BRIHANMUMBAI MUNICIPAL CORPORATION

Mumbai Sewage Disposal Project
Stage II - Priority Works
Priority Sewer Tunnel – Phase 2

BID DOCUMENT

FOR

PRIORITY SEWER TUNNEL – PHASE 2

Design and Build Contract

Bid No. –7200036535

VOLUME – IIA

GENERAL SPECIFICATION

EMPLOYER

Brihanmumbai Municipal Corporation
Municipal Head Office Building,
Mahapalika Marg, Fort, Mumbai - 400001
India

CONSULTANT

Tata Consulting Engineers Limited,
15th floor Empire Tower ,
Opp Reliable Tech Park
Cloud City Campus, Airoli,
Navi Mumbai 400708

SEPTEMBER 2022

PRIORITY SEWER TUNNEL PHASE - 2

DESIGN-BUILD CONTRACT

LAYOUT OF THE DOCUMENTS

This volume is one of several that comprise the documents.

These are:

Volume I	Conditions of Contract
Volume II	Employer's Requirements
Volume IIA	**General Specification**
Volume IIB	Void
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PRIORITY SEWER TUNNEL PHASE 2
DESIGN-BUILD CONTRACT

Volume IIA – General Specification

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1.0 Notes to the General Specification

The General Specification includes the general requirements for the design-build of the Priority Sewer Tunnel – Phase 2.

The General Specification forms an integral part of the Contract Documents and should be used in conjunction with all the Volumes which form the Contract Documents especially the detailed project requirements included within the Employer's Requirements, which take precedence over the General Specification.

Unless otherwise specified in the Employer's Requirements the Works shall be in accordance with this General Specification.

Samples of various materials, fittings etc proposed to be incorporated in the work shall be submitted by the Contractor for approval of the Engineer before order for bulk supply is placed.

Prior to manufacture or delivery of fabricated items the Contractor shall submit to the Engineer copies of manufacturer's drawings covering all type/details of work as generally shown in design drawing and envisaged under these specifications. The drawing shall show all dimensions, details of construction, installation of fixtures and connections and relation to adjoining and related works. No fabrication or manufacturing work shall be undertaken prior to obtaining approval of drawings from the Engineer.

2.0 Codes of Practice

Unless specifically otherwise stated, all the applicable codes and standards published by the Indian Standard Institution and all other standards which may be published by them up to the date of receipt of tenders, shall govern in all respects of design, workmanship, quality and properties of materials and methods of testing etc, unless specifically quoted.

In case there is no IS specification for the particular work, such work shall be carried out in accordance with this General Specification and the instructions in all respects and requirements of the Engineer. Wherever any reference to any Indian Standard occurs in the documents relating to this Contract, the same shall be inclusive of all amendments issued there to or revisions thereof, if any, upto the date of receipt of tenders.

The following table includes various pertinent standards, relevant to the Contract, (all latest versions of codes shall be referred, unless a different code and standard system is referenced). All standards, tentative specifications, specifications, codes of practice, referred to herein shall be the latest editions including all applicable official amendments and revisions. In case of discrepancy between this specification and those referred to herein this specification shall govern.

IS Code No.	Subject
Carriage of Materials	
4082-1996	Recommendations on stacking & storage of construction materials and components at site
Earthwork	
3764	Safety Code for Excavation Work
2720	Part II - Determination of Moisture Content
2720	Part VII - Determination of Moisture content dry density relation using light compaction
2720	Part VIII - Determination of Moisture Content Dry Density using heavy compaction
2720	Part XXVIII - Determination of Dry Density of soils, in place, by the sand replacement method
2720	Part XXIX - Determination of Dry Density of soils, in Place, by the core cutter method
6313 – 1981	Code of Practice for Anti Termite Measure in Buildings
Roadworks	
Section 900	MORT Specifications for Road and Bridge Works (IV Revision)
Section 902	MoSRT&H Specifications for Road and Bridge Works (IV Revision).
Construction Materials	
196-1966	Atmospheric conditions for testing (Reaffirmed - 1990)
269-1989	33 Grade Ordinary, rapid hardening and low heat Portland cement
383-1970	Coarse and fine aggregates from natural sources for concrete
455-1989	Portland blast furnace slag cement
650-1991	Standard sand for testing of cement
1489-1991(Pt-I)	Portland pozzolana cement fly ash based
1514-1990	Methods of sampling & Test for Quick Lime & Hydrated Lime.

IS Code No.	Subject
	(Reaffirmed - 1996)
1542-1992	Sand for Plastering
1727-1967	Methods of tests for pozzolanic materials
2116-1980	Sand for masonry mortars. (Reaffirmed – 1998)
2250-1981	Code of practice for preparation and use of masonry mortar. (Reaffirm- 1990)
2386-1963	Methods of Test for Aggregates for Concrete
2386 Pt.I-1963	Particle size and shape
2386 Pt. II-1963	Estimation of deleterious materials and organic impurities
2386 Pt.III-1963	Specific gravity, density, voids, absorption and bulking
2686-1977	Cinder as fine aggregate for use of Lime Concrete. (Reaffirmed – 1992)
3025-2009	Methods of sampling & test (Physical & Chemical) water used in industry. (Reaffirmed-2003)
3068-1986	Broken brick (burnt clay) coarse aggregate for use in lime concrete (II-R.)
3182-2013	Broken brick (Burnt clay) fine aggregate for use in lime mortar
3812-2003	Fly Ash using as pozzolana and admixtures (Reaffirmed - 1999)
4031-1996	Methods of physical tests for hydraulic cement (Reaffirmed – 1996)
4032-1985	Method of chemical analysis of hydraulic cement (Reaffirmed - 1990)
4098-1983	Lime pozzolana mixture (Reaffirmed - 1989)
4443-1980	Code of practice for use resin type chemical resistant mortars
8042	Specification for white Portland cement
8112	Specification for 43 grade ordinary Portland Cement
12269	Specification for 53 grade ordinary Portland Cement
12330	Specification for sulphate resisting Portland Cement

Concrete Work	
SP 23	Handbook on concrete mixes (based on Indian Standards)
269-2013	Specification for 33 grade ordinary Portland Cement
280-2006	Specification for mild steel wire for general engineering purposes
1343-1980	Code of practice for pre-stressed concrete
383-1970	Coarse and fine aggregate from natural sources for concrete (Reaffirmed - 1990)
432-1982	Specification for mild steel and medium Tensile (Part 1 & 2) steel bars and hard-drawn steel wire for concrete reinforcement
455	Specification for Portland slag cement
456-2000	Code of practice for plain and reinforced concrete
457-1957	COP for general const. of plain & reinforced concrete for dams & other massive structure
458-2003	Specification for pre-cast concrete pipes (with and Without reinforcement)
516-1959	Method of test for strength of concrete (Reaffirmed in 2004)
650-1991	Specification for standard sand for testing cement
1786-2008	Specifications for cold twisted steel bars for concrete reinforcement *
875-1987	Code of Practice for structural safety of buildings, loading standards
1139-1966	Deformed bars for concrete reinforcement, hot rolled for mild steel or medium tensile steel

IS Code No.	Subject
1161-1998	Specifications for steel tubes for structural purposes
1199-1959	Methods of sampling and analysis of concrete. (Reaffirmed - 1999)
1322-1993	Bitumen felts for waterproofing and damp proofing. (Reaffirm - 1998)
1566-1982	Hard drawn steel wire fabric for concrete reinforcements (II Rev.) (Reff.1998)
1661-1972(Pt.III)	Code of practice for application of cement lime plaster finishes.(Reaffirm- 1999)
1786-2008	Specification for high strength deformed steel bars and wires for concrete reinforcement.
1893	Criteria for Earthquake Resistance Design of Structures
2386-1963(Pt.1 to 8)	Methods of test for aggregate for concrete
2386 (Pt.I)-1963	Test for particle size and shape
2386 (Pt.II)-1963	Test for estimation of deleterious materials and organic impurities
2386 (Pt.III)-1963	Test for specific gravity, density, voids, absorption and bulking
2386 (Pt.IV)-1963	Mechanical properties
2502-1963	Code of practice for bending and fixing of bars for concrete reinforcement
2645-2003	Specification for integral waterproofing compounds
2686-1977	Specification for cinder aggregate for use in lime concrete. (Reaffirm - 1992)
2751-1979	Recommended practice for welding of mild steel plain and deformed bars for reinforced construction
3201-1988	Criteria for design and construction of pre-cast trusses and purlins
3370	Code of practice for concrete structures for the storage of (Parts 1 to 4) Liquids
3414-1968	Code of practice for design and installation of joints in Buildings
7861-1975	(Pt. I Hot weather concreting. .(Reaffirmed -1990)
7861-1981	(Pt. II Cold weather concreting. .(Reaffirmed -1992)
9103-1999	Admixture for concrete
3935-1966	Code of practice for composite construction. (Reaffirmed – 1998)
4014-1967 (Pt. I& II)	COP for steel tubular scaffolding (I: Definition/Material; II: Safety Resolutions) (Raffir 1999)
4926-2003	Code of practice for Ready Mix Concrete
4990-1993	Specifications for plywood for concrete shuttering work. (Reaffirmed - 1998)
10262-2009	Code of practice for design mix (Reaffirmed - 1999)
1785-1983 (Part-I& II)	Specifications for plain hard drawn steel wire for pre-stressed concrete
1786-2008	H.Y.S.D./ Cold twisted steel bars for concrete reinforcement Reaffirmed - 1990)
2090-1983	Specifications for high tensile steel bars used in pre-stressed concrete
2204-1962	Code of practice for construction of reinforced concrete shell roof. (Reaffirmed – 1990)
2210-1988	Criteria for the design of shell structure and folded plates (Reaffirmed - 1998)
2502-1963	COP for bending and fixing of bars for concrete reinforcement. (Reaffirmed - 1999)
2751-1979(Reaf-1992)	COP for welding of mild steel bars used for reinforced concrete construction
2911-2010	Code of practice for design & Construction. of pile foundations

IS Code No.	Subject
2911(Pt.I)-2010.(Reaf-97)	Design & construction of Pile Foundations - Bored pre-cast concrete piles
2911 (Pt.III)-2010	Under reamed pile foundations
2911 (Pt.IV)-2010	Load test on Piles
3201-1988	Criteria for design and construction of pre-cast concrete trusses. (Reaffirmed - 1995)
3385-1965	Code of practice for measurement of Civil Engineering works - Pile Foundation)
3414-1968	Code of practice for design and installation of joints in buildings. (Reaffirmed - 1990)
3558-1983(Reaf-91)	Code of practice for use of immersion vibrators for consolidating concrete
6932 (Pt.I to X)	Methods of Test for Building Lime
6932 (Pt.I)-1973	Determination of insoluble residue, loss of ignition, silicon-dioxide, ferric & Alum. Oxide, calcium oxide & magnesium oxide insoluble matter
6932 (Pt.II)-1973	Determination of carbon dioxide content
6932 (Pt.III)-1973	Determination of residue on slaking of quick lime
6932 (Pt.IV)-1973	Determination of fineness of hydrated lime
6932 (Pt.V)-1973	Determination of unhydrated oxide
6932 (Pt.VI)-1973	Determination of volume yield of quick lime
6932 (Pt.VII)-1973	Determination of compressive and transverse strength
6932(Pt.VIII)-1973	Determination of workability
6932 (Pt.IX)-1973	Determination of soundness
6932 (Pt.X)-1973	Determination of popping and pitting of hydrated Lime
13620-1993	Fusion Bonded Epoxy coated Reinforcing Bars specification
13920-1993	Code of ductile detailing of reinforced concrete structures
9417-1989	Recommendations for welding cold worked steel bars for reinforced concrete construction
ASTM. A615	Standard specifications for deformed & plain carbon steel bars for concrete reinforcement
ASTM A.185	Standard specifications for steel welded wire reinforcement, plain for concrete

Equipment	
14687-1999	Code of Practice for Formwork
460-1985(Pt-I,II& III)	Specification for test sieves. (Reaffirmed - 1998)
1791-1985	Specification for batch type concrete mixer. (Reaffirmed – 1990)
2430-1986	Methods for sampling of Aggregates for concrete
IS 2438-1963	Specification for roller pan mixer
2505-1992	General requirement for concrete vibrators, immersion type
2506-1985	General requirements for screed board concrete vibrators
2514-1963	Specification for concrete vibrating tables. (Reaffirmed - 1991)
3366-1965	Specification for pan vibrators. (Reaffirmed – 1991)
4656-1968	Specification for form vibrators for concrete. (Reaffirmed-1991)
2722-1964	Specification for portable swing weigh batchers for concrete (single and double bucket type) (Reaf-95)
2750-1964	Specification for steel scaffolding. (Reaffirmed – 1991)
4990	Specification for plywood for concrete shuttering work

IS Code No.	Subject
Brickwork	
1077-1992	Common burnt clay building bricks
2185	Specification for concrete masonry units(parts 1,2 &3)
2212-1991	Code of practice for brick work
2572-2005	Code of practice for construction of hollow concrete block masonry
2691-1988	Specification for burnt clay facing bricks
3102-1971	Classification of burnt clay solid bricks
3495 (Pt I to IV)-1992	Method for test for burnt clay building brick
4832	Specification for chemical resistant mortars
4860-1968	Specification for acid resistant bricks
5454-1978	Method for sampling of clay building bricks. (Reaffirmed - 1995)
6041-1985	Code of practice for construction of autoclaved cellular concrete block masonry
6042-1969	Code of practice for construction of light weight concrete block masonry
Stonework	
1121 (Pt I)-1974	Methods for determination of compressive, transverse & shear strengths of natural building stones
1122-1974	Methods for determination of specific gravity and porosity of natural building stones
1123-1975	Methods for identification examination of natural building stones
1124-1974	Methods of test for water absorption of natural building stones
1125-1974	Methods of test for weathering of natural building stones
1126-1974	Methods of test for durability of natural building stones
1129-1972	Dressing of natural building stones
1130-1969	Marble (blocks, slabs and tiles)
1597-1992	Code of practice for construction of stone masonry
1597 (Pt I)-1992	Code of practice for construction of Rubble stone masonry. (Reaffirmed -1996)
1597 (Pt II)-1992	Code of practice for construction of ashlar masonry (Reaffirmed - 1996)
1805-1973	Glossary of Terms relating to stone Quarrying and dressing. Reaffirmed - 1993)
4101 (Pt I)-1967	Stone facing. (Reaffirmed - 1990)
Steelwork	
12406 - 2003	Medium density fibre board for general purpose - (1992)
226-1975	Structural Steel (Standard quality)
277-2003	Specification for galvanised steel sheets (plain and corrugated)
278-2009	Galvanised steel barbed wire for fencing. (Reaffirmed - 1991)
800-2007	Code of practice for use of structural steel in general building construction
806-1968	Code of practice for use of steel tube in general building construction
808-1989	Dimension for hot rolled steel sections
813-1986	Scheme of symbols for welding. (Reaffirmed – 2003)

IS Code No.	Subject
814-2004	Covered electrodes for manual metal arc welding of structural steel (Reaffirmed 2003)
817-1966	Code of practice for training and testing of metal arc welders. (Reaffirmed – 2003)
818-1968 (Reaf-03)	COP for safety & healthy requirements in electric & gas welding & cutting operation
919	Recommendations for limits and fits for engineering
961	Structural steel (High Tensile)
1030-1988	Specifications for Carbon steel casting for general engineering purposes
1038-1983	Steel doors, windows and ventilators
1079	Specifications for light gauge structural quality hot rolled carbon steel sheet and strip
1081-1960	COP for fixing & glazing of metal (steel & aluminium) doors, windows & ventilators (Reaf-91)
1148-2009	Hot rolled steel rivet bars (up to 40 mm diameters) for structural purposes, (Reaf-92) (Reaffirmed 2001)
1149-1982	High Tensile rivet bars for structural purposes
1161-1998	Steel tubes for structural purposes
1182-1983	Recommended practice for radiographic examination of fusion welded butt joints in steel plates (Reaf-00)
1363-2002 (Pt. 1- 3)	Hexagon bolts, nuts & lock nuts (dia. 6 to 39 mm) & black hexagon screws (dia. 6 to 24 mm). (Reaf-98)
1442	Specifications for covered electrodes for metal are welding of high tensile steels
1599-2012(Reaf-91)	Method for bend test for steel products other than sheet, strip, wire & tube (reaffirmed 1996)
1608-2005	Method for tensile testing of steel products (Reaffirmed 2001)
1730-1989	Dimension for steel plate, sheet and strip for Structural and General Engineering purpose
1732-1989	Dimensions for sound and square steel bars for Structural and General Engineering purpose
1821-1987	Dimensions for clearance holes for metric bolts. (Reaffirmed - 2003)
1852-1985	Rolling and cutting tolerance for hot rolled steel products. (Reaffirmed - 1991)
1977-1969	Structural steel (ordinary quality) (Reaffirmed 2001)
2062-2011	Structural steel (fusion welding quality). Supersedes IS 226-1975
3613-1974	Acceptance tests for wire flux combination for submerged arc welding
3757-1985	High tensile friction grip bolts
4351-2003	Steel door frames. (Reaffirmed – 1991)
4736-1986	Hot-dip zinc coatings on steel tubes. (Reaffirmed – 2001)
5624-1993	Foundation bolts
6248-1979	Metal rolling shutters and rolling grills
6639-1972	Hexagonal bolts for steel structures
6761-1994	Countersunk-head screws with hexagon sockets
6572-1987	Dimensions for pneumatic light rivet snap shanks
6649-1985	High tensile friction grip bolt washers
7452-1990	Hot rolled steel sections for doors, windows & ventilators
7205	Safety code for erection of structural steel work

IS Code No.	Subject
Materials & Workmanship	
Castings	
IS 3005 Part 1 to 4	Grey-iron
IS 1030:1998	Carbon steel
IS 3038:2006	Stainless steel
IS 3288:1986 Part 1 to 8	Copper and copper alloy
IS 10238:2001	Nuts, Bolts, fasteners and Washers
1364:2002 Part 1 to 6	Hexagonal head bolts, screws,nuts
IS 3138:1966	Specification for hexagonal bolts and nuts
IS 1367	Cap copper alloy strip
IS 2016:1967	Plain washers
BS 4320:1968	Specifications for metal washers for general engineering purposes
SP 6:1969 Part 4	Hand book for structural engineers-cold formed, light guage steel structures
IS: 3757:1985	Specification For High Strength Structural Bolts
IS 4000:1992	Code of practise for high strength bolts in steel structures
IS 4218:2001 Part 1 to 4	Iso General Purpose Metric Screw. Threads
IS 14962:2001 Part 1 to 5	ISO General Purpose Metric Screw Threads
BS 3643:2007	Specification for. ISO metric screw threads
Welding	
IS 816: 1969	Code of practice for use of metal arc welding for general construction in mild steel
IS 15769: 2008	Flux cored (tubular) electrodes for gas shielded and self-shielded metal welding of carbon or carbon-manganese steel
IS 10234:1982	General pipeline Welding
IS 11790:1986	Practice for preparation of butt-welding ends for pipes, valves flanges and fittings
IS 822	Code of procedure for inspection of welds
IS 1024	Use of Welding In Bridges And. Structures Subject To Dynamic. Loading
IS 819	Code of Practice for Resistance Spot Welding for Light Assemblies in Mild Steel
IS 1261	Code Of Practice For. Seam Weld1ng In Mild Steel
IS 1323	Code of practice for oxy-acetylene welding for structural work in mild steel
IS 7307	Approval tests for welding procedures
IS 7310	Approval tests for welders
IS 814 :2004	Welding Consumables
IS 1395-1982	Low and medium alloy steel covered electrodes for manual metal arc welding
IS 1278:1972	Filler rods and wires for gas welding
IS 7280-1974	Bare wire electrodes for submerged arc welding of structural steels
I.S. 3613-1974	Acceptance tests for wire flux combination for submerged arc welding
IS 6419-1996	Welding rods and bare electrodes for gas shielded arc welding of structural steel.
IS 6560-1972	Molybdenum and chromium-molybdenum low alloy steel welding rods and bare electrodes for gas shielded arc welding
BS EN ISO 14171:2010	Size of Electrode Runs
IS 2825:1969	Welding Procedure
AWWA Standard C206	Welded Joints for Steel Pipelines
BS 2633	Specification for Class I arc welding of ferritic steel pipework for carrying fluids
IS 1182:1983	Recommended practice for radiographic examination of fusion

