The prepared surface shall be approved by the Project Manager.
- iii) Preparation of concrete for the dry-pack mortar repair method:

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<div> <div>a)</div> <div>Holes for dry pack should have a minimum depth of 25 mm,</div> </div> <div> <div>b)</div> <div>For the dry-pack repair method, holes should be made sharp and square at the surface edges, but corners within the holes should be rounded with a radius of about 25 mm, especially when water tightness is required,</div> </div> <div> <div>c)</div> <div>The interior surfaces of holes left by cone bolts, she bolts, etc., shall be roughened to develop an effective bond. Other holes should be under-cut slightly in several places around the perimeter so that they are slightly wider at their deepest portion than at the surface. This creates a key. For example when an unsightly crack occurs in a wall, a power driven saw-tooth bit can be used, whereby rocking of the bit makes the undercut-key. The undercut-key is done typically to a depth of about twice the saw-tooth bit diameter.</div> </div> <div> <div>iv)</div> <div>Preparation of concrete for the concrete replacement repair method:</div> </div> <div> <div>a)</div> <div>Holes should have a minimum depth of 100 mm in recent concrete, and 150 mm in old concrete, and the minimum area of repair should be 1000 cm² for un-reinforced concrete and 1500 cm² for reinforced concrete,</div> </div> <div> <div>b)</div> <div>Reinforcement bars should not be left partially embedded; if necessary concrete which covers only a portion of the rebar should be chipped away so that there is a clearance of at least 25 mm around each exposed bar,</div> </div> <div> <div>c)</div> <div>The top edge of the holes at the face of the structure should be cut to a fairly horizontal line. If the shape of the defect makes it advisable, the top of the cut may be stepped down and continued on a horizontal line. The top of the hole should be cut on a 1 to 3 upwards slope from the back towards the face of the wall or beam from which new concrete will be placed. It is important to slope upward in order to avoid air pockets at the top of the concrete when vibrating. It may be necessary to fill the hole from both sides in</div> </div>		
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which case the slope of the top of the cut should be modified accordingly,

- d) The bottom and sides of the hole should be cut sharp and approximately square with the face of the wall. When the hole goes entirely through the concrete section, spalling or feathered edges shall be avoided by having chippers work from both faces. All interior corners should be rounded to a minimum radius of 25 mm.
- v) Preparation of concrete for the mortar replacement repair method:
 - a) The mortar replacement method is used for repairing defects on surfaces not prominently exposed and too wide for dry-pack filling. Moreover, the defects are too shallow for concrete filling, or where the defects are shallower than the far side of the reinforcement that is nearest the surface. Repair may be either by the use of shotcrete or by hand methods,
 - b) The surface of the concrete to be repaired should be made moist for at least 24 hours unless this concrete is still green.
- vi) Preparation of concrete with Epoxy repair method:
 - a) Preparation for epoxy bonded repairs should be in general identical to that for other concrete repairs except that every effort should be made to provide surfaces that are completely free of surface water. Moistening of the immediate surface for at least 24 hours and a temperature between 18°C to 30°C are usually essential for proper application of epoxy bonded repairs; but the specifications of the epoxy manufacturer may impose different limits and these should be followed unless decided otherwise by the Project Manager,
 - b) Preparation for the use of epoxy mortars should include thorough cleaning and drying of the areas to be repaired. A wash of dilute 1:4 muriatic acid, followed by thorough scrubbing and rinsing with clear water and subsequent removal of all surface water using an air jet may be required by some epoxy manufacturer. If in the latter case acid wash is not feasible, preparation may be accomplished

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as for other concrete repairs with a thorough clean up by means of a sand blast method, followed by air-water jet washing and complete removal of surface water using an air jet or mopping up.

vii) Use of the dry-pack mortar repair method:

- a) Application of dry-pack mortar should be preceded by a careful inspection to see that the hole is completely clean, rough and free from dust and loose pieces, and free of surface water. However, the surface should be moist,
- b) Then a bonding grout coating should be applied to the surface using a brush. The surfaces after preparing should be thoroughly brushed with a stiff mortar or grout barely wet enough to thoroughly wet the surface, after which the dry pack material should be immediately packed into place before the bonding grout has dried. The mix of bonding grout is to be 1:1 cement and fine sand mixed to a consistency like fluid paste consistency. However, under no circumstances should the bonding coat be so wet or applied so heavily that the dry-pack material is more than slightly rubbery,
- c) Dry-pack mortar is usually a mix, by weight, consisting of 1 part cement to 2½ part sand that passes through a 1.2 mm standard sieve (US Standard Sieve No. 16). Note that a mortar patch is usually darker than the surrounding concrete unless special precautions are taken. Where uniform colour is desired, white cement in a sufficient proportion as determined by trial test may be used to produce a uniform appearance.

For packing cone-bolt holes, a leaner mix of 1 : 3½ to 1 : 3½ should be sufficiently strong, and blend better to the colour of the wall. In preparing dry-pack mortar sufficient water should be used to produce a mix, which is at the point of becoming rubbery when solidly packed. Any less water will not make a sound solid pack; any more water will result in excessive shrinkage, which will give a loose repair,

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d) Dry-pack should be placed in layers having a compacted thickness of about 10 mm. Thicker layers will not compact well at the bottom. The surface of each layer should be scratched with a nail to facilitate bonding with the next layer. One layer may be placed immediately after another unless a considerable rubbery appearance develop; if this occurs work on the repair should be delayed by approximately 30 to 40 minutes. Under no circumstances should alternate layers of wet and dry materials be used. Each layer should be compacted over the entire surface by a hardwood stick or wooden handle of a hammer. Such a stick should be approximately 300 mm long and not more than some 25 mm in diameter. The stick is used on fresh mortar like a calking tool. Hardwood sticks are preferable to metal rods because the latter tend to polish the surface of each layer and thus make the bond less certain and the filling less uniform. The tamping should be predominantly directed at a slight angle and towards the side of the hole to assure maximum compaction of those areas,


e) The holes should not be overfilled and finishing is usually completed by using the flat side of a piece of hardwood to strike against the fill. Steel finishing tools should not be used, nor should water be added to facilitate finishing,

f) Because of the relatively small amount of mortar in the repairs and the tendency of the adjoining concrete to absorb moisture, water curing is an essential procedure for at least 7 days. When forms are used for the repair, they can be loosened after some 12 hours to let the curing water come in contact with the repair area, or preferably a few layers of wet burlap placed on top of the repair area for curing.

viii) Use of the concrete replacement repair method:

a) Application of the concrete replacement should be preceded by a careful inspection to ensure that the hole is completely clean, rough, free from dust and loose pieces, and free of surface water.


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However, the surface should be moist. A bonding grout coating should be applied to the surface using a brush, for defects in horizontal top surfaces the bonding grout can consist of a grout barely wet enough to thoroughly wet the surface, and in other positions of a adhesive epoxy that binds new concrete to old concrete such as SIKA MonoTop 610 or similar. Afterwards the filler material is placed on the bonding grout or adhesive epoxy before it has dried. The mix of bonding grout shall consist of 1:1 cement and fine sand mixed to a consistency similar to a thick cream,

- b) The filler material shall then consist preferably of concrete with similar properties as the old concrete, but the water cement ratio should not exceed 0.47 by weight. Concrete filling shall be tightly packed and completely bonded to the surface of the holes. The mix proportions of the filling materials shall be such as to provide a strong dense repair with consideration given to the colour variations of surfaces exposed to view. For wall repairs higher than some 450 mm the concrete filler should be placed in lifts not exceeding 300 mm depth,
- c) The concrete slump for the repair of top of slabs shall be limited to 50 mm, and for other defect locations the slump shall be limited to 75 mm. Immersion type vibrators should then be used during and after the depositing of the concrete,
- d) On surfaces permanently exposed to view, and where required by the Project Manager, the Contractor shall use a sufficient amount of white cement, as determined in trials, which when blended to normal cement, will produce a finish similar in appearance to the adjoining concrete. A non-shrink agent shall be used where a watertight joint is required,
- e) Manipulation in finishing should be kept to a minimum. The surface of patches shall be smooth and flush with the surrounding concrete. A wood float finishing is preferable to a steel-trowel finish. Water should not be used when finishing,