IS Code No.	Subject
	welded butt joints in steel plates.
BS EN 1435	Non destructive of examination of welds
API Spec 5L	Butt Welded Joints
IS 3600:1985 Part 1 to 2	Method of Testing Fusion Welded Joints and Weld Metal in Steel
IS 3600:2009 Part 3	Destructive tests on welds in metallic materials
IS 3600: 1984 Part 4	Longitudinal Tensile Test On Cylindrical All Weld Metal Test Pieces Using Butt Joint
IS 3600:1983 Part 5 to 6	Transverse root,face bend test and side bend test on butt welds on butt welds
IS 3600:1985 Part 7 to 9	Longitudinal root and face bend test on butt welds, Nick break test and fillet weld fracture test,
IS 3613:1974	Acceptance tests for wire flux combination for submerged arc welding
IS 7307:1974 Part 1	Approval tests for welding procedures,
IS 2595:2008	Industrial radiographic testing
IS 4260:2004	Recommended practice for ultrasonic testing of butt welds in ferritic steel
BS EN 1321:1997	Destructive test on welds in metallic materials. Macroscopic and microscopic examination of welds
BS EN 895:1995	Destructive tests on welds in metallic materials. Transverse tensile tes
BS EN 10208:2009 Part 1 to 2	Steel pipes for pipelines for combustible fluids
BS EN 10208-2:2009	Steel pipes for pipelines for combustible fluids
BS EN ISO 15614-1:2004+A1:2008	Specification and qualification of welding procedures for metallic materials. Welding procedure test. Arc and gas welding of steels and arc welding of nickel and nickel alloys
BS 4871:1985 Part 2	Specification for approval testing of welders working to approved welding procedures. Arc welding of tube to tube-plate joints in metallic materials
BS 4872:1985 Part 1	Specification for approval testing of welders when welding procedure approval is not required. Fusion welding of steel
IS 4853:1982	Recommended practice for radiographic inspection of fusion welded butt joints in steel pipes.
IS 1182:1983	Recommended practice for radiographic examination of fusion welded butt joints in steel plates..
IS 2595:2008	Industrial radiographic testing
Surface Protection	
BS EN ISO 1456:2009	Consideration for Electroplating/Galvanising
BS EN ISO 12540:2000	Corrosion protection of metals. Electrodeposited coatings of nickel, nickel plus chromium, copper plus nickel and copper plus nickel plus chromium
BS EN ISO 12944-5:2007	Paints and varnishes. Corrosion protection of steel structures by protective paint systems. Protective paint systems
IS 2629: 1985	Recommended Practice For Hot-dip Galvanizing Of Iron And Steel
IS 3655:1985	Recommended Practice For. Electroplating
IS 3656:1968	mechanical polishing of metals for electroplating
BS EN ISO 6158:2011	Metallic and other inorganic coatings. Electrodeposited coatings of chromium for engineering purposes
IS 13238:1991	Epoxy Based Zinc Phosphate Primer (two Pack)

Safety Codes	
818-1968	(Reaf-03) Safety and healthy requirements in Electric and gas welding and cutting operations
1200 -1976	Method of Measurement of building and civil engineering works part-3 brick work
2750	Specification for steel scaffoldings

IS Code No.	Subject
3696 (Pt I)-1987	Safety code for scaffolds
3696 (Pt II)-1991	Safety code for ladders
3764-1992	Safety code for Excavation works
4130-1991	Safety code for Demolition of Building
5916-1970	Safety code for construction involving use of hot bituminous materials
7293-1974	Working with construction machinery- safety code for
	National Building Code of India—2005
	Safety Manual, Central Water and Power Commission, Ministry of Irrigation & Power, Govt. of India.

3.0 Mandatory Tests

3.1 Notes

Tests as specified and other tests for specialised works or important structures and as required by the Engineer shall be carried out as specified and/or in accordance with the relevant IS.

In case of non-IS materials, it shall be the responsibility of the Contractor to establish the conformity of material with relevant IS and this specification by carrying out necessary tests.

The mandatory tests shall include, but are not limited to, the following:

Material	Test	Field/Lab	Test procedure	Minimum quantity of material / Work for carrying out the test	Frequency of testing
Reinforced Cement Concrete Work					
Water for construction purposes	Ph value, Limits of Acidity, Limits of Alkalinity, Percentage of solids, Chlorides, Suspended matter, Sulphates, Inorganic solids, Organic solids	Lab	IS 3025	Water from each source	Before commencement of work & thereafter: Mandatory – Once in one year from each source; Optional: once in 3 months from each source;
Reinforced Cement Concrete	b) slump test	Field	IS 1199	a) 20 cu.m. for slabs, beams and connected columns. b) 5 Cu.m in case of columns	a) 20 cu.m. Part there of or more frequently as required by the Engineer. b) Every 5 Cu.m.
	c) cube test	Lab	IS 516	a) 20 cu.m. In slab, beams, & connected columns. b) 5 cum in columns	a) every 20 cum of a day's concreting .(Ref. as per frequency of sampling). b) Every 5 cum.
Ready mixed cement concrete (IS-4926)	Cube test	Lab	IS 516 and as per para 6.3.2 of IS-4926-2003	50 cum	One for every 50cum of production or every 50 batches, whichever is the greater frequency
Note : for all other small items and where RCC done in a day is less than 5 cum, test may be carried out as required by Engineer.					
Mortars					
Lime	Chemical & physical properties of lime	Lab	IS 6932 (part 1 to x)	5 M.T.	10 M.T. or part there of as decided by the Engineer
Sand					
	Bulking of Sand	Field		20 CU.M	Every 20 cu.m or part there of or more frequently as decided by the Engineer
	Silt Content	Field	IS 383	20 CU.M	
	Particle Size and	Field/Lab	IS 383	40 CU.M	Every 40 cu.m or

Material	Test	Field/Lab	Test procedure	Minimum quantity of material / Work for carrying out the test	Frequency of testing
	Distribution	as per the requirements of the Employer's Rep.			part there of or more frequently as decided by the Engineer
	Organic Impurities	Field	DO	20 CU.M	Every 20 cu.m or part there of or more frequently as decided by the Engineer
	Chloride & Sulphate Content Tests	Field	Optional		1 per 3 months
Cement					
	Fineness (m^2/kg)		IS 4031 (Part-II)	Each fresh lot	Every 50 MT or part thereof
	Normal Consistency		IS 4031 (Part-IV)		
	Setting time (minutes) a) Initial b) Final		IS 4031 (Part-V)		
	Soundness a) Le-Chat expansion (mm) b) Auto clave(%)		IS 4031 (Part-III)		
	Compressive strength(Mpa) a) 72+/-1 hr b)168+/-2hr		IS 4031 (Part-VI)		
Stone Aggregate					
	a) Percentage of soft or deleterious materials	General visual inspection/ Lab test where required by the Employer's Rep to IS 2386 Part II		One test for each source	One test for each source
	Particle size distribution	Field/Lab	-	10 cu.m	Every 40 cum. or part thereof and:
		Once in three months for each source for coarse and fine aggregates required in RCC works, for a minimum quantity - 10 cum for coarse aggregate and 40 cum for fine aggregate.			
	a) Estimation of Organic impurities	Field/Lab	IS 2386 Part II	10 cu. m	as above
	b) Specific Gravity Field				
	c) Bulk Density				
	Aggregate crushing strength				
	Aggregate Impact Value				
Bricks					
	Testing of bricks / brick tiles for dimensions Compressive strength	Lab	IS 3495 Part I to IV	No of bricks to be selected & bricks lot	Permissible defective bricks in the sample

Material	Test	Field/Lab	Test procedure	Minimum quantity of material / Work for carrying out the test	Frequency of testing
	Water absorption Efflorescence				
				20:2001-10000	1
				32:10001-35000	2
				50:35001-50000	3
				20: for every addl. 50000 or part thereof	1
				If < 2000, As per decision of the ER	
Steel for RCC					
	Physical Tests	**Lab/Field**		**< 100 tonnes**	**> 100 tonnes**
	Tensile Strength		IS 608	Dia < 10 mm 1 sample per 25 tonnes or part thereof Dia is >10 mm < 16 mm: 1 1 sample per 35 tonnes or part thereof. Dia >16 mm 1 sample per 45 tonnes	Dia < 10 mm 1 sample per 40 tonnes or part thereof Dia is >10 mm < 16 mm: 1 1 sample per 45 tonnes or part thereof. Dia >16 mm 1 sample per 50 tonnes
	Retest		IS 1786		
	Rebound Test		IS 1786		
	Nominal Mass		IS 1786		
	Bend Test		IS 1599		
	Elongation Test		IS 1786		
	Proof Test		IS 1786		
	Chemical Tests		IS 786		For every fresh lot of one truck or less as approved by the ER
	Carbon Constituent				
	Sulphur				
	Phosphorus				
	Phosphorus & Sulphur				
Soil Core Test					
	OMC Proctor Density		IS 12175	2 per 50 sqm	As per para 1.10 & 1.11 of IS 12175

4.0 DEMOLITION

4.1 General

Demolition work includes, but is not necessarily limited to, the following tasks:

1 Demolition, removal and disposal of existing structures, mechanical and electrical installations, pipelines and other buried structures and services described in the Employer's Requirements at the project sites or included within the project working areas.

2 Demolition, removal and disposal of those structures, mechanical and electrical installations, pipelines and other buried services encountered during excavation which are not required to be retained for future use.

3 Temporary and/or permanent relocation of existing utilities and other buried services to be retained for future use which are either encountered or affected by demolition works.

4 Temporary and permanent support and protection of existing utilities and other buried services affected by or encountered during demolition works which are to be retained for future use.

5 Temporary and permanent support for existing above ground and buried structures affected by or encountered during demolition works.

6 Filling, backfilling and compaction to grade level further to demolition and removal.

The Contractor shall complete, at a minimum, the tasks included in the following paragraphs in the execution of dismantling, demolition and removal of the required items and shall submit a detailed execution and safety plan to the Engineer for acceptance prior to commencing his activities.

4.2 Existing Services, Utilities and Structures

Work shall be carried out in such a way that no damage is caused to the adjoining utilities, work or property and precautions shall be taken to minimise dust- nuisance.

4.3 Temporary Fencing and Hoarding

The Contractor shall erect a fence around the perimeter of the safe working area required for demolition and shall demonstrate to the Engineer that the extent of this area fulfils safety requirements.

The Contractor shall provide hoarding as required and to the satisfaction of the Engineer, to protect all those who may be affected by those works.

4.4 Demolition and Reinstatement

The Contractor shall demolish the required structures in accordance with the detailed execution plan submitted to the Engineer.

Dismantling shall be commenced in a systematic manner. All materials which are to be dismantled at height, such as during the demolishing of roofs, shall be carefully lowered to the ground and not dropped.

The Contractor shall remove and dispose of demolition waste off-site, in accordance with the regulatory requirements.

The Contractor shall backfill excavated areas and voids due to demolition or the removal of materials, immediately. Backfilling and compaction shall be suitable for the final requirements at that location. As a minimum, backfilling shall include compacted hardcore to 300mm below grade level and granular fill or topsoil to grade as appropriate.

4.5 Removal of Debris

Any serviceable material obtained during dismantling or demolition shall remain the property of the Employer and be separated out and stacked properly. All unserviceable materials shall be disposed of from the site and the site left in a neat and orderly condition, to the satisfaction of the Engineer and in accordance with prevailing regulations.

4.6 Treatment

All the demolition areas shall be rendered clean of all debris.

Where a building has been partially demolished, after the removal of any doors, windows chowkhats etc and unless otherwise required, the sides of jambs, sills, soffits etc shall be plastered in 1:3 cement mortar with neeru finish to render sides, corners, edges etc. true and square.

4.7 Asbestos Based Materials

Asbestos based materials may be present in buildings to be demolished under this contract.

If any suspected asbestos based materials are discovered during demolition work this shall be reported immediately to the Engineer.

Removal of asbestos based materials shall be carried out by a specialist, licensed sub-contractor prior to any other works starting in the location.

5.0 LANDSCAPING

5.1 Clearance of Large Trees, Structures etc

Clearance of large trees and structures shall include the removal of large trees, stumps and structures or parts thereof lying within the site of the works as demarcated at the site.

5.2 Removal of Top Soil

All shrubs, vegetation and other plants shall be removed and cleared from the site and disposed of.

The top 15 to 20cm of fertile topsoil shall be carefully stripped and stored at a suitable location on the site, separate from other excavated material, for future reuse by the Employer for landscaping. Excess topsoil and topsoil unsuitable for landscaping and grassing shall be removed from the site and disposed of.

All debris and material unsuitable for re-use at the site shall be excavated to a depth of 30cm shall be removed from the site.

5.3 Grading

Areas of exposed soil shall be graded, landscaped and planted to produce a neat and attractive environment not subject to ponding.

Where required, areas shall be refilled to correct grade with selected suitable excavated material from the site, or suitable material imported to the site. The quality and compaction of such fill or embankments shall be in accordance with the requirements of Section 6.0.

Backfilling and compaction shall be suitable for the final requirements at the given location. As a minimum, backfilling shall include compacted hardcore to 300mm below grade level and granular fill or topsoil to grade as appropriate.

The Contractor shall, where necessary, refill and compact any existing pits, wells, existing dry-wells or other areas where the levels are below the general finished grade.

5.4 Fencing

5.4.1 Mild Steel Posts and Struts

Mild steel posts and struts shall be free from rust, scale, cracks, twists and other defects and shall be fabricated to the required shape and size out of the suitably sized sections. The posts and struts shall have split ends for proper fixing and shall be embedded in cement concrete of mix 1:3:6. The exposed surfaces of the posts and struts shall be painted with two coats of synthetic enamel paint of approved make and shade over a coat of approved primer.

5.4.2 Reinforced Concrete Posts and Struts

Reinforced concrete posts and struts shall be of a standard size and be cast in suitable bases in cement concrete M-20 and shall have appropriate reinforcement and dimensions. The posts and struts shall be free from honeycombing, cracks and other defects.

After casting, the posts/struts shall be cured for a minimum period of 7 days without being moved. After 7 days curing the posts/struts shall be moved to a levelled area and stacked for 14 days of further curing. After 21 days of curing, the posts/struts may be transported for fixing in position.

5.4.3 Spacing of the Posts and Struts

Posts shall be installed at 3 m. centres unless otherwise specified or as agreed with the Engineer, to suit the dimensions of the area to be fenced. Every 10th post, last but one end posts, corner posts and posts where the level of fencing changes in steps and end post when the fencing changes its direction shall be strutted on both sides, or as agreed with the Engineer. End posts where barbed wire fencing is discontinued shall be strutted on one side only.

5.4.4 Fixing of Mild Steel/Reinforced Concrete Posts and Struts

Pits of size 45 x 45 x 45cm. deep, shall first be excavated centrally in the direction of the proposed fencing work, true to line and level to receive the posts. For struts, the pits shall be excavated to receive a minimum of 15cm concrete cover at any point to suit its inclination.

The pits shall be filled with a 15cm layer of cement concrete of 1:2:4 mix. The posts and struts shall then be placed in the pits to the required height above ground level and held true to line, plumb and position by providing adequate temporary supports and then filled with cement concrete so that the posts are embedded. The concrete in foundation shall be watered for at least seven days to ensure proper curing.

5.4.5 Barbed Wire

Barbed wire shall conform to IS 278-1978.

5.4.6 Chain Link

The chain link shall be plastic coated galvanised mild steel of approved manufacture and colour and of appropriate size, gauge etc. The base materials of the wire shall be of good commercial quality mild steel. The wire shall be circular in section, free from rust, scale, cuts, welds and other defects and shall be uniformly galvanised.

5.4.7 Fixing of the Chain Link Fencing to Mild Steel/Reinforced Concrete Post

The chain link fencing shall be fixed first to the end post with the approved GI U type clamps threaded at both ends and GI nuts, bolts and washers and with a 6mm diameter full height galvanised anchor bar. After fixing the chain link at the end post, it shall be stretched tightly and fixed to the next posts sequentially using the clamps and bars etc leaving 50mm ground clearance, if soil, or 20mm if surfaced. At points of change in the level of the fencing, the necessary links shall be adjusted suitably as per the manufacturers' recommendations.

5.4.8 Mild Steel Crimpnet Gate

All steel work, pipe frame work and crimpnet shall be galvanised and of suitable sizes and sections and shall conform to relevant IS specifications. The crimpnet shall be minimum 25 x 25mm x 8 g unless otherwise stated and of approved manufacturer.

For each leaf of the gate, the crimpnet shall be welded to an internal angle iron frame of suitable size. The iron frame shall then be fixed to the 50mm dia seamless pipe outer frame of by means of 65mm long angle iron lugs welded together. Suitable cleats for the locking arrangement shall be welded at a convenient height. Both the leaves of the gates shall be fitted with suitable hinges provided on the galvanised mild steel channel posts. The side post shall be welded with mild steel plates 250 x 150 x 5mm at the bottom. These posts shall be properly embedded in cement concrete foundations of suitable sizes and be allowed to set properly. All the assembly shall be properly erected correct to line, level, plumb and allow easy and proper movement of the gates.

The steel parts shall be thoroughly cleaned and painted with red oxide primer of approved make and shade. Final painting with two coats of synthetic enamel paints of approved shade and make shall be carried out to the approval of the Engineer.

6.0 EARTHWORK AND EXCAVATION

6.1 Site Clearance

Before the earthwork is started, the areas coming under cutting and filling shall be cleared of all obstructions, loose stones, shrubs, vegetation, grass, brush-wood, trees and saplings of a girth up to 30cm. measured at a height of one metre above ground and rubbish removed from of the area under clearance. The roots of trees shall be removed to a minimum depth of 60cm below ground level, or a minimum of 30cm below formation level whichever is lower and the hollows filled up with compacted earth.

The trees with a girth above 30cm at a height of one metre above ground shall only be cut after permission of the Engineer is obtained in writing.

Any useful materials obtained from the site will remain the property of the Employer and shall be properly protected and stored. The Contractor shall dispose off other materials off site.

6.2 Setting Out and Making Profiles

The Contractor shall erect masonry or concrete pillars at suitable points in the area to serve as bench marks for the execution of the work. These bench marks shall be connected with GTS or any other permanent bench mark approved by the Engineer. Necessary profiles with pegs, bamboos and strings shall be made to show the correct formation levels before the work is started.

6.3 Excavation

Excavations shall be prepared with shallow side slopes to minimise the risk of slope failure. Where this is not possible and the depth exceeds 0.6m then the trench slopes must be stabilised. Prior to man entry into the excavation the Contractor must ensure the excavation is stable. Further checks should be made following periods of rainfall or when excessive loadings occur within close proximity to the excavation.

No excavated material shall be placed, even temporarily, nearer than three metres to the outer edge of an excavation.

The removal of obstructions that would interfere with the proper execution and completion of the work shall conform to the correct lines and grades or be limited generally to 60cm beyond the outer limit of the structure. It shall be the Contractor's responsibility to provide all required pumping, ditching or other approved measures for the removal or exclusion of water from excavations.

The Contractor shall notify the Engineer before any ground is disturbed and shall conduct a ground level survey. The ground levels shall be taken at 5 to 15 metres intervals in uniformly sloping ground and at closer distances where local mounds, pits or undulations occur. The ground levels shall be recorded in field books and plotted on plans, which shall be signed by the Contractor and the Engineer, before the earth work commences.

When excavating to the required levels for the foundation of any structure or to the required limits for the face of any structure abutting undisturbed ground, the Contractor shall not excavate the last 150mm until immediately before commencing the constructional work. Should the Contractor have excavated to within 150mm above these specified levels or to within 150mm of these specified limits before he is ready or able to commence the construction work, he shall excavate further to remove not less than 150mm of material immediately before commencing the construction work.

The excavations shall be carried out systematically. No under-pining or undercutting will be allowed. The bottom and sides of excavation shall be dressed to proper levels, slopes, steps, cambers etc by removing high spots and filling and thoroughly as necessary.

The width of excavations shall generally be of the width of the mudmat concrete and depth as required by the design and according to availability of the desired bearing capacity of soil below. The minimum depth of foundations for all structures, equipment, buildings and frame foundations and load bearing walls shall be 1.50 m below average ground level, whether the foundation is in soil or in murrum. For any excavation, if taken below the required depth and level, the Contractor shall fill such over-cut to the specified level with 1:4:8 cement concrete in the case of all types of soils and with 1:2:4 cement concrete in the case of soft or hard rock.

The Contractor shall provide adequate ventilation and efficient apparatus to keep all excavation trenches, tunnels and heading structures, sewers and manholes free from all noxious gases and he shall take precautions to ascertain that they are in a safe condition before allowing workmen to proceed.

After the excavation is completed, the Contractor shall notify the Engineer to that effect and no further work shall be taken up until the Engineer has approved the depth and dimensions and also the nature of the foundation material. Levels and measurements of the excavation shall also be recorded prior to taking up any further work.

6.4 Excavation Side Slopes

Loose soil or boulders shall be removed from the sides of the trenches before workmen shall be allowed into the excavation and the trench sides shall be stabilized with screening or other methods agreed with the Engineer.

6.5 Undercutting of Adjacent Works

In no case shall the Contractor undercut the foundations of adjacent facilities. Should such a situation be envisaged or develop the Contractor shall provide protection measures as necessary to ensure the safety of the adjacent facility.

The Engineer shall be given every opportunity to review the methods adopted by the Contractor and where required, the Contractor shall satisfy the Engineer of the adequacy of the methods employed.

6.6 Shoring

The Contractor shall be responsible for the design of shoring for the proper retaining of the sides of trenches, pits etc with due consideration to any traffic or other superimposed loads. Shoring shall be of sufficient strength to resist the pressure and ensure safety from slips and to prevent damage to work and property and injury to persons. Any shoring shall be removed after the items for which it is required are completed. Should slips occur, the slipped material shall be removed and slope dressed to a modified stable slope.

6.7 Trench Excavation

The Contractor shall not keep trenches open for unduly long periods, creating public hazards, such that laying and jointing of pipes can reasonably be expected to be completed and the trench refilled not later than three days after excavation of the trench, except by special permission of the Engineer.

Loose soil or boulders shall be removed from the sides of the trenches before workmen shall be allowed into the excavation and the trench sides shall be stabilized with screening or other methods agreed with the Engineer.

Excavation for pipe trenches in hard rock shall be carried out so that the clearance between the pipe, when laid in position and the sides and trench bottom shall be kept to the minimum limits necessary to provide for the thickness of bedding and surround to the pipe.

The minimum width of trenches measured at the crown of the pipe shall permit adequate working space. The trenches may be widened at sockets and other structures as may be necessary.

Care should be taken to avoid excessive trench widths and thereby increasing the load on the pipes. Where this is the case the Contractor shall provide either special bedding or stronger pipes.

Over-excavation of Trench Bottoms:

1 All pipeline trenches shall be excavated to a depth of 150mm below the bottom of the outside of the pipe and backfilled with the appropriate bedding.

2 All excavation below the required level shall be refilled with compacted bedding material.

6.8 Surface Reinstatement

6.8.1 Surface Reinstatement Outside Roads and Footpaths

In areas outside roads and footpaths, after backfilling trenches, the Contractor shall replace all top soil previously removed, spreading it evenly over the full stripped area. Areas grassed before commencement of work shall be suitably prepared and sown with grass seed of equivalent quality and maintained.

6.8.2 Road and Footpath Reinstatement

(i) Unclassified Roads

Backfilling shall be carried out in accordance with this specification to within 300mm of the finished ground level. The last 300mm shall be backfilled with material, approved by the Engineer, and which shall, as far as practicable, match the existing surface both in quality and level.

(ii) Macadamized and Premixed Roads

Backfill, compaction and finishing of macadamized and premixed roads shall be reinstated in accordance with Section 13.0 of this specification. The finished surface shall match the undamaged sections in quality and level.

7.0 EXCAVATION DEWATERING

7.1 General

Continuous operation of dewatering systems shall be required to complete all portions of the works where dewatering is necessary to prevent inflow and collection of surface water or groundwater, or to protect adjacent properties or constructions from damage resulting from a rise or fall in groundwater levels.

Dewatering systems shall effectively intercept and remove water from the strata and thus enable the excavations to be kept dry when necessary.

The Contractors shall provide and operate all pumps, engines and machinery necessary to keep excavations clear of water. The pumping shall be continued until after the execution of any portion of the work and continued afterwards as necessary.

Where ground water is encountered or anticipated the Contractor shall provide sufficient pumps to handle the ingress of water and shall provide, and maintain in working order, standby pumping units to be available and employed in the event of mechanical failure. The Contractor shall also arrange for night and day management and operation of the pumps as necessary to ensure that at all times and weather the works may proceed.

The Contractor shall furnish for the Engineer review, the proposed drawings and method statements giving the intended plan for dewatering and re- charging operations. These should include locations and capacities of dewatering wells, well point, pumps, sumps, collection and discharge lines, standby units, recharge system (if any), water disposal methods, monitoring and settlement, measuring equipment and data collection.

7.2 Components of Dewatering Systems

Units of standard manufacture and in good working order shall be used. Unserviceable equipment shall be removed from the site. Major items of equipment for which spare parts are not available from local suppliers shall not be used.

7.3 Execution

7.3.1 Preparation

Coordination: The dewatering installation shall be laid out and installed outside the limits of the permanent works, without interfering with access or other activities.

Barricades, Shelters and Safety: Vital sections of the works shall be protected from accidental damage and barricades and suitable prominent signs shall be provided to indicate and where necessary, isolate hazardous areas.

7.3.2 Performance

Dewatering arrangements shall be adequate to enable underground and below-grade work to be performed in the dry except where sections of the work have been specified to be done in the wet. Dewatering shall, wherever required or agreed, be continuous from commencement to completion, including placing and compaction of back-fill.

When and where required by the Engineer, the Contractor shall provide an approved monitoring system to measure groundwater levels and settlement.

7.3.3 Maintenance of Existing Water Table

Where deep pits and heavy, continuous dewatering have to be maintained for long periods in developed areas, the possible effects of groundwater depletion beyond the range of usual fluctuations shall be given due consideration before commencement. Special methods shall be adopted, as necessary, to avoid such dangers. Any observations or complaints of subsidence in the vicinity shall be promptly brought to the notice of the Engineer and corrective measures adopted immediately.

7.3.4 Protection of Existing facilities

Adequate standby units and spares shall be provided by the Contractor to ensure uninterrupted dewatering. Where any sloped excavation potentially endangers any existing facilities or structures, the Contractor shall provide shoring, sheeting and bracing to the satisfaction of the Engineer.

7.3.5 Drainage

During the entire course of operations at any site, the Contractor shall provide and maintain an effective drainage system to prevent inundation of the site. The effluent from the drainage system shall be disposed of as approved by the Engineer.

Grading in the vicinity of excavations shall be such as to exclude rain/surface water from draining into the excavations. The excavation shall be kept clear of rain or such other water by suitably pumping out.

Care shall be taken to ensure that the water is discharged sufficiently away from existing foundations to keep it free from nuisance to other works.

7.3.6 Removal

When no longer needed for dewatering or control operations, the equipment used for such purposes shall be removed from the site. This shall be done after monitoring and settlement measuring operations, if any, are completed and the removal of the equipment is approved. Any underground components such as well-points may be abandoned in place only to the extent of the approval of the Engineer.

The Contractor shall not allow any accumulation of water either from the discharge of their dewatering pumps or their water connections on the site. If an accumulation is unavoidable, it shall be treated with insecticides to the satisfaction of the Engineer.

8.0 BACKFILLING AND FILLING

8.1 Materials

Fill material shall be free of rubbish, roots or debris of any sort. Boulders, rock or concrete fragments over 100mm in size shall not be present in backfill material. The fill material shall be subject to the approval of the Engineer.

Acceptable fill shall consist of suitable earth or granular material that has been retained from excavations, taken from designated borrow areas or been hauled from an approved off-site source. This material will be acceptably dry, free from roots, large stones, boulders or large broken rocks, refuse, vegetable matter, topsoil, silt or debris.

Pea gravel shall be washed, rounded durable stone, 9.5mm to 4.74mm in size with no more than 2% passing a 75 micrometer sieve.

All other materials, not specifically described but required for proper completion of the work of this section, will be subject to the approval of the Engineer.

The Contractor shall reserve, separate and stockpile suitable excavated materials for use in backfilling later.

If the Engineer deems the native material to be unsound for the purpose of backfill and an adequate amount of suitable material cannot be so collected, or if the Contractor fails to collect and preserve the requisite quantity, the Contractor shall furnish the additional quantity required. The additional material shall be natural sand, gravel or crushed murrum and shall be readily incorporated in a 100mm lift and containing not more than 25% by weight of material passing a No. 200 sieve.

If a portion of the excavated materials is found to be unsuitable for use as backfill, the Contractor shall provide suitable material from another source.

8.2 Execution

8.2.1 General

The use of stones, rocks or concrete fragments of more than 100mm in their greatest dimension shall not be permitted in any trench backfill and stones, rock or concrete fragments larger than 60mm shall not be permitted in the backfill within 300mm of the pavement sub grade or within 300mm of any utilities.

Some backfilling may have to be carried with sand, as agreed with the Engineer. The sand used shall be medium grain, clean, sharp, angular, hard and durable, free from clay, mica and soft flaky pieces and free from other impurities. Sea sand shall not be used except under special circumstances. All sands must be well washed and cleaned before use.

Sand fill shall be kept flooded with water for 24 hours to ensure maximum consolidation. The surface of the consolidated sand shall be dressed to the required level or slope. Construction of floors or other structures on sand fill shall not be started until the Engineer has approved the fill.

Backfilling work shall be suspended at any time when satisfactory compaction results cannot be obtained due to rain, or other adverse conditions in the field. The surfaces of any fill shall be maintained with a slope at all times to provide proper surface drainage.

Materials shall be compacted in maximum 300mm layers and shall be of the proper moisture content before compacting to facilitate obtaining the required compaction.

Temporary planking and formwork etc, shall be removed as backfilling progresses to avoid the formation of voids.

Excavated foundations shall be inspected and approved by the Engineer before proceeding with further work, including placing of any mudmat, reinforcing steel etc.

Complete final grading at grassed or seeded areas shall be to within 50mm.

The Contractor shall repair damage and correct deficiencies that may result from the settlement of backfilled areas.

8.2.2 Foundation Bedding

Unless otherwise specified, new concrete foundation floors and base slabs shall be constructed on a suitably prepared formation and 100mm PCC mudmat.

Bedding material, except for clear crushed stone, shall be compacted by mechanical means at optimum moisture content to a value of 98% standard Proctor maximum dry density (SPD).

8.2.3 Backfill around Structures

Backfill under this item shall be considered as all replaced excavation or new embankments adjacent to structures. No backfill shall be placed against any structural elements until the method has been approved by the Engineer. Backfilling shall be done as soon as practicable after the required conditions are satisfied. Backfill against waterproofed surfaces shall be carefully placed to avoid any damage to the waterproofing material.

The scope of work for filling and backfilling shall include filling for all the buildings covered under the contract.

Mechanical tampers or other approved compactors shall be used to compact all backfill and embankments within 1.2m of a structure and heavy compaction equipment beyond 1.2m of this area. The backfill shall be placed in 200mm un-compacted depth lifts.

Backfilling shall only be carried out after the concrete or masonry has fully set and shall be done in such a way as not to cause under-thrust on any part of the structure.

All timber shoring and formwork left in excavations shall be removed after use and waste materials shall be cleared out from the excavation.

All the space between foundation masonry or concrete and the sides of excavations shall be backfilled to the original surface level with approved materials in layers not exceeding 300mm in thickness, watered and well consolidated by means of rammers to at least 90% of the consolidation obtainable at optimum moisture content (Proctor density). Flooding with water for consolidation will not be allowed.

Areas inaccessible to mechanical equipment such as areas adjacent to walls and columns etc shall be tamped by hand rammer or by hand held power rammers to the required density.

Tests to establish proper consolidation as required will be carried out by the Contractor. Two tests per 50 m^2 will be taken to ascertain the proper consolidation.

Unless otherwise specified or approved by the Engineer, the period of time after which the Contractor may place backfill against or on top of any cast-in-place structures is greater than or equal to the time periods as shown in the table below:

Operation	Location	
	Against sides of structures	On top of structures
Placement of loose backfill	5 days	21 days
Compaction of backfill	7 days	28 days

The Contractor shall observe any special backfilling requirements or materials, such as those for sub-drains and perimeter drain filters and insulation/expansion material where required.

Where walls are waterproofed on the exterior, or where insulation/expansion material has been placed, backfill shall be placed by hand to prevent damage to the waterproofing membrane. Should any damage to waterproofing occur, such areas shall be re-excavated and the membrane or coatings repaired or replaced to the satisfaction of the Engineer.

Where fill is required on both sides of a wall, foundation or culvert, it shall be deposited layer by layer at each side alternately.

8.2.4 Filling Beneath Plinths and Floors

Construction of floors or other structures on fill shall not be started until the Engineer has inspected and approved the fill.

Suitable fill material shall be placed in 15cm layers, each layer being well watered and consolidated by approved hand or mechanical tampers or other suitable means to achieve the required density.

Gravel if required to be filled under floors, shall be single washed gravel of approved quality and of size varying from 12mm to 20mm it shall be uniformly blinded with approved type of soil and/or sand to obtain full compaction. Gravel shall be placed in 15cm layers and shall be well watered and rammed entirely to the satisfaction of the Engineer.

8.2.5 Slab Base (Rubble Hard Core)

The rubble shall be of the best variety of black trap/granite/basalt or other approved stone available locally. The stone shall be hard, durable, free from defects and of the required size and shall be approved by the Engineer before incorporation in the work.

The stone used for the work shall be broken rubble of fairly regular shape and free from weathered, soft or decayed pieces.

8.2.6 Workmanship

The bed on which rubble soling is to be laid shall be cleared of all loose materials, levelled, watered and compacted and approved by the Engineer before laying the rubble soling. Cable or pipe trenches shall be completed before the soling is started.

Over the prepared surface, the stone shall be set as closely as possible and well packed and firmly set. The stones shall be of full height and shall be laid so as to have their bases of the largest area resting on the sub-grade. Soling shall be laid in one layer of 230mm or 150mm or other specified thickness and no stones shall be less than 230mm or 150mm depth or specified thickness of soling with a tolerance of 25mm

After packing the stones properly in position, the interstices between them shall be carefully filled with quarry spoils or stone chips, to obtain a hard, compact surface.

The entire surface shall be examined for any protrusions and the same shall be knocked off by a hammer and all interstices shall be filled with approved murrum. Excess murrum over the surfaces shall be removed. The surfaces shall then be watered and consolidated with mechanical or sufficiently heavy wooden tampers and log-rammers, as approved by the Engineer, to give the required slope or level and density of sub-base. After compaction, the surface shall present a clean look.

Adequate care shall be taken by the contractor while laying and compacting the rubble soling to see that concrete surfaces in contact with soling are not damaged.

8.3 Trench Backfilling

Backfilling over pipes shall not take place until after the pipes have been successfully tested except for bracing purposes.

Trench backfilling shall start at top of theconduit bedding. All materials below this elevation are considered as bedding.

Filling in trenches for pipes and drains shall be commenced as soon as the joints of pipes and drains have been tested and passed.

The bedding between the bottom of the trench and up to a specified level as directed by engineer. shall consist of granular material or murum. The maximum size of coarse material or stone shall not exceed 20mm. The bedding shall be placed in layers not exceeding 150mm watered and consolidated, taking care that no damage is caused to the pipe. Placing the bedding around thin-walled pipes shall receive special consideration.

The backfill materials shall be suitable excavated material, gravel, crushed stone or murrum or sand, free from any boulders and lumps of hard earth larger than 100mm in size. Backfill material shall be spread evenly in 225mm horizontal layers, brought to approximately the optimum moisture content and then tamped or rolled until 98% of the maximum dry density is achieved as determined by the standard Proctor Test as per IS 2720 (Part VII) or a higher value if one is required in particular circumstances.

Backfill for cast-in-place piping, appurtenances or structures such as manholes shall start at the sub-grade for the structure. Backfill shall be brought up simultaneously and equally on all sides of the structure.

Care shall be exercised during backfill operations to prevent damage or dislodging of the pipes or conduits. Any damage or dislodging of pipes or conduits shall be repaired to the satisfaction of the Engineer.

8.4 Site Grading

Generally site grading shall include the grading of un-surfaced areas to the final landscape profile with due allowance for topsoil and turfing or as approved by the Engineer. The grading shall ensure that the ground profile slopes away from the structures and does not create ponding.

The site grading shall be subject to the approved by the Engineer before any landscaping is commenced.

Fill for site grading shall be placed in 300mm layers and compacted to 90% SPD.

Imported fill material shall be used if there is insufficient excavated material on the site.

Ditches and swales shall include trim, grade and slope, to the satisfaction of the Engineer.

8.5 Roads and Parking Areas

The backfill in areas under roads and parking areas shall be filled to the underside of the sub-base using approved granular fill and compacted in layers of 150mm to 98% SPD. In areas adjacent to structures thinner layers may be required to suit lighter compaction equipment.

In road cut sections, unsuitable material (silt, humus, topsoil etc) shall be excavated and replaced to the level of the sub-base with approved granular fill, ensuring that the minimum excavation in cut sections extends to the depth of the road base.

9.0 EMBANKMENTS

9.1 General

This work shall include the clearing of the site, setting out and preparing the ground and forming the embankments required for the roads, paths etc with approved excavated or imported material, spread in maximum 200mm layers, watered and compacted to the 98% SPD, to line, curve, grade, camber and cross section and dimensions as approved by the Engineer.

Embankments shall be set out by fixing batten pegs at regular intervals before commencing the earthwork. The pegs shall be fixed 0.5 metres back from the limits of the fill and painted in a distinctive colour.

The size of the coarse material in the fill shall not exceed 50mm unless approved by the Engineer. Such material shall be free of logs, brush, stumps, roots rubbish, organic matter, humus, or any other unsuitable material.

The Contractor shall carry out the tests to determine the maximum density of the material to be used by the Proctor method before starting the work.

If the cross slopes are steeper than 1 in 3, steps with reverse slope shall be cut into the slopes to give proper hold and seating to the bank as approved by the Engineer. The top 15cm of soil shall be scarified and watered and compacted to 98% SPD density before any embankment material placed.

Fill shall be placed extending to the full width of the embankment, including the slopes at the level of the particular layer, and 300mm. more on both sides to allow for compaction of the full section. The extra loose earth at the edges shall be trimmed after completion of the embankment leaving the correct section fully compacted.

Each layer of the embankment shall be watered, levelled and compacted as specified before the succeeding layer is placed. The surface of the embankment shall, at all times during construction, be maintained in such a manner to prevent ponding. Water to be used shall be free from all harmful contaminants and approved by the Engineer.

If the material for the embankment contains less than the optimum moisture content, water shall be added to the 100 mm embankment layers to bring moisture uniformly up to the optimum. If the excavated material contain more than the required moisture, it shall be allowed to dry until the moisture is reduced to required extent. If due to the wetness, the moisture content of the soil cannot be reduced to the appropriate amount by exposure, embankment work shall be suspended until suitable conditions prevail.

When a loose layer is placed, levelled and appropriately moistened or dried, it shall be compacted by 8 to 10 tonne power roller, sheep's foot rollers or heavy hauling or dozing equipment until 98% of the maximum dry density is achieved, as determined by the standard Proctor Test as per IS 2720 (Part VII) or a higher. If on testing, the density is found to be less than 98% of the Proctor density, the Contractor shall carry out additional compaction as necessary to get the specified density. If the density cannot be improved by such reasonable efforts, the work may be accepted as substandard work by the Engineer, if he thinks it is not harmful for the purpose.

Embankments not accessible to rollers, such as those adjoining bridges, culverts and other works shall be carried out independently of the main embankments and shall have the layers placed in 150 mm height and each layer shall be moistened and thoroughly compacted with mechanical or manual tampers. Before placing the next layer, the surface of the under layer shall be moistened and scarified to provide a satisfactory bond with the next layer.

Embankments shall be finished and dressed to a smooth and even finish, in conformity with the alignment levels and cross sections and dimensions required. On curves, sections shall be provided with super elevations and increased widths as approved by the Engineer.

The joining of old and new embankments shall be done by stepping in an overall slope of 1 to 5.

The surface of the embankment shall, at all times during construction, be maintained at such a cross-fall to shed water and prevent flooding. All rain water shall be drained away from the toe of the embankment. The Contractor shall maintain the embankment in an approved manner throughout the Contract.

Tests on the embankments shall include the following:

Sr. No.	Test	Frequency
1.	Plasticity	As directed by the Engineer
2.	Density	Each soil type to be tested. 1 test per 8000 m^3 of soil
3.	Deleterious content	As directed by the Engineer
4.	Moisture content	1 test for every 250 m^3 of soil
5.	CBR test	As required by the Engineer

Density tests shall be carried out for the embankment work during the progress of the work. One set of three core samples for every 1,000 m2 area of each layer of embankment work shall be taken and tested. The average density shall not be less than 90% of the Proctor density, obtained in the laboratory.

The arrangements for obtaining the samples and transporting to a laboratory shall be made by the Contractor.