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<div> f) Curing shall be done on the repair for a minimum of 7 days. </div>		
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- ix) Use of the mortar replacement repair method:
- a) Application of the mortar replacement should be preceded by a careful inspection to ensure that the hole is completely clean, rough, free from dust and loose pieces, and free of surface water. However, the surface should be moist,
 - b) When mortar gun is used with the replacement mortar method, comparatively shallow holes should be flared outwardly at about 1:1 slope to avoid inclusion of rebound. Corners within the holes should be rounded. Shallow imperfections in new concrete may be repaired by mortar replacement if the work is done promptly after removal of the forms and while the concrete is still green. For instance when it is considered necessary to repair the “peeled” areas resulting from surface material sticking to steel forms, the surface may be filled using a mortar gun without further trimming or cutting. In completing the repair, the hole should be filled slightly more than the full level. After the material has partially hardened but can still be trimmed off, excess material should be shaved off with a steel trowel, working from the centre towards the edges. Extreme care must be taken to avoid impairment of the bond. Neither the steel trowel nor water should be used in finishing. A satisfactory finish can usually be obtained by slightly rubbing the surface with a soft rag. Prior to using the mortar replacement method, the Contractor shall submit all details of the approach he wishes to use, which shall be subject to the approval of the Project Manager. Further, the Contractor shall provide the result of trial panel tests indicating the validity of the method,
 - c) For minor restorations, satisfactory mortar replacement may be performed by hand. Whenever hand placed mortar replacement is used the edges of chipped out areas should be squared with the surface, leaving no feathered edges,
 - d) The repair mortar should be pre-shrunk by mixing it to a plastic consistency as long in advance of its use as the cement will permit.


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Depending on the mix, cement, temperature, and humidity, the time for preshrinking may vary from 1 to 2 hours. Trial mixes should be made to determine the longest time required for the mortar, after reworking, will retain sufficient plasticity to permit application. The mortar should be stiff yet still permit workmanship,

- e) Immediately prior to application of the mortar, the moist surface of the old concrete shall be brushed completely with a wire brush and a small quantity of the mortar. The mortar should then be compacted into the surface taking care to fill all edges,
- f) Curing shall be done on the repair for a minimum of 7 days.
- x) Use of the epoxy repair method:
 - a) Application of epoxy resin should be preceded by a careful inspection to ensure that the hole is completely clean, rough, free from dust and loose pieces, and free of surface water. However, the surface should usually be moist,
 - b) The method of repair shall be as recommended by the manufacturer. The product used shall preferably contain no toxic elements. Proper ventilation shall always be available. The product used shall be chosen so as to give a surface colour and texture that closely resembles the adjoining concrete, especially where the repair area is exposed to public view,
 - c) In areas exposed to public view, the surface of the epoxy repair patch shall be lightly ground to eliminate the gloss of the finished epoxy surface, and effort shall be made to closely match not only the colour but also the texture of the patch to that of the adjoining concrete.

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6.15 **EMBEDMENTS IN CONCRETE/ROCK (Wherever required)**

6.15.1 **ANCHOR BARS**

- i) Wherever indicated on the drawings or directed by the Project Manager, holes shall be drilled into rock to receive bars for anchoring to the rock, concrete or masonry structures or parts, thereof.
- ii) The type and dimensions of the anchor bars, locations, diameter and depths of anchor bar holes shall be as shown on the drawings or as directed.
- iii) Anchor rods shall be thoroughly cleaned before being placed in the drill hole. The hole shall be filled with grout. The grout shall be a workable 1:1 sand/cement mix with low water cement ratio. Admixtures for fast setting and low shrinkage may also be required. A vent pipe shall be used to make sure that air is not trapped when the grout is placed.
- iv) Wherever practicable, anchors shall be installed before the concrete is placed, except when otherwise provided or permitted.
- v) Drilling for the installation of anchors in the concrete shall not be carried out except with the prior approval of the Project Manager.
- vi) Where the installation of anchors prior to placing of the concrete, is not practicable, satisfactory formed openings shall be provided or holes drilled for the purpose and the anchors grouted in the openings at some later date.
- vii) In the case of reinforced concrete foundations, anchor bolts for machinery may be placed in approved pipe sleeves to facilitate machinery installation and the sleeve shall be completely filled with grout or mortar as directed by the Project Manager. The exact method adopted shall be subject to the prior approval of the Project Manager.
- viii) The anchors shall be protected against disturbance for a minimum time of 48 hours after installation or more as required by the Project Manager.

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6.15.2 EMBEDDED PARTS

- i) Before placing concrete, care shall be taken to ensure that all embedded parts are firmly and accurately fastened in place as indicated on the drawings or as directed.
- ii) All embedded parts shall be thoroughly cleaned, free from all foreign matter such as scale, rust, oil etc.
- iii) The Contractor shall not place concrete on embedded parts unless these are checked and approved by the Project Manager.
- iv) Parts of gates, gate hoists, valves, operating machines and other control equipment as also the anchor bolts, structural shape plates and bearings required in connection with the installation of these parts will be supplied to the Contractor by the Project Manager. These parts shall be installed/embedded in concrete/rock by the Contractor as shown on the drawings or as directed.
- v) If concrete is placed by the Contractor without correctly placing in position, the necessary embedded parts, concrete shall have to be removed and replaced by him to enable such embedded parts to be installed in position, without any extra payment to him.
- vi) Care shall be taken not to disturb or displace embedded parts during concrete placement.

6.15.3 POROUS CONCRETE

- i) Porous concrete shall be used at locations shown on the drawings or as directed. Porous concrete shall be composed of 1 part cement to 5½ parts of aggregate by weight.
- ii) Up to 10% fines (i.e. sand) in the aggregate may be permitted of the total aggregate. Only so much water shall be used in the concrete as is required to produce a paste, which will coat the particles and not fill the voids. In placing porous concrete, care shall be taken to ensure that it is not over tamped or compacted. The porous concrete as laid shall be pervious and

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free draining when it hardens. As soon as the concrete hardens (so that paste can not be washed away) it should be kept moist for a minimum of 14 days. The compressive strength of porous concrete at 7 days as determined by test on 15 cm x 15 cm cube should not be less than 70 kg/cm² and the porosity at 7 days be such that water shall pass through a slab of the concrete 30 cm thick at a minimum rate of 500 litres/ m² of the slab with a constant 10 cm depth of water standing on the slab. The porous concrete shall be placed as shown in the drawings or as directed by the Project Manager.

6.16 CONCRETE FOR TUNNEL (SHAFT) LINING

- i) The contractor shall prepare the tunnel for placing concrete lining in accordance with the Section for "Preparations for placing of concrete".
- ii) Where appreciable quantities of water flows from the material surrounding the tunnel, it shall be excluded from the space to be filled with concrete by grouting, by caulking, by diverting with pipes, pans or other means or by pumping with sumps until the concrete has hardened and gained sufficient strength to be unaffected by the action of the water through percolation, hydrostatic pressure, or abrasion.
- iii) Except as otherwise provided in the Section for "Tunnel excavation" for a cast in-situ concrete tunnel lining, all materials projecting inside the minimum excavation line ("A" line) shall be removed by the Contractor before concrete is placed in the lining. The removal of such projections within the minimum excavation line ("A" line) may be performed at any time during the progress of the work. Provided that immediately before the concrete lining is placed the contractor will be required to remove all material within the minimum excavation line ("A" - Line).
- iv) Cleanup of the tunnel shall be a part of preparations for placing the concrete tunnel lining. Clean up shall include the removal of the following:
 - a) Where concrete is used for lagging, blocking or wedges, such lagging, blocking and wedges shall be left in place and lining concrete placed about them as approved by the Project Manager,