10.0 SHEETING SHORING AND BRACING

10.1 General

10.1.1 Description

The Contractor shall supply and install piling, diaphragm walls, bracing, underpinning shoring and dewatering systems to adequately protect existing buildings and facilities and to maintain the excavations required for the construction of facilities.

The Contractor shall be solely responsible for the adequacy of the piling, diaphragm walls, bracing and shoring on the site to maintain safety and prevent damage to existing buildings, facilities, excavation and new construction. The configuration of the proposed shoring and bracing shall be approved by the Engineer.

To obtain the approval of the Engineer, the Contractor shall, if so required, provide drawings of the proposed sheeting and bracing including sheeting sizes, waling, rakers, anchor systems, struts, earth anchors, anchor piles, tie rods and other components pertinent to the effectiveness and adequacy of the shoring and bracing.

10.2 Existing Conditions

10.2.1 Soils

Any information provided by the Employer relating to boring logs and soil tests carried out are supplied in good faith. Any conclusions drawn from them, however, shall be the responsibility of the Contractor.

Where slopes steeper than the natural angle of repose or other conditions inconsistent with the safety of personnel required to work within an excavated area are encountered such excavations shall be sheeted or shored as may be needed to provide adequate safety.

The Contractor’s attention is specially drawn to the necessity for a thorough study of the site and soil conditions, groundwater levels and other relevant factors, particularly in the case of any wet wells, incoming sewer connections and force mains at great depths, before deciding on the necessity or otherwise of sheeting, shoring and bracing and if provided, the adequacy of same.

10.2.2 Obstructions

Prior to driving sheeting etc, the Contractor shall locate existing facilities in service, if any, and avoid sections that may interfere with such. If such avoidance is not possible the Contractor shall relocate the facility or arrange for its relocation as required to clear the interference. Any action proposed in such circumstances shall be subject to the prior approval of the Engineer.

10.3 Products and Materials

10.3.1 Steel Piling and Shoring

Steel sheet piles shall conform to the requirements of IS 2314 and the steel for walls, struts braces and tie rods shall comply with IS 226. Any materials to be incorporated into the permanent works shall be new.

Piles shall be of the types and sizes indicated in the approved shop drawings or as specified herein and shall be of a design that provides continuous interlocking throughout their entire lengths. Standard handling holes shall generally be provided located approximately 100 mm below the top of each pile.

10.3.2 Timber Shoring

Where the Contractor elects to use timber shoring for trench and structure excavations he shall provide details of the shoring he proposes to adopt, taking into consideration the nature and condition of the soil to be excavated and the depths to which the excavations are to be carried. The quality and strength of the timber and the cross-sectional details and spacing of the shoring, walling and struts together with the calculations, where required or requested by the Engineer, demonstrating the structural adequacy of the proposed shoring and timbering shall be included in the submittals.

Approval of the submittals shall however not relieve the Contractor in any way from his sole responsibility for the stability of the works and the safety of the employees engaged on the work and of the general public.

10.3.3 Dimensions

Piles and ancillary structural members shall be as shown on the approved shop drawings. All procedures shall be subject to the approval of the Engineer approval.

10.4 Execution

10.4.1 General

Piling shall be accurately located and driven to the required depths, plumb and true to line with each pile interlocking with the adjacent pile throughout its entire length. Frames, temporary walls templates, guide-frames and bracing as are necessary shall be installed to guide and support the sheet piling in the correct position and alignment.

The choice of specific construction procedure appropriate for any works or phase thereof shall be the Contractor's responsibility. The procedure adopted shall meet the requirement of the works and specific procedures adopted such as construction methods, shoring, sheet piling, bracing, dewatering etc are at the option of the Contractor. He shall however submit to the Engineer a detailed construction procedure prior to commencement of work.

10.4.2 Driving

Piling shall be driven by approved methods in such a manner as not to subject the piles to damage and to ensure interlocking throughout the length of each pile.

Pile hammers shall be of the size and type needed to achieve the required penetration with the minimum damage to the piles. Hammers shall be maintained in a proper alignment with the piles during driving by use of suitable leads or guides. A protective driving cap of approved design shall be used, as required, to minimize the damage to tops of piles. Unless otherwise approved by the Engineer, pile driving shall be done without jetting.

The piles shall be driven plumb and if the sheet piling goes progressively out of plumb, corrective steps shall be taken. If necessary, the piles shall be withdrawn and re-driven so that no part of any pile is more than 75 mm from the design location of the alignment on completion of the work.

Piling shall be driven in stages. No sheet pile, or pair of piles if driven in pairs, shall be driven more than one-third of its length before the adjacent sheet pile is set. Piling that is damaged or driven without interlocking shall be withdrawn and re-placed. The Engineer is empowered to order withdrawal if he has reasonable grounds to suspect damage. Any encroachment of piles upon concrete piles shall be sufficient grounds for withdrawal and replacement.

If obstructions are encountered during driving, the piles in question shall be driven at least to the specified refusal driving resistance after adjacent piles have been set and driven. However, the number of sheet piles permitted to be driven short of the required depths shall be limited in the field by the Engineer and if so approved, the Contractor shall remove obstructions encountered by whatever means necessary.

10.4.3 Splices

Splices shall be avoided if practicable, but where unavoidable shall be designed to develop the full strength of the piling. Drawings of the proposed splices shall be approved by the Engineer prior to execution. Extreme care shall be exercised to align the spliced sections so that the axis of the pile will be straight and that the interlocks of the piles shall form a straight, smooth and continuous groove.

10.4.4 Driving Resistance

Steam, air or diesel hammers shall be provided with a rated energy not less than the hammer manufacturer's recommendation for the total weight of pile and the type of subsurface material to be encountered. The Engineer may require the Contractor to change the hammer in use to obtain the required minimum penetration.

Piling shall be driven to such depth as required to provide the degree of protection needed.

10.4.5 Stressing Rods

All tie rods shall be stressed to minimum of 10 percent of their design load. The Contractor shall submit to the Engineer for his approval the proposed procedure for pre-stressing tie rods.

11.0 ANCHORS TO RESIST UPLIFT

The use of anchors to resist uplift shall not be permitted.

12.0 ANTI TERMITE TREATMENT AND PESTICIDES

12.1 General

Anti-termite treatment shall be applied to structures during the early stages of construction in the foundation trenches for columns, plinth beams, pile caps, brick walls, service trenches, lift pits, steps, ramps, in the top surfaces of plinth filling, at junction of walls and floor, in expansion joints etc in stages as detailed in this specification. Unless otherwise stipulated, the anti-termite treatment will be carried out as per IS6313 (part II) 1981 and/or as per direction of the Engineer.

Soil treatment shall be applied during the construction stages of the sub-structure up to plinth level.

12.2 Products

Pesticide and/or termiticide emulsions, recommended by the Indian Pest Control Association (IPCA) and approved by the Engineer, shall be used uniformly over the area to be treated. The Contractor shall comply with the requirements on Contractor's licensing, certification and record keeping.

The Contractor shall submit certification for the chemicals purchased and obtain verification that the containers of the chemicals are sealed from the Engineer before preparing the emulsion for the treatment.

The pesticide shall be dispersed uniformly in the soil and to the required strength to form an effective chemical barrier.

12.3 Delivery, Storage and Handling

Pesticides shall be delivered to the site in sealed and labelled containers in good condition as supplied by the manufacturer or formulator. The pesticides shall be stored, handled and used in accordance with manufacturer's instructions. Labels shall bear evidence of registration as per the IS or appropriate regulations.

12.4 Site Preparation

In order to ensure uniform distribution of the chemical emulsion and to assist penetration, the following site preparation shall be carried out:

1 Remove all felled trees, stumps, logs or roots from the site.

2 Remove any concrete formwork, levelling pegs, timber off-cuts and other builder's debris from the area to be treated.

3 If the soil to be treated is sandy or porous, preliminary moistening will be required to fill capillary spaces in the soil to prevent the loss of emulsion through piping or excessive percolation.

4 In the event of water logging of foundation, the water shall be pumped out before application of the chemical emulsion and it should be applied only when the soil is absorbent.

5 On clays and other heavy soils where penetration is likely to be slow and on sloping sites, where the treating solution is likely to run-off, the surface of the soil should be scarified to a minimum depth of 75 mm.

6 All sub-floor levelling and grading shall be completed, all cuttings, trenches and excavations shall be completed with backfilling in place. If this is not done, supplementary treatments shall be carried out to complete the barrier.

At the time of application, the soil shall have sufficiently low moisture content to allow uniform distribution of the treatment solution throughout the soil. Application of the chemicals shall not be made during or immediately following heavy rains or when conditions may cause runoff and create an environmental hazard.

12.5 Application

The Contractor shall apply termiticide to the soil material which will be covered by or lie immediately adjacent to the buildings and structures to provide a protective barrier against subterranean termites.

The termiticide shall be applied as a coarse spray and in such manner as to provide uniform distribution onto the soil surface. This treatment shall be applied prior to placement of a vapour barrier or waterproof membrane and prior to concrete pouring. Where treated soil or fill material is not to be covered with a vapour barrier or waterproof membrane, the Contractor shall exercise adequate precautions to prevent its disturbance.

The chemical emulsion will be applied uniformly by sprayers at the prescribed rates as detailed below in all the stages of the treatment.

12.5.1 Treatment in Foundation Trenches

In case of normal wall load bearing structures, column pits, wall trenches and basements, the treatment shall be at 5 l/m^2 of surface area of the bottom and sides to a height of at least 300 mm. After the foundation work, the sides shall be treated at 7.5 l/m^2 of vertical surface of substructure on each side. After the earth filling is completed, treatment shall be by rodding the earth at 150 mm centres close to the wall surface and spraying the chemical at a rate of 7.5 l/m^2.

In the case of framed structures, the treatment shall start at a depth of 500 mm below ground level. From this depth the backfill around the columns, beams and RCC basement walls shall be treated at a rate of 7.5 l/m^2 for the vertical surface and at 5 l/m^2 for horizontal surfaces at the bottom of trenches/pits.

12.5.2 Treatment on Top Surfaces of Plinth Filling

The top surface of filled earth within plinth walls shall be treated with chemical emulsion at the rate of 5 l/m^2 of the surface area before sub-base to floor is laid. If filled earth has been well rammed and the surface does not allow the emulsion to seep through, holes up to 50 to 75mm deep at 150 mm centres both ways shall be made with crow bars on the surface to facilitate saturation of the soil with the emulsion.

12.5.3 Treatment at Junction of Walls and Floors

Special care shall be taken to establish continuity of the vertical chemical barrier on the inner wall surfaces from the finished ground level (or from level where the treatment has stopped) up to the level of the filled earth surface. To achieved this, a small channel 30 x 30 mm shall be made at all the junctions of wall/column with the floor (before laying sub-grade) and rod holes made in the channel up to the finished ground level at 150 mm spacings and the iron rod moved backward and forward to break the earth and the chemical emulsion shall be poured along the channel at 7.5 l/m^2 of the vertical wall/column surfaces to soak the soil right up to the bottom. The soil shall be tamped back into place after this operation.

12.5.4 Treatment for Expansion Joints

The soil beneath expansion joints shall be supplemented by treating through the expansion joint after sub-grade has been laid at the rate of 2 l/m length of expansion joint.

12.5.5 Precautions during Treatment

Utmost care shall be taken to ensure that the chemical barrier is complete and continuous. Each part of the area shall receive the prescribed dosage of chemical emulsion.

The treatment should not be carried out when it is raining or when the soil is wet with rain or sub-soil water.

The Contractor shall ensure that these chemicals do not enter water supply systems or potable water supplies or aquifers and that they do not endanger plants and animals. The Contractor shall notify the Engineer at least 48 hours prior to the beginning of treatment and perform any formulating, mixing and application.

Once formed, the treated soil barrier shall not be disturbed. If treated soil barriers are disturbed, immediate steps shall be taken to restore the continuity and completeness of the barrier system.

If soil or fill material has been disturbed after treatment, the Contractor shall provide further treatment before placement of slabs or other covering structures. Treatment of the soil on the exterior sides of foundation walls, grade beams and similar structures shall be coordinated with final grading and planting operations to avoid disturbance of the treated barriers by such operations.

12.6 Safety Requirements

The manufacturer's warnings and precautions in the handling and use of materials and the manufacturer's method of application shall be followed by the Contractor. Where the manufacturer's method differs from this document then the Contractor shall submit his method statement to the Engineer for approval.

The Contractor shall formulate, treat and dispose of termiticides and their containers in accordance with the manufacturer's instructions. The Contractor shall draw water for formulating only from sites as approved by the Engineer and fit the filling hose with a backflow preventer meeting local plumbing codes or standards. The filling operation shall be under the direct and continuous observation of a Contractor's representative to prevent overflow. Pesticides and related materials shall be kept secure under lock and key when unattended. Proper protective clothing and equipment shall be worn and used during all phases of termiticide application. Used pesticide containers shall be disposed of in accordance with guidelines and to the satisfaction of the Engineer.

All the chemicals are poisonous and hazardous to health. These chemicals can have an adverse effect upon health when absorbed through the skin, inhaled as vapours or spray mist or swallowed. Persons handling or using these chemicals shall be instructed of these dangers and advised that absorption through the skin is the most likely source of accidental poisoning and cautioned to observe carefully, as a minimum, the safety precautions given in this document and as recommended by the supplier, particularly when handling these chemicals in the form of concentrates.

These chemicals are usually brought to the site in the form of emulsifiable concentrates. The containers shall be clearly labelled and kept securely closed.

Particular care shall be taken to prevent skin contact with concentrates. Prolonged exposure to dilute emulsions shall also be avoided. Workers shall wear clean clothing and wash thoroughly with soap and water especially before eating and smoking. In the event of severe contamination, clothing shall be removed at once and the skin washed with soap and water. If chemicals splash into the eyes they shall be flushed with plenty of soap and water and immediate medical attention sought.

The concentrates are oil solutions and present a fire hazard owing to the use of petroleum solvents. There shall be no naked flames in the proximity during mixing.

Care should be taken in the application of chemicals/soil-toxicants to ensure that they are not allowed to contaminate wells or springs.

12.7 Inspections

For the duration of the Contract, following the treatment, the Contractor shall perform annual inspections of all buildings treated.

If during the inspections, or at any other time, live subterranean termite infestation or subterranean termite damage is discovered and the soil and building conditions have not been altered in the interim, the Contractor shall:

1 Excavate the soil and perform other treatment as may be necessary for elimination of subterranean termite infestation;

2 Repair damage caused by termite infestation; and

3 Re-inspect the building approximately 180 days after the additional treatment.

In the event of a reappearance of termites within the building area due to defective materials or workmanship or due to any other reason, the Contractor will carry out the necessary post construction treatment to keep the entire area free from termites once again.

The Contractor shall maintain a Pest Management Maintenance Record, identifying target pest, type of operation, brand name and manufacturer of pesticide, formulation, concentration or rate of application used and submit copies of records when requested by the Engineer.

13.0 ROADS AND PAVEMENTS

13.1 General

The construction and reinstatement of roads and parking areas shall be carried out in accordance with the specifications for road works, kerb stone and water table works of the Municipal Corporation of Greater Mumbai.

13.2 Materials

13.2.1 General

All materials shall be obtained from local sources and shall be subject to approval by the Engineer prior to use.

Substitution of material shall be on an approved equivalent basis as determined by the Engineer and shall result in finished roads as designated in this specification.

Material aggregates shall consist of natural or crushed stone, gravel or sands, shall be of reasonably uniform quality throughout and shall be clean and free from soft or decomposed particles, excess clay, foreign, organic or other deleterious matter.

13.2.2 Coarse Aggregate for Sub-Base, Base and Semi-grout

Coarse aggregate shall be crushed or broken stone and shall conform to the physical requirement given in the following table.

Physical requirements of Crushed Stone for Road Work

Sr. No.	Test	Limiting Value	
		For aggregates to be used for Road base and surfacing	For aggregate to be used for sub-grade
1.	Specific Gravity	Not less than 2.6	Not less than 2.0
2.	Water Absorption	Not more than 2%	Not more than 5%
3.	Flakiness Index	Maximum 25%	----
4.	Elongation Index	Maximum 40%	----
5.	Aggregate Impact Value or Aggregate Crushing Value	Not more than 30%	Not more than 40%
6.	Los Angeles Abrasion Value	Not more than 30%	Not more than 50%
7.	Stripping Test	Maximum 15%	----

Crushed or broken stone shall be hard, durable and free from an excess of flat, elongated, soft and disintegrated particles, dirt and other objectionable matter.

Crushed or broken stone shall conform to the grading given in the following table.

Grading Requirements of Coarse Aggregates

Grading No.	Size Range	IS. Sieve Designations	Percent by Weight passing the sieve

1.	90mm to 40mm	100mm 80mm 63mm 40mm 20mm	100 65 - 85 25 - 60 0 - 15 0 - 5
2.	63mm to 40mm	80mm 63mm 50mm 40mm 20mm	100 90 - 100 35 - 70 0 - 15 0 - 5
3.	50mm to 20mm	63mm 50mm 40mm 20mm 10mm	100 95 - 100 35 - 70 0 - 10 0 - 5

13.2.3 Screenings

Screenings shall consist of predominantly non-plastic materials such as sandy gravelly murrum or gravel (other than rounded river borne material) with Liquid Limit and Plasticity Index below 20 and 6 respectively and the fraction passing 75 micron sieve not exceeding 10%. The materials shall be sound and hard, of a quality not affected by weather and shall be screened at the quarry and shall be free from all impurities. Any large lumps of murrum shall be broken to pass gradation given in the above table. Gravel shall be composed of large, coarse, silicious grains, sharp and gritty to the touch, thoroughly free from dirt and impurities.

Screenings shall conform to the grading indicated in the following table.

Grading for Screenings

Grading Classification	**Size of Screenings**	**IS Sieve Designations**	**Percent by Weight passing the sieve**
A	12.5mm	12.5mm 10.0mm 4.75mm 150 microns	100 90 - 100 10 - 30 0 - 8
B	10.0mm	10.00mm 4.75mm 150 microns 75 microns	100 85 - 100 10 - 30 0 - 10

13.2.4 Blinding Material

To fill in the voids in the coarse aggregates, any non-plastic material such as gravel/ grit/ sand/ brick powder may be used. The plasticity index of the material shall not exceed six.

13.2.5 Binder

The binder shall be straight run bitumen of grade S35 or S65 and shall conform to the requirements specified in IS 73 and the following table.

Requirements of Bitumen Binder

Sr. No.	Characteristic	Requirement for Grade		Method of Test Reference to
		S 35	S 65	
1.	Specific gravity at 27°C, Min.	0.99	0.99	IS : 1202
2.	Water prevent by weight, Max.	0.2	0.2	IS : 1211
3.	Flash point, Pensky Martens closed type °C, Min.	175	175	IS : 1209 (Method A)
4.	Softening point, °C	50 - 65	40 - 55	IS : 1205
5.	Penetration, at 25°C, 100 g, 5 sec in 1/100 cm	30 - 40	60 - 70	IS : 1203
6.	Ductility at 20 °C in cm, Min	50	75	IS : 1208
7.(a)	Loss on beating, percent by weight, Max.	1	1	IS : 1212
7.(b)	Penetration of residue (expressed as percentage of item 5), Min	60	60	IS : 1203
8.	Matter soluble in carbon disulphide, percent by weight, Min.	99	99	IS : 1216

13.3 Setting Out

The Contractor shall provide all labour and materials such as lines, strings, pegs, nails, bamboo, stones, mortar, concrete etc, required for setting out, establishing benchmarks and giving profiles. The Contractor shall be responsible for maintaining the benchmarks, profiles, alignments and other stakes and marks as long as they are required for the works.

The surface of the installed layers will be parallel and have the same grade as the designed asphalt surface and all subsequent layers.

13.4 Earthworks for Roads

Profiles of road excavation shall be laid at 25m intervals to conform to the required alignment, sections, grades and side slopes and the lines of cuts shall be clearly marked.

The Contractor shall, on no account, excavate beyond the slopes or below the specified grade on the drawings unless so directed by the Engineer in writing.

13.4.1 Preparation of Sub-grade

Immediately prior to the laying of the sub-base metal, the sub-grade shall be cleaned of all foreign substances and vegetation etc. Any ruts or soft yielding patches that appear shall be corrected and the sub-grade dressed off parallel to the finished profile. The camber of sub-grade shall conform in shape to that of the finished road surface. Camber boards shall be used to get the required section.