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	<ul style="list-style-type: none"> b) All timber spreaders if used to brace the structural steel supports shall be removed before the concrete tunnel lining is placed, c) Track system including ties and ballast shall be removed, if used, d) All loose material on surfaces of excavations, except loose material behind lagging or blocking that cannot be removed, shall be removed before the concrete is placed, e) Where loosened material in the invert is found to be sound and compactable as determined by the Project Manager, and where such material is located outside the Pay line ("B"-line), between radial lines 30 degree of each side of the vertical centre line the material may be allowed to remain in place provided that such loosened material shall be thoroughly compacted in accordance with the specification and as directed by Project Manager. v) Concrete in the tunnel lining shall conform to the requirements of the Section "Concrete Placing" before placing concrete lining in the tunnel, the tunnel shall be prepared therefore in accordance with this specification. vi) Concrete to be used for the tunnel concrete lining shall be of the grade as specified on the drawings or as directed by the Project Manager. Concreting shall be done using concrete Pumps. vii) Loose material in the invert shall be removed before concrete is placed thereon, and loose rock material shall be removed. viii) All spaces outside of the minimum required thickness of concrete lining shall be filled completely and solidly with concrete and special care shall be taken to force concrete into all irregularities in the contact surfaces and to completely fill the tunnel arch. ix) The finished interior surfaces of the tunnel shall conform accurately to the shape, alignment grades and sections shown. The interior surfaces, except the invert, of all tunnel lining shall have an F3/F3C finish. The invert shall have a U3 finish. x) The steel reinforcement wherever required in the concrete lining shall be as shown on the drawings and as directed by the Project Manager. 	<div style="border: 1px solid black; padding: 5px; text-align: center;"> ISSUE P0 </div>

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6.16.2 BACKFILL CONCRETE BEHIND STEEL LINERS:


- i) No windows for introduction of vibrators shall be provided in the steel liners. Working space shall be provided at the crown of the tunnel to permit access for the necessary vibration of the backfill concrete. Special care shall be taken to ensure compaction of concrete and complete filling of the space beneath the steel lining and filling of the crown.
- ii) Concrete used for backfilling behind the steel liner shall be of the grade as specified on the drawings or as directed by the Project Manager. Concreting shall be done using concrete pumps.
- iii) Concreting shall be coordinated and carried out in conjunction with the installation of the permanent steel liner according to the following sequence:
 - a) 1st, installation of the permanent steel liners, a maximum of 3 units (or 18 m), may be installed before the surrounding backfill concrete is placed,
 - b) 2nd, placing of the surrounding concrete by the Civil Tunnel Contractor,
 - c) 3rd, installation of further steel liner units shall not proceed until either 24 hours have elapsed since placing of the backfill concrete, or the concrete has attained 20% of its required 28-days compressive strength.


6.17 MEASUREMENTS AND PAYMENTS

6.17.1 STRUCTURAL CONCRETE

- i) Measurement of each grade of concrete, unless specified otherwise hereafter, shall be made of the volume, in cubic metres, within the neat lines of concrete and rock Pay lines, in the various structures, in niches, as shown on the drawings or as required or determined by Project Manager.
- ii) Payment will be made at the Unit Rate in cubic metres for different grades and types of concrete entered in the Bill of Quantities, which shall include, but not be limited to, the following:

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<div><div><div>a)</div><div>Supply of aggregates including excavation, loading, transportation, crushing, screening, washing, blending and storage,</div></div><div><div>b)</div><div>Batching, supply of mixing water, mixing, transportation, placing and compacting the concrete,</div></div><div><div>c)</div><div>Labour, tools and equipment for cleaning and preparing surfaces prior to concreting,</div></div><div><div>d)</div><div>Forming and treatment of construction joints including furnishing and spreading of mortar layers before concrete placing,</div></div><div><div>e)</div><div>Surface finishing,</div></div><div><div>f)</div><div>Attaining the concrete temperature as specified, and following hot and/or cold weather precautions,</div></div><div><div>g)</div><div>Protection and curing of concrete,</div></div><div><div>h)</div><div>Repair of defective concrete,</div></div><div><div>i)</div><div>Furnishing samples of materials i.e. cement, coarse and fine aggregates, water, admixtures as also the samples of concrete, mortar and providing assistance for sampling required in connection with the tests to be performed by the Corporation as and when required,</div></div><div><div>j)</div><div>Chipping and roughening of concrete surface,</div></div><div><div>k)</div><div>All laboratory tests to be performed by the Contractor as stipulated in this specification.</div></div></div>		
<div><div>6.17.2</div><div><div><div><div><div>SECOND STAGE CONCRETE AND CONCRETE IN BLOCK OUTS FOR EMBEDDING OF EQUIPMENT</div></div></div></div></div></div>		
<div><div><div>i)</div><div>Measurement for payment of second stage concrete and concrete in block outs will be of the volume of placed concrete. Only second stage concrete placed in spaces exceeding 0.10 m³ in volume will be considered for payment. Second stage concrete placed in block-outs or spaces less than that stated above shall be deemed to be included in the Unit Rate for concrete in the structure with which it is associated.</div></div></div>		
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- ii) Payment will be made at the Unit Rate per cubic metre entered in the Bill of Quantities, which shall include, in addition to the Works included herein, the entire cost of preparation of contact surfaces with parent concrete, furnishing of non-shrink agent where directed for any other related work.

6.17.3 GROUTING OF EQUIPMENT BEARING PLATES AND ANCHORS

Grouting of the equipment bearing plates, bolts etc. will not be paid separately and the cost thereof, including materials, shall be included in the Unit Rate for concrete in the structure with which it is associated.


6.17.4 EMBEDMENT IN CONCRETE/ROCK

- i) Anchor Bars:
- a) The cost of anchor bar will be made at the Unit Rates for reinforcing steel in the Bill of Quantities,
 - b) The drilling of holes in rock/concrete including the cost of grouting, will be paid at the Unit Rates provided in the Bill of Quantities.
- ii) Embedded Parts:
- a) Embedded parts such as, gates, gate hoists, valves, operating machines and other control equipment and their relevant anchor bolts, structural-shape, plates, and bearings or other alike parts required in connection with the installation of these parts will be supplied to the Contractor, free of cost, by OWNER,
 - b) The above parts shall be installed/embedded in concrete/rock by the Contractor and will be paid for by weight at the Unit Rates provided in the Bill of Quantities.

6.17.5 CONCRETE CORES

The payment for drilling of holes in concrete for taking out samples for testing purposes will be made at the appropriate Unit Rate for drilling provided in the Bill of Quantities.

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6.17.6 CEMENT

- i) The Unit Rates for various grades of concrete shall include the cost of the cement content specified therein.
- ii) The cement contents of the original mix(es) on which the bid has been priced and the mix(es) finalised after trial mix stage may differ. However, no separate payment will be made to the Contractor for such increase or decrease in the cement content.


6.17.7 ADMIXTURES

No separate payment will be made for supplying & adding admixtures to concrete, which shall be the Contractor's liability.