The prepared sub-grade shall be lightly sprinkled with water, if necessary, and rolled with a power roller of 10-12 tonnes. The roller shall pass over the same area of the sub-grade a minimum of five runs. Any undulations in the surface that develop due to rolling shall be made good with approved earth and sub-grade re-rolled.

13.4.2 Granular Sub Base

A. Scope

This work shall consist of laying and compacting well-graded material on prepared sub-grade in accordance with the requirements of these Specifications. The material shall be laid in one or more layers as sub-base or lower sub-base and upper sub-base (termed as sub-base hereinafter) as necessary according to lines, grades and cross-sections shown on the Drawings or as directed by the Engineer.

B. Material specification

The material to be used for the work shall be natural sand, Murrum, gravel, crushed stone, or combination thereof depending upon the grading required. Materials like crushed slag crushed concrete, brick metal and kankar may be allowed only with the specific approval of the Engineer. The material shall be free from organic or other deleterious constituents and conform to one of the three grading given in Table 1-1.

While the grading in Table 1-1 are in respect of close-graded granular sub-base materials, one each for maximum particle size of 75mm, 53mm and 26.5mm, the corresponding grading for the coarse-graded materials for each of the three maximum particle sizes are given at Table 1-2. The grading to be adopted for a project shall be as specified in the Contract.

Physical requirements

The material shall have a 10 percent fineness value of 50 KN or more (for sample in soaked condition) when tested in compliance with BS:812 (Part III). The water absorption value of the coarse aggregate shall be determined as per IS:2386 (Part 3): if this value is greater than 2 percent , the soundness test shall be carried out on the material delivered to site as per IS:383. For Grading II and III materials, the CBR shall be determined at the density and moisture content likely to be developed in equilibrium conditions which shall be taken as being the density relating to a uniform air voids content of 5 per cent.

Table : Grading For Close-Graded Granular Sub-Base Materials

IS sieve	Per cent by weight passing the IS sieve		
Designation	Grade I	Grading II	Grading III
75.0 mm	100	-	-
53.0 mm	80-100	100	-
26.5 mm	55-90	70-100	100
9.50 mm	35-65	50-80	65-95
4.75 mm	25-55	40-65	50-80
2.36 mm	20-40	30-50	40-65
0.425 mm	10-25	15-25	20-35
0.075 mm	3-10	3-10	3-10

CBR Value (Minimum)	30	25	20

Table : Grading For Coarse Graded Granular Sub-Base Materials

IS Sieve	Percent by weight passing the IS Sieve		
Designation	Grading I	Grading II	Grading III
75.00 mm	100	-	-
53.0 mm		100	
26.5 mm	55-75	50-80	100
9.50 mm			
4.75 mm	10-30	15-35	25-45
2.36 mm			
0.425 mm			
0.075 mm	< 10	< 10	< 10
CBR Value (Minimum)	30	25	20

Note: The material passing 425 micron (0.425 mm) sieve for all the three grading when tested according to IS:2720 (Part 5) shall have liquid limit and plasticity index not more than 25 and 6 per cent respectively.

Strength of Sub-base

It shall be ensured prior to actual execution that the material to be used in the sub-base satisfies the requirements of CBR and other physical requirements when compacted and finished.

When directed by the Engineer, this shall be verified by performing CBR tests in the laboratory as required on specimens remoulded at field dry density and moisture content and any other tests for the “quality” of materials, as may be necessary.

Construction Specifications

Preparation of sub grade

Immediately prior to the laying of sub-base, the sub grade already finished shall be prepared by removing all vegetation and other extraneous matter, lightly sprinkled with water if necessary and rolled with two passes of 80-100 KN smooth wheeled roller.

Spreading and compacting

The sub-base material of grading specified in the Contract shall be spread on the prepared sub grade with the help of mechanical grader, of adequate capacity, its blade having hydraulic controls suitable for initial adjustment and for maintaining the required slope and grade during the operation or other means as approved by the Engineer.

When the sub-base materials consist of combination of materials mentioned in section 2.70 mixing shall be done mechanically by the mix-in-place method.

Manual mixing shall be permitted only where the width of laying is not adequate for mechanical operations, as in small-sized jobs. The equipment used for mix-in-place construction shall be a rotavator or similar approved equipment capable of mixing the material to the desired degree. If so desired by the Engineer, trial runs with the equipment shall be carried out to establish its suitability for the work.

Moisture content of loose material shall be checked in accordance with IS:2720 (Part 2) and suitably adjusted by sprinkling additional water from a truck mounted or trailer mounted water tank and suitable for applying water uniformly and at controlled quantities to variable widths of surface or other means approved by the Engineer so that, at the time of compaction, it is from 1 per cent above to 2 per cent below the optimum moisture content corresponding to IS:2720 (Part 8). While adding water, due allowance shall be made for evaporation losses. After water has been added, the material shall be processed by mechanical or other approved means like disc harrows, rotavator until the layer is uniformly wet.

Immediately thereafter, rolling shall start. If the thickness of the compacted layer does not exceed 100 mm, a smooth wheeled roller of 80 to 100 KN weight may be used. For a compacted single layer up to 225 mm. the compaction shall be done with the help of vibratory roller of minimum 80 to 100 KN static weights with plain drum or pad foot drum or heavy pneumatic typed roller of minimum 200 to 300 KN weight having a minimum tyre pressure of 0.7 MN/m2 or equivalent capacity roller capable of achieving the required compaction. Rolling shall commence at the lower edge and proceed towards the upper edge longitudinally for portions having unidirectional cross fall (camber) and super elevation and shall commence at the edges and progress towards the centre for portions having cross fall (camber) on both sides.

Each pass of the roller shall uniformly overlap not less than one-third of the track made in the preceding pass. During rolling, the grade and cross fall (camber) shall be checked and any high spots or depressions which become apparent, corrected by removing or adding fresh material. The speed of the roller shall not exceed 5 km per hour.

Rolling shall be continued till the density achieved is at least 98 per cent of the maximum dry density for the material determined as per IS:2720 (Part 8). The surface of any layer of material on completion of compaction shall be well closed, free from movement under compaction equipment and from compaction planes, ridges, cracks or loose material. All loose, segregated or otherwise defective areas shall be made good to the full thickness of layer and re-compacted.

Surface Finish and Quality Control of Work

The surface finish of construction shall conform to the requirements of Section 902 of MoSRT&H Specifications for Road and Bridge Works (IV Revision).

Control on the quality of materials and works shall be exercised by the Engineer in accordance with Section 900 of MORT Specifications for Road and Bridge Works (IV Revision).

Arrangement for Traffic

During the period of construction, the arrangement of traffic shall be done accordingly, by providing proper diversions as per the directives of Engineer.

13.4.3 Wet Mix Macadam (WMM) Sub Base

Providing and laying WMM (wet mix macadam) Sub-base / base for required depth with black stone metal, size specified in detailed specification on sub base. Metal shall be mixed by approved mixing plant of suitable capacity having provision for controlled addition of water and forced / positive mixing arrangement like pug mill or pan type mixer of concrete batching plant, laying and spreading with mechanical spreader for required consolidated depth. Including rolling with 8 / 10 MT power roller to required slope and camber, etc. complete as per instruction of Engineer.

A. Scope

This work shall consist of laying and compacting clean, crushed, graded aggregate and granular material, premixed with water to a dense mass on a prepared sub-grade /sub-base / base or existing pavement as the case may be in accordance with the requirements of these specifications. The material shall be laid in one or more layers as necessary to lines, grades and cross-sections shown on the approved drawings or as directed by the Engineer .

The thickness of a single compacted Wet Mix Macadam layer shall not be less than 75mm. When vibrating or other approved types of compacting equipment are used, the compacted depth of a single layer of the sub-base course may be increased to 200 mm upon approval of the Engineer.

B. Materials specification

a. Aggregates

Physical requirements

Coarse aggregates shall be crushed stone. If crushed gravel / shingle are used, not less than 90 percent by weight of the gravel / shingle pieces retained on 5.75 mm sieve shall have at least two fractured faces. The aggregates shall conform to the physical requirements set forth in Table below

Table: Physical Requirements of Coarse Aggregates for Wet Mix Macadam for Sub-Base / Base Courses

	Test	Test Method	Requirements
1.	*Los Angeles Abrasion value	IS : 2386 (Part-4)	40 percent (Max)
	OR		
	*Aggregate Impact value	IS: 2386 (Part-4) or IS : 5640	30 percent (Max)
2.	Combines Flakiness and Elongation Indices (Total)	IS : 2386 (Part-1)	30 percent (Max)

* Aggregate may satisfy requirements of either of the two tests.

If the water absorption value of the coarse aggregate is greater than 2 per cent, the soundness test shall be carried out on the material delivered to site as per IS: 2386 (Part-5)

Grading requirements:

The aggregates shall conform to the grading given in Table

Table: Grading Requirements of Aggregates for Wet Mix Macadam

IS Sieve Designation	Per cent by weight passing the IS sieve
53.00 mm	100
45.00 mm	95-100
26.50 mm	--
22.40 mm	60-80
11.20 mm	40-60
5.75 mm	25-40
2.36 mm	15-30
600.00 micron	8-22
75.00 micron	0-8

Materials finer than 425 micron shall have Plasticity Index (PI) not exceeding 6.

The final gradation approved within these limits shall be well graded from coarse to fine and shall not vary from the low limit on one sieve to the high limit on the adjacent sieve or vice versa.

Table: Frequency of tests for Subgrade, GSB and WMM

Section	Type of Construction	Test	Spec. Limits	Frequency (min.)
1.4.1	Sub Grade	Sand content	-	2 tests / 3000 m3
		Plasticity Index test	-	2 tests / 3000 m3
		Density of Compacted Layer	97%	2 tests / 3000 m3
		Deleterious content test	-	Once per source
		Moisture content test	-	1 /250 cum
		C.B.R. test	As specified in RFP	1 / 3000 cum
1.4.2	Granular sub base	Gradation	MORTH Table no.400.1, grading– I	1 /200 cum
		Atterberg Limit	PI - < 6%, LL - <25%	1 /200 cum
		Moisture Content Prior to compaction	+1%, -2% of the OMC	1 /250 cum
		Density of compacted layer	97%	1 /500 cum
		Water absorption of aggregate	2%, if water absorption more than 2% do soundness test as below	Initially one set of 3 representative specimen for each source of supply subsequently when warranted by changes in the quality of aggregates
		Soundness (Magnesium & Sodium Sulphate)	Max.12% Max.18%	Initially one set of 3 representative specimen for each source of supply subsequently when warranted by changes in the quality of aggregates
1.4.3	Wet Mix Macadam	Aggregate Impact value Los Angeles abrasion value	Max 30% Max 40%	
		Quality of Screening Material	LL max – 20%, PI – Max – 6%	Once per source
		Shape and Size	As per tech. spec.	Once per source
		Grading		1 test per 200 cum

C. Construction Specifications

a. Preparation of base

As per clause 405.3.1 MoSRT&H specification.

b. Provision of lateral confinement of aggregates

While constructing wet mix macadam, arrangement shall be made for the lateral confinement of wet mix. This shall be done by laying materials in adjoining shoulders along with that of wet mix macadam layer and following the sequence of operations described in Clause 407.5.1 of MoSRT&H Specification.

c. Preparation of mix:

Wet Mix Macadam shall be prepared in an approved mixing plant of suitable capacity having provision for controlled addition of water and forced / positive mixing arrangement like pugmill or pan type mixer of concrete batching plant.

Optimum moisture for mixing shall be determined in accordance with IS: 2720 (Part-8) after replacing the aggregate fraction retained on 22.4 mm sieve with material of 5.75 mm to 22.4 mm size. While adding water, due allowance should be made for evaporation losses. However, at the time of compaction, water in the wet mix should not vary from the optimum value by more than agreed limits. The mixed material should be uniformly wet and no segregation should be permitted.

d. Spreading of mix:

Immediately after mixing, the aggregates shall be spread uniformly and evenly upon the prepared sub grade / sub-base / base in requirement quantities. In no case should these be dumped in heaps directly on the area where these are to be laid nor shall their hauling over a partly completed stretch be permitted.

The mix may be spread either by a pavers finisher or motor grader. For portions where mechanical means cannot be used, manual means as approved by the Engineer shall be used. The motor grader shall be capable of spreading the material uniformly all over the surface. Its blade shall have hydraulic control suitable for initial adjustments and maintaining the same so as to achieve the specified slope and grade.

The paver finisher shall be self-propelled, having the following features:

Loading hoppers and suitable distribution mechanism.

The screed shall have tamping and vibrating arrangement for initial compaction to the layer as it is spread without rutting or otherwise marring the surface profile.

The paver shall be equipped with necessary control mechanism so as to ensure that the finished surface is free from blemishes.

The surface of the aggregate shall be carefully checked with templates and all high or low spots remedies by removing or adding aggregate as may be required. The layer may be tested by depth blocks during construction. No

segregation of larger and fine particles should be allowed. The aggregates as spread should be of uniform gradation with no pockets of fine materials.

e. Compaction

After the mix has been laid to the required thickness, grade and cross fall / camber the same shall be uniformly compacted, to the full depth with suitable roller. If the thickness of single compacted layer does not exceed 100mm, a smooth wheel roller of 80 to 100 KN weight may be used. For a compacted single layer upto 200 mm, the compaction shall be done with the help of vibratory roller of minimum static weight of 80 to 100 KN or equivalent capacity roller. The speed of the roller shall not exceed 5 Km/hr

In portions having unidirectional cross fall / super elevation, rolling shall commence from the lower edge the progress gradually towards the upper edge. Thereafter, roller should progress parallel to the centre line of the road, uniformly over-lapping each preceding track by at least one third width until the entire surface has been rolled. Alternate trips of the roller shall be terminated in stops at least 1 m away from any preceding stop.

In portions in camber, rolling should begin at the edge with the roller running forward and backward until the edges have been firmly compacted. The roller shall then progress gradually towards the centre parallel to the centre line of the road uniformly overlapping each of the preceding tracks by at least one-third width until the entire surface has been rolled.

Any displacement occurring as a result of reversing of the direction of a roller or from any other cause shall be corrected at once as specified and/or removed and made good.

Along forms, kerbs, walls or other places not accessible to the roller, the mixture shall be thoroughly compacted with mechanical tampers or a plate compactor. Skin patching of an area without scarifying the surface to permit proper bonding of the added material shall not be permitted.

Rolling should not be done when the sub grade is soft or yielding or when it causes a wave-like motion in the sub-base/base course or sub grade. If irregularities develop during rolling which exceed 12 mm when tested with a 3 meter straight edge, the surface should be loosened and premixed material added or removed as required before rolling again so as to achieve a uniform surface conforming to the desired grade and cross fall. In no case should the use of unmixed material be permitted to make up the depressions.

Rolling shall be continued till the density achieved is at least 98 per cent of the maximum dry density for the material as determined by the method outlined in IS: 2720 (Part-8).

After completion, the surface of any finished layer shall be well-closed, free from movement under compaction equipment or any compaction planes, ridges, cracks and loose material. All loose, segregated or otherwise defective areas shall be made good to the full thickness of the layer and re-compacted.

f. Setting and drying

After final compaction of wet mix macadam course, the road shall be allowed to dry for 24 hours.

g. Opening to Traffic

Preferably no vehicular traffic of any kind should be allowed on the finished wet mix macadam surface till it has dried and the wearing course laid.

h. Surface Finish and Quality Control of Work

Surface evenness:

The surface finish of construction shall conform to the requirements of Clause 902 of MoSRT&H specification.

Quality control:

Control on the quality of materials and works shall be exercised by the Engineer in accordance with Section 900 of MoSRT&H specification.

a. Rectification of Surface Irregularity

Where the surface irregularity of the wet mix macadam course exceeds the permissible tolerances or where the course is otherwise defective due to sub grade soil getting mixed with the aggregates, the full thickness of the layer shall be scarified over the affected area, re-shaped with added premixed material or removed and replaced with fresh premixed material as applicable and re-compacted in accordance with Clause 406.3 of MoSRT&H specification. The area treated in the aforesaid manner shall not be less than 5 m long and 2 m wide. In no case shall depressions be filled up with unmixed and un-graded material or fines.

b. Arrangement for traffic

During the period of construction, arrangement of traffic shall be done as per Clause 112 of MoSRT&H specification.

13.4.4 Tack Coat

(i) Preparation of Base

The base on which a tack coat is to be applied shall be prepared, shaped and conditioned to the specific line, grade and cross section by repairing all potholes or patches and ruts. The potholes shall be drained of water and cut to regular shape with vertical sides. All loose and disintegrated materials shall be removed. The potholes shall then be filled either with (i) coarse aggregate and screenings and compacted with heavy hand rammers or approved mechanical tempers or (ii) premixed chippings binders (bitumen grade S 35/ S 65) content of 3 percent by weight of total mix, after painting the sides and bottom of the holes with a thin application of bitumen, or a combination of both (i) and (ii) as approved by the Engineer. The surface shall be thoroughly swept and scraped clean and free of dust and other foreign matter.

(ii) Application

The binder used for tack coat shall be bitumen of suitable penetration grade within S35 to S65 conforming to IS: 73. The binder shall be heated to the temperature appropriate to its grade and as approved by the Engineer. The binder shall be sprayed on the prepared base at the rate of 1.0 kg/m^2. The binder shall be applied uniformly with the aid of either self propelled or towed bitumen pressure sprayer with self heating arrangement and spraying nozzle arrangement capable of spraying bitumen at the above specified rate and temperature to provide a uniform unbroken spread of bitumen. The tack coat shall be applied just ahead of laying asphalt macadam.

13.4.5 Asphalt Macadam

(i) Brushing

Prior to spreading of the asphalt surface, the water bound surface shall be swept clean to remove blinding to expose the metal surface.

(ii) Application of Macadam

The bituminous macadam shall be laid by mechanical compactor and finisher, the final consolidation being by means of power roller weighing not less than 10 tonnes. The finished surface shall not vary by more than 12.5mm above or below the designed level and the average thickness shall not be less than 65 mm after consolidation.

The grading, composition and characteristics of the bituminous macadam shall be as follows:

Aggregate Grading

IS Sieve Designation	Percentage passing
50 mm	100
40 mm	60 - 100
25 mm	30 – 70
20 mm	20 - 70
6.3 mm	10 - 20
2.36 mm	0 – 5

Bitumen (Grade S 65) Content: 3.7% to 4.3% by weight of total mix.

The bituminous macadam may be prepared in a hot mix plant or the bitumen may be cut back with a suitable solvent so that the heated cut back bitumen may be mixed with the aggregate. In either case mixing shall be carried out in a power driven pugmill mixer and shall be continued until all the aggregate is coated.

The Contractor shall ensure that the installation temperature is adequate during the rolling / compaction of asphalt.

(iii) Protection of Pavement

During the period between initial compaction of the coarse aggregate and completion of the seal coat, the surface shall be protected from all traffic other than that which is absolutely essential to its construction.

(iv) Premixed Seal Coat

After the full grout has been rolled, the interstices shall be completely filled with pre-coated grit of the following composition.

Aggregate Grading

IS Sieve Designation	Percentage passing
6.3 mm	100
2.36 mm	70 - 100
600 micron	25 – 50
300 micron	0 - 10

Bitumen (Grade S 65) Content : 7% to 8% by weight of total mix.

The premixed seal coat may be prepared in a hot mix plant or the bitumen may be cut back with a suitable solvent so that the heated cut back bitumen may be mixed with the aggregate. In either case, mixing shall be carried out in a power driven pugmill mixer and shall be continued until all the aggregate is coated.

The premixed seal must be brushed to fill in the interstices, additional material being applied during rolling if found necessary. The quantity of premixed seal required for this purpose shall be approximately 1.22 m^3 per 100 m^2.

(v) Liquid Seal

On the completion of consolidation, which may be assisted by opening the road to traffic, a liquid seal coat of Grade 565 bitumen shall be applied at a temperature of between 163°C to 191°C (325°F to 375°F) at the rate of 1.25 kg/m^2. The application of bitumen shall be immediately followed with a cover coat of clean dry ¼ cubical chippings at the rate of 1.22 m^3 per 100 m^2. The surface shall then be rolled with a power roller weighing not less than 10 tonnes. The composition of this seal coat shall be as follows :

Aggregate Grading

IS Sieve Designation	Percentage passing
12.5 mm	100
10 mm	70 - 100
4.75 mm	20 – 40
2.36 mm	7 – 20
75 micron	0 - 4

Bitumen (Grade S 65) Content : 4.5% to 5% by weight of total mix.

13.5 Quality Control

13.5.1 General

All works performed shall conform to the lines, grades, cross sections and dimensions as specified or as approved by the Engineer subject to the permitted tolerances described hereinafter.

13.5.2 Horizontal Alignments

These shall be reckoned with respect to the centreline of the carriageway as specified. The edges of the carriageway as constructed and all other parallel alignments shall be corrected within a tolerance of ± 20 mm.

13.5.3 Longitudinal Profile

The level of any point on the various surfaces after compaction shall comply with the following :

Surface	Tolerance from the specified

	Level
Sub-grade	± 25 mm
Sub- base	± 20 mm
Base-course	± 15 mm
Wearing course	± 10 mm

The negative tolerance for wearing course, shall not be permitted in conjunction with the positive tolerance for the base course, if the thickness of the wearing course is thereby reduced by more than 6 mm.

The longitudinal profile shall be checked with a 3.0m long straight edge, along the centreline of the road. The transverse profile shall be checked with a camber board at intervals of 30m. Permitted tolerances of surface regularity for pavement courses are specified in the table below:

No.	Type of construction	Longitudinal profile (Maximum permissible undulation when measured with a 3m straight edge) (mm)
1.	Sub-grade	18
2.	Sub- base	18
3.	Base-course	12
4.	Asphalt macadam	10

13.5.4 Rectification

Where the surface irregularity of the sub-grade and the various pavement courses falls outside the specified tolerances, the Contractor shall rectify these in the manner described below and to the satisfaction of the Engineer.

(i) Sub-grade

Where the surface is high, it shall be trimmed and suitably compacted. Where it is low, the deficiency shall be corrected by adding fresh material.

(ii) Stabilised Sub-base

Where the surface is high, the same shall be suitably trimmed while taking care that the material below is not disturbed due to this operation. Where the surface is low, the same shall be corrected as described below.

When the time elapsed between detection of irregularity and the time of mixing is less than two hours, the surface shall be scarified to a depth of 50 mm, supplemented with freshly mixed material as necessary and re-compacted to the relevant specification. When this time is more than two hours, the full depth of the layer shall be removed from the pavement and replaced with fresh material to the specification. In either case the area treated shall not be less than 5m long and 2m wide.

Where the surface is high or low, the top 75 mm shall be scarified, reshaped with added material as necessary and re-compacted. The area treated shall not be less than 5m long and 2m wide.

(iii) Bituminous Construction

For bituminous construction other than for a wearing course where the surface is low, the deficiency shall be corrected by adding fresh material and compacting in accordance with the specification. Where the surface is high, the full depth of the layer shall be removed and replaced with fresh material and compacted to the specification.

For wearing course where surface is high or low, the full depth of the layer shall be removed and replaced with fresh material and compacted to specifications. In all cases where removal and replacement of bituminous layer is involved, the area treated shall not be less than 5m long and 2m wide.

13.5.5 Quality Control Test During Construction

For ensuring the requisite quality of construction, the materials and works shall be subjected to quality control test, as described hereinafter, by the Engineer. The testing frequencies set-forth are the minimum required and the Engineer shall have the authority to carry out tests as frequently as he may deem necessary to satisfy himself that the materials and works comply with the appropriate specifications. The tests and their frequency to be used for different materials and works shall be as detailed in the following Table:

Sr. No.	Type of construction	Test		Frequency
1.	Sub-base	i)	Gradation	1 test per 2000 m²
		ii)	Plasticity	As required
		iii)	Deleterious Constituents	As required
		iv)	CBR test	As required
		v)	Moisture content prior to compaction	1 test per 250m²
		vi)	Dry density	1 test per 500 m²
2.	Water Bound Macadam	i)	Gradation	1 test per 1000 m²
		ii)	Flakiness index	1 test per 2000 m²
		iii)	Plasticity of binding material	1 test per 1000 m²
3.	Bitumen Macadam	i)	Quality of binder	As required
		ii)	Aggregate impact value	1 test per 50 – 100 m² of aggregate
		iii)	Flakiness index	1 test per 50 - 100 m² of aggregate
		iv)	Grading of Aggregates	2 tests per day plant, both on the individual constituents and mixed aggregates from the dryer (one at plant and

Sr. No.	Type of construction	Test		Frequency
				one at Municipal Lab)
		v)	Binder content	Periodic subject to 2 tests per day per plant
		vi)	Control of temp. of binder and aggregate for mixing and of the mix at the time of laying and rolling	All regular close intervals
		vii)	Rate of spread of mixed material	Regular control through checks on layer thickness
4.	Seal Coat	i)	Quality of binder	As required
		ii)	Aggregate Impact Value	1 test per 2000 m²
		iii)	Flakiness Index	1 test per 2000 m²
		iv)	Aggregate grading	2 tests per day
		v)	Temp. of application	At regular close intervals
		vi)	Rate of spread 2 materials	2 tests per day

Where a specific procedure is not indicated for quality control tests in these specifications, the same shall be carried out as per prevalent accepted engineering practice and to the approval of the Engineer.

Control shall be exercised by taking at least one measurement of density for each 1000 m^2 of compacted area or as required to yield the minimum number of test results for evaluating a day's work on a statistical basis. The determination of density shall be in accordance with IS: 2720 (Part 28). Test locations shall be chosen only through random sampling techniques. Control shall not be based on the result of any one test but on the mean value of a set of 5 – 10 density determinations. The number of tests in one set of measurements shall be five, as long as it is felt that sufficient control over material and the method of compaction is being exercised. If considerable variations are observed in individual density results, the minimum number of tests in one set of measurement shall be increased to ten. The acceptance of work shall be subject to the condition that the mean standard deviation for any set of results is below 0.08 g/cc.

For earth work in shoulders and in the top 500 mm portion of an embankment below the sub-grade, at lease one density measurement shall be taken for every 500 square metres of each set of measurements. In other respects the control shall be similar as described earlier.

13.6 Slab Culvert

13.6.1 General

Where slab culverts are provided for cross drainage purposes, these shall conform to the following specifications. The concrete works specifications for construction of RCC slab and the rubble masonry specification for the supporting rubble walls are given in this specification.

13.6.2 Bitumen at Location of Contact

Two coats of grade S 35 bitumen shall be applied to the top of the bed concrete at the point of contact with the RCC slab above.

13.6.3 Free Draining Graded Gravel Backfill

On each side of un-coursed rubble walls supporting the slab culvert, a free draining backfill of thickness 200 mm shall be provided. The material shall be granular, consisting of sound, tough, durable particles of crushed or uncrushed gravel, crushed stone or brickbats which will not become powdery under loads or in contact with water. The material shall be free from soft, thin, elongated or laminated pieces and vegetation or other deleterious substances. The material shall be graded and shall meet the grading requirements given above.

13.6.4 Weep Holes

Weep holes as required or as directed by the Engineer shall be provided in the masonry to drain water from the backfilling. Weep holes shall be of PVC pipe in rubble walls with M-10 concrete cushioning 75 mm thick. The weep holes shall extend through the full width of the masonry at a spacing of 1.5 mm c/c and with a slope of 1 vertical to 20 horizontal towards the draining face.

13.7 Rough / Natural Faced Shahabad Stone Pavement

13.7.1 Materials

Hand cut rough/natural faced Shahabad stone shall be of the best quality and of suitable thickness, size etc and shall be subject to the approval of the Engineer. The stone shall be hard, sound, durable, tough, free from flaws, cracks, decay and weathering. The edges shall be hand cut and dressed true and squares. The evenness of surfaces and edges of the slabs shall not be marred by careless dressing or handling and no patching up shall be allowed.

The under face may be left as required or rough dressed. Before taking up the work, samples of stone slabs to be used and their dressing shall be subject to the approval of the Engineer. The work shall be carried out strictly in accordance with the approved samples.

13.7.2 Bedding/Backing Coat

In case of plinth protection or other pavements over a concrete sub base, the bedding shall be of 12 mm thick 1:2 cement mortar

In case of pavement work for footpaths, approaches and other similar works, to be laid directly over levelled and consolidated ground, the bedding shall be of 150 mm thick quarry spoil and 60 mm thick stone grit or as otherwise approved by the Engineer.

13.7.3 Laying and Fixing Stone Slabs and Tiles

Stones should be laid on a bed of lime mortar of proportion 1:2 or cement mortar of proportion 1:3. Thickness of mortar bedding should not be less than 12mm and not more than 25 mm

Before laying, the stone slabs should be thoroughly wetted with clean water. Thick cement slurry should be spread over the mortar bed over as much area as could be covered with the slabs within half an hour. The slabs are then laid and gently tapped with mallet until they are firmly and properly bedded.

There shall be no hollows left. If there is a hollow sound on gently tapping the slab, such slab shall be removed and reset properly. The joints shall be pointed with 1:3 cement mortar and finished flush or with grooves as approved. The joints shall be raked out uniformly to a depth of not less than 12 mm before grouting and pointing the same.

13.7.4 Curing

The pavement work shall be kept well wetted for at least seven days.

13.7.5 Cleaning

When the bedding and joints have been completed, set and attained the required strength, the surface shall be thoroughly cleaned and handed over free from any mortar stains, dust, dirt etc.

13.8 Surface Water Drainage Systems

13.8.1 General

All surface storm water drains shall be constructed to the correct sizes and shapes as required for a sustained storm of 100 mm per hour. The finished product shall be sound and shall have smooth inside surfaces for optimum flow and be to the acceptance of the Engineer.

13.8.2 Materials

(i) Common Bricks

All common bricks shall be sound, hard, thoroughly baked, clean, of proper rectangular size and give a clear ring when tapped. They shall comply with IS 2212. All bricks shall be obtained from a manufacturer subject to the approval of the Engineer.

Testing of bricks shall be in accordance with IS 2212. Mortar shall be composed of one part cement to three parts sand, mixed thoroughly on a clean watertight platform before the appropriate amount of water is added. Mortar shall be used within one hour of adding water to the mix and no softening or revival of mortar shall be permitted after one hour of mixing.

(ii) Plaster

Where specified, plaster shall be rendered 20 mm thick in cement mortar consisting of one part cement to three parts sand. Plasticizer may be used with cement with the approval of the Engineer.

13.8.3 Setting Out

As soon as the embankments or fill areas are completed in accordance with the requirements of Sections 8.0 and 9.0 the Contractor shall set out the lines for road-side and surface storm-water drains. The centre lines shall be marked with pegs at not more than 30 metre intervals and at turning points and positions of manholes, with the lines and levels of cut for drain laying clearly set out.

13.8.4 Execution

Surface drains shall be laid in trenches dug to the correct levels and alignment and constructed to produce an even alignment and gradient. Over-excavation shall be made good by selected fill well compacted and to the satisfaction of the Engineer.

14.0 CONCRETE

14.1 Definitions

Liquid retaining structures shall be construed to mean any structure of which any part contains water or other process liquids, or which are designed or intended to protect spaces from ground water.

14.2 Materials

14.2.1 General

The quality of material and method and control of manufacture and transportation of all concrete work irrespective of mix; whether reinforced or otherwise shall conform to the applicable portions of this specification.

The Engineer shall have the right to inspect the sources of materials, the layout and operation of procurement and storage of materials, the concrete batching and mixing equipment and the quality control system. Such an inspection shall be arranged and the approval of the Engineer obtained, prior to starting any concrete work.

The ingredients to be used in the manufacture of standard concrete shall consist solely of a standard type Portland/Portland pozzolana cement, clean sand, natural coarse aggregate, clean water, ice and admixtures if specially called for.

14.2.2 Storage

All materials shall be stored in the required manner immediately upon delivery to the site. It will be the responsibility of the Contractor to provide and maintain requisite stocks, handle the materials with care and store them in such a manner that the materials will remain fresh for use at the appropriate time.

Cement shall be stored in silos or in dry weather proof and well ventilated structures the floors of which shall be at least 450 mm above ground level with adequate precautions to prevent moisture absorption. The storage arrangements shall be subject to the approval of the Engineer and shall provide easy access for inspection. The different consignments shall be identifiable and shall be utilized in the order in which they are received at site or as instructed by the Engineer.

Aggregates shall be so stored that different specified sizes are kept separate and protected against contamination by soil or other impurities. Adequate storage facilities shall be provided to prevent the possibility of intermixing of the different sizes of aggregates.

The use of wet fine aggregates shall be permitted if the moisture content is uniform and after such content is accurately determined to adjust the batching and the water content of the proposed mix. Wherever possible, the fine aggregate shall be kept dry.

All coarse and fine aggregates shall be stacked separately in stock piles in the material yard near the work site in bins properly constructed to avoid inter mixing of different aggregates. Contamination with foreign materials and earth during storage and while heaping the materials shall be avoided. The aggregate shall be of specified quality, not only at the time of receiving at site but also at the time of loading into mixer. Rakers shall be used for lifting the coarse aggregate from bins or stock piles. Coarse aggregate shall be piled in layers not exceeding 1.00 metre in height to prevent coning or segregation. Each layer shall cover the entire area of the stock pile before succeeding layers are started. Aggregates that have become segregated shall be rejected. Rejected material after remixing may be accepted, if subsequent tests demonstrate conformity with the required gradation.

14.2.3 Cement

Cement shall be as per the latest version of IS 269. Cement for use in concrete for sewage treatment works and pumping stations shall be sulphate resistant. Tests shall be carried out as and when required by the Engineer. The cement shall be tagged for identification at location for sampling.

Unless otherwise specified or called for in the contract, the cement to be used shall be selected from the following and the type selected shall be appropriate for the intended use and as per the Contract.

1 Sulphate resisting Portland cement conforming to IS 12330.

2 53 Grade ordinary Portland Cement conforming to IS 12269

3 Portland slag cement conforming to IS 455.

4 Portland pozzolana cement (fly ash based) conforming to IS 1489 (Part I)

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

Should the project require specific use of any of the following cements the same shall be used with the prior consent of the Engineer and necessary precautions with regard to their setting and hardening time, time required for removal of shuttering and curing etc shall be taken after carefully complying with specific literature with regard to those types.

1 High alumina cement - conforming to IS 6452

2 Low heat cement - conforming to IS 12600

3 Super sulphate cement - conforming to IS 6909

4 Rapid hardening cement - conforming to IS 8041

5 Blended cement for finishing work as below

Other combinations of Portland cement with mineral admixtures of quality conforming to relevant Indian Standards laid down may also be used in the manufacture of concrete provided that there are satisfactory data on their suitability, such as performance test on concrete containing them and only in such case where it is specifically called for in the contract.

No pre-hardened cement shall be used on any permanent works.

(i) Mineral Admixtures for Cement

Pozzolana: Pozzolanic materials conforming to relevant Indian Standards may be used with the permission of Engineer, provided uniform blending with cement is ensured.

Fly ash (pulverized fuel ash): Fly ash conforming to IS 3812 may be used as part replacement of ordinary Portland cement provided uniform blending with cement is ensured.

Silica fume: Silica fume can be used as part replacement of cement provided it is of sufficient quality approved by the Engineer and uniform blending with the cement is ensured.

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

Metakaoline: Metakaoline having fineness between 700 to 900 m^2/kg may be used as a pozzolanic material in concrete.

Ground Granulated Blast Furnace Slag: Ground granulated blast furnace slag obtained by grinding granulated blast furnace slag conforming to IS 12089 may be used as part replacement of ordinary Portland cement provided uniform blending with cement is assured.

Quality Assurance of Cement: A certified report attesting to the conformity of the cement to IS specifications by the cement manufacturer's chemist shall be furnished to the Engineer, if demanded. The Contractor, shall make his own arrangements for the storage of adequate quantities of cement at the site of work.

Storage of Cement: Cement in bags shall be stored and stacked in a shed, which is dry, leak-proof and moisture proof as far as possible. Storage under tarpaulins will not be permitted. Flooring of the shed shall consist of the two layers of dry bricks laid on well consolidated earth to avoid contact of cement bags with the floor. Stacking shall be about 150 to 200 mm clear above the floor using wooden planks. Cement bags shall be stacked at least 450 mm clear of the walls and in rows of two bags leaving a space of at least 600 mm between two consecutive rows. In each row the cement bags shall be kept closed together to reduce air circulation. Stacking shall not be more than ten bags high to avoid lumping under pressure. In stacks more than eight bags high, the cement bags shall be arranged in header and stretcher fashion i.e. alternately lengthwise and crosswise to tie the stacks together and minimize the danger of toppling over.

Damaged or reclaimed or partly set cement will not be used and shall be removed from the site. The storage arrangements shall be such that there is no dead storage consignments so cement shall be stored as received and shall be consumed in the order of their delivery.

Cement held in store for a period of ninety days or longer shall be retested before used in work. Should the Engineer have reasons to consider that any cement is defective, then irrespective of its origin and/or manufacturers test certificate, such cement shall be tested immediately at a National Test Laboratory or other approved laboratory and until the results of such tests are found satisfactory, it shall not be used in any work.

14.2.4 Aggregates

Aggregate in general designates both fine and coarse inert materials used in the manufacture of concrete.

Fine aggregate is aggregate most of which passes through 4.75 mm IS sieve.

Coarse aggregate is aggregate most of which is retained on 4.75 mm IS sieve. Aggregate shall comply with requirement of IS 383. As far as possible preference shall be given to machine broken and graded aggregate.

All fine and coarse aggregates proposed for use in the work shall be subject to the Engineer's approval and after specific materials have been accepted, the source of supply of such materials shall not be changed without prior approval of the Engineer.

Aggregate shall, except as noted above, consist of natural sand, crushed stone and gravel from a source known to produce satisfactory aggregate for concrete and shall be chemically inert, strong, hard, durable against weathering, of limited porosity and free from deleterious materials that may cause corrosion to the reinforcement or may impair the strength and/or durability of the concrete. The grading of aggregates shall be such as to produce a dense concrete of specified strength and consistency that will work readily into position without segregation and shall be based on the mix design and preliminary test on concrete specified.

The maximum percentages of permissible deleterious materials shall be as follows, subject to total combined impurities, limit of 5 percent by weight.

Impurity	**Coarse Aggregate**		**Fine Aggregate**	
	Crushed	Uncrushed	Crushed	Uncrushed
Clay lumps	1	1	1	1
Soft fragments	3	-	-	-
Fine material passing through 75 micron sieve	3	1	3	3
Shale	-	-	1	-
Coal, lignite	1	1	1	1

(i) Specific Gravity

Aggregates having a specific gravity below 2.6 (saturated surface dry basis) shall not be used without special permission of the Engineer.

(ii) Fine Aggregate

Fine aggregate except as noted above and for other than light weight concrete shall consist of natural or crushed sand conforming to IS 383. The sand shall be clean, sharp, hard, strong and durable and shall be free from dust, vegetable substances, adherent coating, clay, loam, alkali, organic matter, mica, salt or other deleterious substances which can be injurious to the setting qualities, strength or durability of the concrete.

Machine Made Sand: Machine made sand will be acceptable, provided the constituent rock composition is sound, hard, dense, non-organic, uncoated and durable against weathering. Machine made sand shall be accepted provided grading and fine particle limits conform to IS 383.

Screening and Washing: Sand shall be prepared for use by such screening or washing or both, as necessary, to remove all objectionable foreign matter while separating the sand grains to the required size fractions. Sand with a silt content of more than 3 percent will not be used unless the same is washed and silt content is brought within 3% by weight.

Foreign Material Limitations: The percentages of deleterious substances in sand, delivered to the mixer shall not exceed the following:

	Foreign Material	**Percent by weight**	
		Uncrushed	**Crushed**
i)	Material finer than 75 micron IS sieve	3	15
ii)	Shale	1	---
iii)	Coal and lignite	1	1
iv)	Clay lumps	1	1
v)	Total of all above substances including items (i) to (iv) for uncrushed sand and items (iii) and (iv) for crushed sand	5	2

Gradation: Unless otherwise approved, the grading of sand shall be within the limits indicated. Where the grading falls outside the limits of any particular grading zone of sieves, other than the 600 micron (IS) sieve by not more than 5%, the grading shall be regarded as falling within that grading zone. This tolerance shall not be applied to percentage passing the 600 micron (IS) sieve or to percentage passing any other sieve size on the coarser limit of grading zone I or the finer limit of grading zone IV. Fine aggregates conforming to Grading Zone IV shall not be used unless mix designs and preliminary tests have shown its suitability for producing concrete of specified strength and workability.

IS Sieve Designation	**Percentage passing for**			
	Grading Zone I	**Grading Zone II**	**Grading Zone III**	**Grading Zone IV**
10 mm	100	100	100	100
4.75 mm	90-100	90-100	90-100	95-100
2.36 mm	60-95	75-100	85-100	95-100
1.18 mm	30-70	55-90	75-100	90-100
600 micron	15 – 34	35 - 59	60 – 79	80 – 100
300 micron	5 – 20	8 - 30	12 - 40	15 - 50
150 micron	0 - 10	0 - 10	0 - 10	0 - 15

Fineness Modulus: The sand shall have a fineness modulus of not less than 2.2 or more than 3.2. The fineness modulus is determined by adding the cumulative percentages retained on the following IS sieve sizes (4.75 mm, 2.36 mm, 1.18 mm, 600 micron, 300 micron and 150 micron) and dividing the sum by 100.