6.17.8 MEASUREMENT AND PAYMENTS FOR TUNNEL (SHAFT) CONCRETING

- i) Measurement of concrete placed in the tunnel and shaft lining will be of the theoretical volume of concrete placed within the "B"-line shown on the Construction Drawings. Deductions from this volume will be made for the in-situ concrete, precast concrete, or shotcrete placed earlier, which will be paid for separately. The volume to be deducted will be calculated as area multiplied by the average layer thickness established by an approved method. No deduction will be made for rock projections inside "B"-line or for metal lagging, metal supports, and struts within the prescribed B-Line. No measurement for payment will be made for concrete required to be placed outside of the Pay line ("B"-line) due to over-break or excess excavation to facilitate the Contractor's operations.
- ii) Payment for cast in-situ concrete lining and backfill concrete behind steel liners will be made at the unit price per cubic metre provided in the Bill of Quantities and shall include the entire cost of all plant, labour and materials for the tunnel concreting, including all formwork, placing of concrete, with all pipes and fittings.
- iii) All associated works to concrete placement, such as removal of forms and repair and finishing of concrete shall be completed as soon as practicable

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after concrete is placed. Concrete will not be considered for payment until all associated work has been completed to the satisfaction of Project Manager.


- iv) Employer shall not pay the Contractor for concrete wasted due to the fault of contractor, nor for concrete used in areas of overbreak due to contractor's negligence. However, in cases of overbreaks, which occur entirely due to geological reasons which cannot be controlled by the contractor and subject to the satisfaction and approval of Project Manager, concrete back filling shall be done by the contractor for which only the cost of materials used including royalty as specified in Bill of Quantities limited up to 7% of the theoretical quantity computed on the basis of pay line shall be reimbursed to the Contractor. The cost of all labour for mixing, handling and placement, etc. for backfilling in overbreaks shall be borne by the Contractor.
- v) No separate payments shall be made for preparation of concrete placing. No deductions shall be made in the quantity of concrete for embedment in the concrete for steel supports and accessories, reinforcement steel, pipes and miscellaneous metal works but deduction shall be made for recess, openings and cavities provided in the concrete. Deduction shall also be made for the in-situ concrete, shotcrete and RCC lagging placed earlier, which will be paid for separately.

6.17.9 EXCLUSIONS

No extra measurement or payment will be made for the following:

- a) Any rounded or bevelled edges, fillets, scoring, chamfers, or any deduction made for voids or embedded items, which are either less than 0.10 m³ in volume. No allowance will be made for approved temporary openings, drains, embedded pipes, or recesses created by the Contractor for his own convenience during construction provided they are filled as directed,
- b) Collecting of seepage water or water inflow from rock surfaces and diverting it into the drainage systems as specified in Chapter "Dewatering, Drainage and Pumping",

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<div> <div>c)</div> <div>Any defective and wasted concrete, concrete which has to be removed and replaced due to Contractor's non-compliance with the Specifications or Project Manager's,</div> </div> <div> <div>d)</div> <div>Any concrete which the Contractor places or uses for his own installations or for his own convenience,</div> </div> <div> <div>e)</div> <div>Developing alternative sources of aggregates by the Contractor and the resulting additional material testing,</div> </div> <div> <div>f)</div> <div>Pumping of the concrete and plasticisers,</div> </div> <div> <div>g)</div> <div>Any precast and precast-prestressed concrete units damaged by improper storing, handling or transportation,</div> </div> <div> <div>h)</div> <div>Any replacement or repair of concrete damaged by blasting carried out by the Contractor,</div> </div> <div> <div>i)</div> <div>Making stockpiles for coarse and fine aggregates,</div> </div> <div> <div>j)</div> <div>Removal and replacement of any concrete placed without the prior knowledge and agreement of the Project Manager,</div> </div> <div> <div>k)</div> <div>Removal and replacement of concrete not manufactured, placed and compacted in accordance with these Specifications,</div> </div> <div> <div>l)</div> <div>Curing compound and all operations involved in its use,</div> </div> <div> <div>m)</div> <div>Forming expansion and contraction joints including making drainage and other holes where such joints occur,</div> </div> <div> <div>n)</div> <div>Filling of holes left by the removal of concrete samples with the concrete of the same grade,</div> </div> <div> <div>o)</div> <div>For preparing the tunnel for placing concrete tunnel lining and for excluding water from spaces to be filled with concrete.</div> </div> <div> <div>End of Chapter</div> </div>		
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