(iii) Coarse Aggregate

Coarse aggregate for concrete, except as noted above and for other than light weight concrete, shall conform to IS 383. This shall consist of natural or crushed stone and gravel and shall be clean and free from elongated, flaky or laminated pieces, adhering coatings, clay lumps, coal residue, clinkers, sag, alkali, mica, organic matter or other deleterious matter.

Screening and Washing: Crushed rock shall be screened and/or washed for the removal of dirt or dust coating, if so required by the Engineer.

Grading: Coarse aggregates shall be either single size or graded. The grading shall be within the limits on the table below. The aggregate pieces shall be angular in shape and shall have granular or crystalline surfaces.

Friable, flaky and laminated pieces, mica and shale, if present, shall be only in such quantities that will not, in the opinion of Engineer, affect adversely the strength and/or durability of concrete.

The maximum size of coarse aggregate shall be the maximum size specified, but in no case greater than 1/4 of the minimum thickness of the member, provided that the concrete can be placed without difficulty to surround all reinforcement thoroughly and fill the corners of form.

Cobbles above 160 mm and up to any reasonable size can be used in plain mass concrete work of large dimensions up to a maximum limit of 20% by volume of concrete when specifically approved by the Engineer.

For heavily reinforced concrete members, the nominal maximum size of the aggregate shall be 5 mm less than the minimum clear distance between the reinforcing main bars or 5mm less than the minimum cover to the reinforcement whichever is smaller. The amount of fine particles occurring shall not exceed 1% when determined by laboratory sedimentation tests as per IS 2386. After 24 hours immersion in water, a previously dried sample shall not have gained more than 10% of its oven dry weight in air, as determined by IS2386.

IS Sieve Design	**Percentage passing for single sized aggregate of nominal size**					**Percentage passing for Graded aggregate of nominal size**			
	40mm	20mm	16mm	12.5mm	10mm	40mm	20mm	16 mm	12.5mm
63 mm	100	--	--	--	--	100	--	--	--
40 mm	85 - 100	100	--	--	--	95 -100	100	--	--
20 mm	0 – 20	85–100	100	--	--	30 –70	95–100	100	--
16 mm	--	--	85–100	100	--	--	--	90–100	--
12.5 mm	--	--	--	85- 100	100	--	--	--	90- 100
10 mm	0 – 5	0 - 20	0 - 30	0 - 45	85- 100	10 - 35	25 - 55	30 –70	40 - 85
4.75 mm	--	0 – 5	0 – 5	0 – 10	0 – 20	0 – 5	0 – 10	0 – 10	0 – 10
2.36 mm	--	--	--	--	0 – 5	--	--	--	--

Foreign Material Limitations: The percentages of deleterious substances in the coarse aggregate delivered to the mixer shall not exceed the following:

	Foreign Material	**Percent by weight**	
		Uncrushed	**Crushed**
i)	Material finer than 75 micron IS sieve	3	3
ii)	Coal and lignite	1	1
iii)	Clay lumps	1	1
iv)	Soft fragments	3	--
v)	Total of all the above substances	5	5

14.2.5 Water

Water for mixing concrete shall be clean and free from harmful impurities, such as silt, organic materials, acids, alkalis, salts and oils. In general the water used shall be of potable quality. In case of doubt, the suitability of water for making concrete shall be ascertained by the compressive strength and initial setting time test specified in IS 456 - 2000. The sample of water taken for testing shall be typical of the water proposed to be used for concreting with due account being paid to seasonal variations. The samples shall not receive any treatment before testing other than that envisaged in the regular supply of water proposed for use in concrete. The sample shall be stored in a clean container previously rinsed out with similar water.

Average 28 days compressive strength of at least three 150 mm concrete cubes prepared with water proposed to be used shall not be less than 90% of the average strength of three similar concrete cubes prepared with distilled water as per IS - 516.

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

Where water contains an excess of acid, alkali, sugar or salt, the Engineer may refuse to permit its use. The following concentrations represent the maximum permissible values:

1 **Limits of acidity:** To neutralize 100 ml sample of water, using phenolphthalein as an indicator, it should not require more than 5 ml. of 0.02 normal NaOH. The details of test shall be as per IS 3025 (Part 22)

2 **Limits of alkalinity:** To neutralize 100 ml sample of water, using mixed indicator, it should not require more than 25 ml. of 0.02 normal H_2SO_4. The details of test shall be as per IS 3025 (Part 23).

3 **Limits for Solids:** Permissible limits for solids in the water shall be as below:

Solids	**Percent**	**Method of Test (ref IS : 3025)**
Organics	0.02	10 and 11 (organic solids = total solids minus ignited residue)
Inorganics	0.30	11 (ignited residue)
Sulphates (as SO_4)	0.05	20
Alkali chloride (as CI)	0.20	24
Suspended matter	0.20	12

4 **pH:** The pH value of water shall be not less than 6.

14.2.6 Admixtures

Admixtures may be used in concrete only with the approval of Engineer based upon evidence that, with the passage of time, neither the compressive strength nor the durability will be reduced. When admixtures are used, the concrete mix design shall be amended accordingly. Admixtures shall be used as per manufacturers' instructions and in the manner and with the control as necessary or as specified by Engineer.

The addition of admixtures during mixing to alter the properties of the concrete mix shall only be with the approval of the Engineer in regard to quality, quantity and redesign of the mix and accompanied by separate preliminary tests.

Admixtures, if used, shall comply with IS 9103. Previous experience with and data on such materials should be considered in relation to the likely standards of supervision and workmanship to the work being specified. Admixtures should not impair durability of the concrete or combine with the constituent to form harmful compounds or increase the risk of corrosion of reinforcement.

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

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

The chloride content of the admixtures shall be independently tested for each batch before acceptance. If two or more admixtures are used simultaneously in the same concrete, mix data should be obtained to assess their interaction and to ensure their compatibility.

(i) Calcium Chloride

Calcium chloride shall not be used for accelerating the setting of the cement for any concrete containing reinforcement or embedded steel parts.

(ii) Air Entraining Agents

Neutralized vinsol resin or any other approved air entraining agent may be used to produce the specified amount of air in the concrete mix and these agents shall conform to the requirements of ASTM standard 6.260, Air Entraining Admixtures for Concrete if approved by the Engineer. The recommended total air content of air entrained concrete is 4% ± 1%. The method of measuring air content shall be as per IS1199.

(iii) Retarding Admixtures

Where prior approval has been given by the Engineer, retarding agents may be added to the concrete mix in quantities in accordance with the manufacturer's recommendations.

(iv) Water Reducing Admixtures

Where prior approval has been given by the Engineer, water reducing lignosulfonate mixture shall be added in quantities in accordance with the manufacturer's recommendations. The admixtures shall be added in the form of a solution.

(v) Waterproofing Agents

Where prior approval has been given by the Engineer, chloride and sulphate free waterproofing agents shall be added in quantities in accordance with the manufacturer's recommendations.

(vi) Other Admixtures

The Engineer may, at his discretion, allow the Contractor to use any other admixture in the concrete.

14.2.7 Fly Ash

The fly ash should have consistent quality satisfying the requirements of IS 3812 Parts I and II.

The source of fly ash should be so selected that test results of fly ash samples collected from these sources during last one year at a frequency of maximum one month intervals should satisfy the requirements of above codes.

The characteristics of fly ash to be used shall be as per the above two codes for each batch of fly ash.

If more than 15% fly ash is used, IS 3812 shall apply and specific care shall be taken in terms of curing, protecting, repairing, finishing, de-shuttering etc as detailed in Section 14.6.2

14.3 Materials Testing

The Engineer shall have the right to inspect the sources of materials, the layout and operation of procurement and storage of materials, the concrete batching and mixing equipment and the quality control system. The Contractor shall arrange such an inspection and the Engineer's approval shall be obtained prior to starting any concrete work.

The Engineer, if he so requires, may order tests to be carried out, at the Contractor's expense, on cement, sand, coarse aggregate, water etc in accordance with the relevant Indian Standards.

14.3.1 Tests on Cement

Tests on cement shall include (i) fineness tests, (ii) tests for normal consistency, (iii) tests for setting time, (iv) tests for soundness, (v) tests for compressive strength, (vi) tests for heat of hydration (by experiment and by calculations) in accordance with IS269.

14.3.2 Tests on Sand

Tests on sand shall include (i) sieve tests, (ii) tests for organic impurities, (iii) decantation tests for determining clay and silt content, (iv) specific gravity tests, (v) tests for unit weight and bulkage factor, (vi) tests for sieve analysis and fineness modulus.

14.3.3 Tests on Aggregate

Aggregates shall be tested before and after the concrete mix is established and when ever there is a change of the source or character of the materials.

Sampling of the aggregates for mix design and determination of suitability shall be taken under the supervision of the Engineer and delivered to the laboratory, well in advance of the schedule for placing of concrete. Records of tests which have been made on proposed aggregates and on concrete made from this source of aggregates shall be furnished to the Engineer in advance of the work for which it is to be used, in determining suitability of the proposed aggregate.

Tests on coarse aggregate shall include (i) sieve analyses, (ii) specific gravity and unit weight of dry, loose and rodded aggregate, (iii) soundness and alkali aggregate reactivity, (iv) petrographic examination, (v) deleterious materials and organic impurities, (vi) tests for aggregate crushing value.

Additional tests on aggregates would normally only be carried out if the Engineer feels the materials are not in accordance with the specifications or if the specified concrete strengths are not obtained and shall be performed by the Contractor, at the Contractor's expense, at an approved test laboratory.

14.3.4 Tests on Water Stops

The water stops shall be tested in accordance with the Central Water Commission (India) standards and shall have the following properties:

Characteristics	**Properties**
Tensile strength	116 kg/cm^2 minimum (162 kg/cm^2 min. for rubber)
Ultimate elongation	300% minimum (500% minimum for rubber)
Tear resistance	49 kg/cm^2 minimum
Stiffness in flexure	25 kg/cm^2 minimum
Accelerated extractions	105 kg/cm^2 minimum (150 kg/cm2 Minimum for rubber)
Ultimate elongation	250% minimum (350% minimum for rubber)
Effect of alkali (7 days):	
Weight increase	0.25% maximum
Weight decrease	0.10% maximum
Hardness change	+ 5 point
Effect of alkali (28 days):	
Weight increase	0.40% maximum
Weight decrease	0.30% maximum
Dimension change	+ 1%

14.4 Concrete Grades

The concrete used on the works of this project shall be of one of the following grades:

Grade	**Minimum Crushing Strength of 150 mm cube at 28 days. In kg/cm^2**	
	Preliminary and Trial Mix Tests	**Work Tests**
M-10	135	100
M-15	200	150
M-20	260	200
M-25	320	250
M-30	380	300

M-35	440	350

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

2 In the designation of a concrete mix, the letter M refers to the mix and the number to the specified characteristic compressive strength of 150 mm size cubes at 28 days expressed in N/ mm^2.

All concrete used on the work shall be dense, sound, homogeneous and durable and free from air voids, bleeding, honeycombing and other allied defects. For grade M-100 the Contractor may be allowed to use an approved nominal mix but for all other grades of concrete, mix designs are obligatory and preliminary test results shall be submitted to the Engineer for approval before the commencement of concreting.

Mixes designed with ordinary Portland cement shall be redesigned if Pozzolona or other cement is to be used. In any event, whether Pozzolona or other cement is used or not, new mix designs shall be submitted for the Engineer's approval for each new batch of cement that is received. To enable this, the cement stocks shall be so stored as to enable easy identification of different batches. Similarly, new mix designs will be required if the source of supply of aggregate is changed or a variation exceeding 10 percent in the sieve analysis is observed from the analysis of the aggregate used in the mix design.

14.4.1 Standard Deviation

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

Standard Deviation Based on Test Results

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

Standard deviation to be brought up to date - The calculation of the standard deviation shall be brought up to date after every change of mix design and at least once a month.

Determination of standard deviation:

1 Concrete of each grade shall be analysed separately to determine its standard deviation.

2 The standard deviation of concrete of a given grade shall be calculated using the following formula from the results of individual tests of concrete of that grade obtained as specified for test strength of sample:

3 Estimated standard deviation $\boldsymbol{S = \sqrt{\{\Sigma \Delta^2 / (n-1)\}}}$

4 Where Δ= Deviation of the individual test strength from the average strength of a sample and n = Number of sample test results.

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

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

Grade of Concrete	**Assumed Standard Deviation N/ mm^2**
M-10 M-15	3.5
M-20 M-25	4.0
M-30 M-35 M-40 M-45 M-50	5.0

1 **Note:** The above values correspond to the site control having proper storage of cement: weigh batching of all materials: controlled addition of water: regular checking of all materials: aggregate grading and moisture content: and periodical checking of workability: and strength. Where there is a deviation from the above, the values given in the above table shall be increased by 1 N/mm^2.

14.5 Mix Designs

The quality of materials and method and control of manufacture and transportation of all concrete work in respect of a mix, whether reinforced or otherwise, shall be Design Mix Concrete as defined in IS 456-2000 and conform to the applicable portions of these specifications.

The different concrete mixes shall be designed by the Contractor for strength, workability and durability of the concrete and shall be strictly in compliance with the relevant standards. If it is found that an increase in the proportion of cement is necessary, the requisite adjustment shall be made. Batching shall be by weight and the combined aggregate shall have a continuous grading. The mixes should produce an average 28 day cube strength not less than that specified in Section 14.3 for trial mix tests for the relevant grade. In the case of concrete for water retaining structures, the cement content shall be a minimum of 340 kg/m3 of concrete. When admixtures are used, the mixes shall be redesigned with the test strengths conforming to those specified in Section 14.3. The workability of the mix shall permit satisfactory compaction with vibration, with no tendency to aggregate during handling, transporting and compaction.

In exceptional cases, where the reinforcement is so crowded that the compaction is difficult, the value of slump may be increased with the explicit approval of the Engineer, but in no case shall it exceed 15cm. Any increase in the slump beyond the values given shall be obtained by the use of additional cement in such quantities as to restrict the water-cement ratio to the maximum specified values. Special care shall be taken in the case of M-25 concrete where the water-cement ratio should not exceed 0.45 under any circumstances.

The minimum cement contents of the different grades shall be as follows, in kg/m3 of concrete mixed and ready to be placed:

Grade	**Cement Content (kg/m^3)**
M-15	240
M-20	300
M-25	300
M-30	320
M-35	340

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

2 Minimum grade for plain concrete under mild exposure condition is not specified.

14.5.1 Adjustment of Minimum Cement Content

The adjustments to minimum cement contents should be made for aggregates other than 20 mm nominal maximum size as shown in the table below:

No	Nominal maximum aggregate size mm	Adjustments to minimum cement content kg/ m3
i)	10	+40
ii)	20	0
iii)	40	-30

1 For concrete of compressive strength greater than M-55 given design parameters may not be applicable and the values may be obtained from specialized literature and experimental results.

2 The mix shall be designed to produce the grade of concrete having the required workability and characteristic strength not less than the appropriate values given in the table above.

14.5.2 Degree of Control

Selection of Water Cement Ratio: Since different cements and aggregates of different maximum size, grading, surface texture, shape and other characteristics may produce concretes of different compressive strength for the same free water cement ratio, the relationship between strength and free water-cement ratio should be established for the materials actually to be used. In the absence of such data, the preliminary free water-cement ratio (by mass) corresponding to the target strength at 28 days may be selected from the relationship shown in Fig.1 of IS 10262 .

Alternatively, the preliminary free water cement ratio (by mass) corresponding to the target average strength may be selected from the relationship in Fig.2- IS 10262, using the curve corresponding to the 28 day cement strength to be used for the purpose.

Other relevant items to be used with design of mix should strictly conform to the relevant clauses and appendices of IS 10262.

The calculated mix proportions shall be checked by means of trial batches as per IS 10262.

The free water cement ratio, selected as above, should be checked against the limiting water cement ratio for the requirement of durability and the lower of the two values should be adopted.

Whenever there is a change either in required strength of concrete or water cement ratio or workability or the source of aggregates and/or cement, fresh tests shall be carried out to determine the revised proportion of the mix to suit the altered conditions. While designing mix proportions, over-wet mixes shall always be avoided.

While fixing the value for water cement ratio for the design mix, assistance may be derived from the standard graph showing the relationship between the 28 day compressive strength of concrete mixes with different water-cement ratios and the 7 day compressive strength of cement tested in accordance with IS269.

It will be the Contractor's sole responsibility to establish the concrete mix designs for different grades of concrete required in the work consistent with the workability required for the nature of work and also taking into consideration the assumed standard deviation to be expected at the site or by establishing the standard deviation based on 30 test results for each grade of concrete to produce concrete of the required strength, durability and surface finish. The materials and proportions used in making the tests to be carried out either at site or under laboratory conditions shall be similar in all respects to those to be actually employed in the works, as the object of these tests is to determine the proportions of cement, aggregates and water necessary to produce the concrete of the required consistency to give such specified strength.

14.5.3 Proportioning

(i) Aggregate

The proportions to be determined by conducting preliminary tests, shall be by weight. These proportions of cement, fine and coarse aggregates shall be maintained during subsequent concrete batching by means of weigh batchers conforming to IS 2722, capable of controlling the weights within one percent of the desired value. Except where it can be shown to the satisfaction of the Engineer, that supply of properly graded aggregate of uniform quality can be maintained over the period of work, the grading of aggregate shall be controlled by obtaining the coarse aggregate in different sizes and blending them in the right proportions. The different sizes shall be stacked in separate stockpiles. The gradings of coarse and fine aggregates shall be checked as frequently as practicable, as determined by the Engineer, to ensure maintaining of grading in accordance with samples used in the preliminary mix design. The materials shall be stockpiled well in advance of use.

(ii) Cement

The cement shall be measured by weight. Every facility should be provided to the Engineer for sampling and inspection of stored cement at the site.

(iii) Water

Only such quantity of water shall be added to the cement and aggregate in the concrete mix as to ensure dense concrete, specified surface finish, and satisfactory workability consistent with the strength stipulated for each class of concrete. The water added to the mix shall be such as not to cause segregation of materials or the collection of excessive free water on the surface of the concrete.

Definition of water cement ratio

The water cement (W/C) ratio is defined as the weight of water in a mix (including the surface moisture of the aggregates) divided by the weight of the cement in the mix.

Water cement ratio

The actual water cement ratio to be adopted shall be determined in each instance by the Contractor and approved by the Engineer.

Proportioning By Water-Cement Ratio

The W/C ratios as approved by the Engineer shall be maintained. The Contractor shall determine the water content of the aggregate as frequently as approved by the Engineer as the work progresses and as specified in IS 2386 part III and the amount of mixing water added at the mixer shall be adjusted as approved by the Engineer to maintain the specified W/C ratio. To allow for the variation in their moisture content, suitable adjustments in the weights of aggregates shall also be made.

(iv) Concrete in Alkali Soils, Water & Aggregates

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

1 A high moisture level, within the concrete;

2 A cement with high alkali content, or another source of alkali;

3 Aggregate containing an alkali reactive constituent.

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

1 Use of non-reactive aggregate from alternate sources

2 Use of low alkali ordinary Portland cement having total alkali content not more than 0.6 per cent (as Na_2O equivalent).

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

1 Measures to reduce the degree of saturation of the concrete during service such as the use of impermeable membranes

2 Limiting the cement content in the concrete mix and thereby limiting total alkali content in the concrete mix as approved by the Engineer.

(v) Chlorides in the Concrete

Whenever there are chlorides in concrete, there is an increased risk of corrosion to the embedded metal. The higher the chloride content, and if subsequently exposed to warm moist conditions, the greater the risk of corrosion. All constituents may contain chlorides and concrete may be contaminated by chlorides from the external environment. To minimise the chance of deterioration of concrete from harmful chemical salts, the levels of such harmful salts in concrete materials, as well as by diffusion from the environment should be limited. The total amount of chloride content (as Cl) in the concrete at the time of placing shall be as given below in the table.

Limits of Chloride Content of Concrete

Sl.No	Type or Use of Concrete	Maximum Total Acid soluble Chloride Content Expressed as kg/m3 of Concrete.
i)	Concrete containing metal and steam cured at elevated temperature and pre-stressed concrete	0.4
ii)	Reinforced concrete or plain concrete containing embedded metal	0.6
iii)	Concrete not containing embedded metal or any material requiring protection from chloride	3.0

The total acid soluble chloride content should be calculated from the mix proportions and the major chloride contents of each of the constituents. The total chloride content of the concrete should be determined to the approval of the Engineer.

(vi) Sulphates in concrete

Sulphates are present in most cements and in some aggregates. Excessive amounts of water-soluble sulphate from these or other mix constituents can cause expansion and disruption of concrete. To prevent this, the total water-soluble sulphate content of the concrete mix, expressed as SO3, should not exceed 4 % by mass of the cement in the mix. The sulphate content should be calculated as the total from the various constituents of the mix to the approval of the Engineer.

The 4 % limit does not apply to concrete made with super sulphated cement complying with IS 6909 or as otherwise approved by the Engineer.

14.5.4 Consistency and slump

Concrete shall be of a consistency and workability suitable for the conditions of the job. After the amount of water required is determined, the consistency of mix shall be maintained throughout the progress of the corresponding parts of the work and approved tests e.g. slump tests, compacting factor tests etc in accordance with IS 1199, which shall be conducted from time to time to ensure the maintenance of such consistency.

The following tabulation gives a range of workability which shall generally be used for various types of construction unless otherwise instructed by the Engineer.

Workability of concrete:

Placing condition	Degree of workability	Slump (mm)
Blinding concrete; shallow sections; pavement using pavers	Very low	See note 1
Mass concrete; lightly reinforced sections in slabs, beams, walls, columns; floors; hand placed pavements; canal linings; strip footings	Low	25-75
Heavily reinforced sections in slabs, beams, walls, columns, slip form work; pumped concrete	Medium	50-100 75-100
Trench fill, in-situ piling	High	100-150
Tremie concrete	Very high	See notes

1 For most of the placing conditions, internal vibrators (needle vibrators) are suitable. The diameter of the needle shall be determined based on the density and spacing of reinforcement bars and thickness of sections. For tremie concrete, vibrators are not required to be used.

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

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

When tested in accordance with IS 1199, the consistency of the concrete should be such that the maximum slumps, unless otherwise specified or permitted by the Engineer do not exceed the following values.

Part of Structure	Maximum Slump (mm)
Footings and un-reinforced mass concrete	76
Slab and Floors	76
Columns, walls over 200 mm thick	102
Walls up to 200 mm thick	102
Equipment bases	127

14.5.5 Batching

To avoid confusion and error in batching, consideration shall be given to using the smallest practical number of different concrete mixes on any site or in any one plant. In batching concrete, the quantity of both cement and aggregate shall be determined by mass; admixture, if solid, by mass; liquid admixture may however be measured in volume or mass; water shall be weighed or measured by volume in a calibrated tank (see also IS4925).

For large and medium project sites, concrete shall be sourced from ready-mixed concrete plants or from on-site or off-site batching and mixing plants (see IS 4926).

Except where it can be shown to the satisfaction of the Engineer that supply of properly graded aggregate of uniform quality can be maintained over a period of work, the grading of aggregate should be controlled by obtaining the coarse aggregate in different sizes and blending it in the right proportions when required, the different sizes being stocked in separate stockpiles.

The accuracy of the measuring equipment shall be within +/- 2 % of the quantity of cement being measured and within +/- 3 percent of the quantity of aggregate, admixtures and water being measured.

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

The water-cement ratio shall be maintained at its correct value. To this end, determination of the moisture content in both the fine and coarse aggregates shall be made as frequently as possible, the given frequency being subject to the approval of the Engineer according to weather conditions. The amount of the added water shall be adjusted to compensate for any observed variations in the moisture content. For the determination of moisture content in the aggregates IS 2386 (Part 3) shall be followed. To allow for the variation in the mass of aggregate due to variation in its moisture content, suitable adjustments in the masses of aggregates shall also be made. In the absence of exact data, and in the case of nominal mixes the amount of surface water may be estimated from the values given in table below.

Surface water carried by aggregate:

Aggregate	Approximate quantity of surface water	
	Percent by mass	l/m3
Very wet sand	7.5	120
Moderately wet sand	5.0	80
Moist sand	2.5	40
Moist gravel or crushed rock	1.25-2.5	20-40
The coarser aggregate the less water it will carry		

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

14.5.6 Mixing

Concrete shall be mixed in a mechanical mixer. The mixers shall comply with IS 1791 and IS 12119. The mixers shall be fitted with water measuring devices. The 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.

The mixing time shall be at least two minutes. For more efficient mixers, manufacturers recommendations shall be followed.

The dosage of retardants, plasticisers and super-plasticisers shall be restricted to 0.5, 1.0 and 2.0 % respectively by weight of cementitious materials unless a higher value is agreed between the manufacturer and the Contractor based on performance tests.

Each time the work stops, the mixer shall be cleaned out and when next commencing the mixing, the first batch shall have 10% additional cement to allow for sticking in the drum.

14.6 Cast-in-Place (In-Situ) Concrete

14.6.1 Execution

(i) Preparation for Placing

All excess water shall be removed from the forms before concrete is placed. No flow of water shall be admitted to the section being concreted. The interior faces of forms shall be cleaned and any hard concrete, debris or foreign material shall be removed. The inner faces of the mixing and conveying equipment shall be similarly cleaned.

Reinforcement shall be secured, inspected and approved in compliance with the relevant specifications and shall be inspected and approved. Embedded metal shall be clean and free of old mortar, oil, mill scale and other encrustations and coatings. Wheeled concrete handling equipment shall not pass over reinforcement nor shall walkways be supported on reinforcement.

Any earth sub-grade on which concrete is to be deposited shall be wetted lightly 24 hours in advance of concreting but not muddied. Re-rolling shall be carried out, where necessary, to create a smooth surface and all loose materials removed.

Where placement of concrete is directly onto a rock base, the rock surface shall be cleaned and washed and loose material removed with air blower or hosed before concreting. All stagnant water collected on the rock surface shall be removed before concreting.

Where a bond between old and new concrete surfaces is required, the steps and precautions stipulated for construction joints shall be adopted. Where no bond is necessary, the existing surface shall be cleaned, removing any dirt or deleterious material which might interfere with the concreting.

Before concrete is poured, the inside of the formwork shall be inspected to ensure that it has been cleaned and oiled. Temporary openings shall be provided where necessary to facilitate inspection, especially at the bottom of columns and wall forms, to permit removal of sawdust, wood shavings, binding wire, rubbish, dirt etc. Openings shall be placed or holes drilled so that these materials and water can be removed easily. Such openings / holes shall be later suitably plugged.

The Contractor shall install drainage and plumbing lines, floor and trench drains, conduits, hangers, anchors, inserts, sleeves, bolts, frames and other miscellaneous embedments to be cast in the concrete as necessary for the proper execution of the work. All such embedments shall be correctly positioned and securely held in the forms to prevent displacement during the depositing and vibrating of concrete.

Slots, openings, holes, pockets etc shall be provided in the concrete work in the positions as necessary.

Prior to concrete placement, all works shall be inspected and approved by Engineer and if found unsatisfactory, concrete shall not be poured until all defects have been corrected.

Approval by the Engineer of any and all materials and work as required herein shall not relieve contractor from his obligations to produce finished concrete in accordance with the Contract.

(ii) Foundation Bedding and Jointing

All surfaces upon or against which concrete will be placed shall be suitably prepared by thoroughly cleaning, washing and dewatering to meet the various situations encountered in the work.

Soft or spongy areas shall be dug out and back-filled with either a soil cement mixture, lean concrete or clean sand fill compacted to a minimum density of 90% modified Proctor.

(iii) Preparation of Rock Strata of Foundations

To provide a tight bond with rock foundations, the rock surface shall be prepared and the following general requirements shall be observed:

Concrete shall not be deposited on large sloping rock surfaces. Where required, the rock shall be cut to form rough steps or benches to provide roughness or a more suitable bearing surface.

Rock foundation stratum shall be prepared by picking, barring, wedging or similar methods which will leave the rock in an entirely sound and un-shattered condition.

Shortly before concrete is placed, the rock surface shall be cleaned with high pressure water and air jet even though it may have been previously cleaned in that manner.

Prior to placing concrete, the rock surface shall be kept wet for a period of at least two hours unless otherwise approved by the Engineer.

Before placing concrete on rock surfaces, all water shall be removed from depressions to permit thorough inspection and proper bonding of the concrete to the rock.

(iv) Preparation of Earth Strata of Foundations

All earth surfaces upon which or against which concrete is to be placed, shall be well compacted and free from standing water, mud or debris. Soft, yielding soils shall be removed and replaced with suitable earth and well compacted and as approved by the Engineer. Where specified, lean concrete shall be placed on the earth stratum for receiving concrete. The surface of absorptive soil against which concrete is to be placed shall be moistened thoroughly.

(v) Preparation of Concrete Surfaces

Preparation of concrete surfaces upon which additional concrete is to be placed, shall be scarified and cleaned while the concrete is between its initial and final set. This method shall be used wherever practicable and shall consist of cutting the surface with picks and stiff brooms and by use of an approved combination of air and water jet and as approved by Engineer. Great care shall be taken in performing this work to avoid removal of too much mortar and the weakening of the surface by loosening of aggregate. When it is not practicable to follow the above method, air tools shall be employed to remove laitance and roughen the surface.

The required final result shall be a pitted surface from which all dirt, unsound concrete, laitance and glazed mortar have been removed.

(vi) Cleaning and Bonding of Formed Construction Joints

Vertical construction joints shall be cleaned as specified above or by other methods and as approved by Engineer. In placing concrete against formed construction joints, the surfaces of the joints, where accessible, shall be coated thoroughly with the specified bed-joint bonding mortar immediately before being covered with concrete or by scrubbing with wire brushes, dipped into the fresh concrete. Where it is impracticable to apply such a mortar coating, special precautions shall be taken to ensure that the new concrete is brought into intimate contact with the surface of the joint with the aid of vibrators and other suitable tools.

(vii) Positioning of Water Stops

Water stops shall be provided in the available maximum lengths and as far as possible, jointing shall be avoided. All joints, when unavoidable, shall be field jointed for water tightness as per manufacturer's specifications.

The water stops shall be positioned with suitable temporary supports to render adequate rigidity to the water stops while concreting. The exposed surfaces of water stops revealed after first concreting shall be cleaned thoroughly of all the droppings, mortar splashings etc before the next pour of concrete.

(viii) Bonding Treatment (Mortar)

All rock or concrete surfaces upon which new concrete is to be placed shall be scarified, cleaned and wetted as specified herein.

Immediately prior to placing new concrete, the scarified surface of the existing concrete shall be thoroughly wetted.

(ix) Cleaning of Equipment

All equipments used for mixing, transporting and placing of concrete shall be maintained in clean condition. All pans, buckets, hoppers, chutes, pipe lines and other equipments shall be thoroughly cleaned after each period of placement.

(x) Conveying and Placing Concrete

Concrete shall be poured or placed only after the forms and reinforcement have been inspected and approved, for which purpose the Contractor shall give the Engineer at least two day's notice. Generally, the use of aluminium equipment shall not be permitted in any operation where the equipment and concrete are likely to come in contact with each other, unless the aluminium surfaces have to be adequately treated to prevent reaction with and having a harmful effect on the concrete.

All buckets, containers or conveyers used for transporting concrete shall be mortar-tight. All means of conveyance shall be adopted to deliver concrete of the required consistency and plasticity without segregation or loss of slump whatever method of transportation is employed. Chutes shall not be used to transport the concrete without the approval of the Engineer and concrete shall not be re-handled before placing.

Conveying - Concrete shall not be released from a mixer, hopper, frame or other conveyance or device through a height exceeding two metres or through reinforcement, in a manner likely to cause segregation. Tremmies discharging close to the point of concreting shall be provided as required. The use of chutes will be restricted to specific locations approved by the Engineer. Concrete shall be deposited directly into the conveyance and from the conveyance directly into the locations in the structure. Deposition of concrete shall be so done to maintain, as far as possible, a level surface throughout. Manual labour may be used for conveying and placing mixed concrete provided the above requirements are not contravened.

Placing Concrete - Concrete shall be placed in position and compacted within 30 minutes after the first addition of water to the mix and no concrete showing signs of initial set shall be used. Re-tampering of set concrete is prohibited.

1 Lifts: Concrete shall be poured into forms after mixing in a manner that will prevent segregation of the ingredients and in horizontal layers not exceeding 2,000 mm thick.

   a Walls: Concrete for walls of water retaining structures, including tank exterior walls, shall be poured, where practicable, as one continuous operation from footing to top of the wall. Each section shall be left in place at least seven days before the adjoining section in similarly concreted.

   b Slabs: Concrete between approved joints shall be poured in one continuous operation in checker-board fashion and shall be allowed to stand at least seven days before adjoining sections are concreted.

   c Concreting of beams and slabs shall be continuous and monolithic with the floor.

2 Pumping Concrete: No increase in the water-cement ratios or specified slumps will be permitted to pumped concrete. The minimum conveyance tube shall be minimum diameter of 100 mm and capable of maintaining the specified pour rates.

3 Pour Rules:

   a Vertical Elements: concrete shall be placed in lifts as specified at a rate that does not cause excessive stresses in the formwork or a hardening of the top layer before next lift is poured.

   b Slabs :Concrete shall be poured at an appropriate time that ensures that all new concrete poured is adjoined to concrete that is still plastic and before the initial set of the previous placing.

   c Construction Joints: Concreting adjoining a construction joint shall not be until the existing surface has been cured for at least seven days, unless otherwise approved by the Engineer.

Before any concrete is placed, the entire placing programme, consisting of equipment, layout, proposed procedures and methods shall be submitted to Engineer for approval and no concrete shall be of such size and design as to ensure a practically continuous flow of concrete during depositing without segregation of materials, considering the size of the job and placement location.

(xi) Time Interval between Mixing and Placing

Concrete shall be placed in its final position before the cement reaches its initial set and concrete shall normally be compacted in its final position within thirty minutes of leaving the mixer and once compacted, it shall not be disturbed. On no account shall water be added after the initial mixing. Concrete which has become stiff or has been contaminated with foreign materials shall be rejected.

(xii) Avoiding Segregation

Concrete shall, in all the cases, be deposited as nearly as practicable directly in its final position and shall not be re-handled or caused to flow in a manner which will cause segregation, loss of material, displacement of reinforcement, shuttering or embedded inserts or impair its strength. For locations where direct placement is not possible and in narrow forms, the Contractor shall provide suitable props and discharge pipes to confine the movement of concrete. Special care shall be taken when concrete is dropped from a height, especially if reinforcement is in the way, particularly in columns and thin walls.

(xiii) Placing by Manual Labour

Except as otherwise approved by Engineer, concrete shall be placed using approved implements and shall not be dropped from a height of more than 2.0m or handled in a manner which will cause segregation.

(xiv) Placing by Mechanical Equipment

The following specifications shall apply when placing of concrete by use of mechanical equipment is specially called for or is warranted, considering the nature of work involved.

The control of placing shall begin at the mixer discharge. Concrete shall be discharged by a vertical drop into the middle of the bucket or hopper and this principle of a vertical discharge of concrete shall be adhered-to throughout all stages of delivery until the concrete comes to rest in its final position.

All concrete shall be conveyed from the mixer to the place of final deposit in suitable buckets, dumpers or containers which shall be leak-tight. All means of conveyance shall be adopted for delivering concrete to the required consistency/ workability and plasticity without segregation.

Central bottom-opening buckets of a type that provides for positive regulation of the amount and rate deposition of concrete shall be employed.

In placing concrete in large open areas, the buckets shall be located directly over the position designated and then lowered for dumping. The open bucket shall remain clear of any concrete already in place and the height of drop shall not exceed 2.0 m. The bucket shall be opened slowly to avoid high vertical bounce. The placing of concrete in any manner which results in separation of ingredients or disturbance of previously placed concrete will not be permitted.

(xv) Placement in Restricted Forms

Concrete placed in restricted forms shall be subject to the requirements for vertical delivery of limited height to avoid segregation and shall be deposited as nearly as practicable in its final position.

(xvi) Chuting

Where it is necessary to use transfer chutes, specific approval of the Engineer must be obtained with regards to the type, length, slopes, baffles, vertical terminal and timing of operations. These shall be arranged so that almost continuous flow of concrete is obtained at the discharge and without segregation. To allow for the loss of mortar against the sides of the chutes, the first mixes shall have less coarse aggregate. During cleaning of chutes, the waste water shall be kept clear of the forms. The concrete shall not be permitted to fall from the end of the chutes by more than 1.0 m. Chutes, when approved for use, shall have slopes not flatter than 1 vertical to 3 horizontal and not steeper than 1 vertical to 2 horizontal. Chutes shall be metal and of rounded cross section. The slopes of all chute sections shall be approximately the same. The discharge end of the chutes shall be maintained above the surfaces of the concrete in the forms.

(xvii) Placing by Pumping/ Pneumatic Placers

Concrete may be conveyed and placed by mechanically operated equipment e.g. pumps or pneumatic placers, with the approval of the Engineer. The slump shall be held to the minimum, necessary for conveying concrete by this method.

When pumping is adopted, before pumping of concrete is started, the pipelines shall be lubricated with one or two batches of mortar composed of one part cement and two parts sand. The concrete mix shall be specially designed to suit pumping. Care shall be taken to avoid stoppages in work once pumping has started.

When pneumatic placing is used, the manufacturer's advice on the layout of pipelines shall be followed to avoid blockages and excessive wear. Restraint shall be provided at the discharge box to cater for the reaction at the end.

The manufacturer's advice shall be followed regarding concrete quality and all other related matters when pumping or pneumatic placing equipment is used.

(xviii) Concrete in Layers

Concreting, once started, shall be continuous until the pour is completed. Concrete shall be placed in successive horizontal layers of uniform thickness ranging between 150 and 900 mm as approved by Engineer. These shall be placed as rapidly as practicable to prevent the formation of cold joints or planes of weakness between each succeeding layer within the pour. The thickness of each layer shall be such that it can be deposited before the previous layer has stiffened. The bucket loads or other units of deposit, shall be located progressively along the face of the layer with such overlap to facilitate spreading the layer of uniform depth and texture with a minimum of shovelling.

The top surface of each pour and bedding planes shall be approximately horizontal unless otherwise instructed.

(xix) Compaction

Effective compaction of newly placed concrete shall be obtained by vibration, agitation, spading and rodding the concrete within the forms. At least two vibrators in dependable working condition shall be available before commencement of concreting and kept in working condition during the scheduled concreting period, each under the charge of an experience workman.

All concrete, excepting slabs of thickness 10cm or less, shall be compacted with high frequency, mechanical vibrating equipment supplemented by hand spading and tamping. Concrete slabs 10cm or less in thickness shall be compacted by wood or metal tampers, spading and settling with a heavy levelling straight edged beam.

Vibrators shall be designed to operate with the vibrating element having a frequency of not less than 7000 impulses per minute. The equipment shall, at all times, be adequate, in terms of units and power, to consolidate the poured concrete. The depth of immersion shall be appropriate for the structure being concreted and the location of concreting.

The vibrators shall not touch the reinforcement. When vibrating a freshly placed layer, the vibrator shall be pushed down vertically into the preceding plastic layers and withdrawn gradually, producing a dense concrete free of set concrete. The intervals at which the vibrator should be immersed shall not exceed 2/3 of the apparent effective area of vibration of the unit used. Excessive vibration and segregation of aggregates shall be avoided.

For concrete containing an approved retarding admixture for structural walls, each layer of concrete shall be in place and compacted for at least 30 minutes before the next layer is placed. Bleed water on the surface of the concrete shall be removed before additional concrete is placed and the concrete in place shall be re-vibrated before the next lift is placed. At the top of walls and columns, concrete containing excess water or fine aggregates cause by vibration shall be removed while still plastic and the space filled with compacted concrete of the correct proportion and vibrated in place.

(xx) Slabs

For slabs, screeds shall be set at maximum of 2.5 metres. Centres and the correctness of elevations shall be checked with an instrument level. The concrete shall be compacted and tamped to bring ten mm of mortar to the surface and wood floated to straight edges and screeds. The finished surfaces shall be level or sloped as required and the maximum deviation permissible being 6 mm from 3m straight edge for the exposed finishes. No steel or plastic floats shall be used for initial floating. Unless otherwise specified, special finishes shall be applied only after the surface has sufficiently hardened. All laitance and bleed water shall be removed as it appears.

Concrete shall be compacted during placing with approved vibrating equipment until the concrete has been consolidated to the maximum practicable density, is free of pockets of coarse aggregate and fits tightly against all form surfaces, reinforcement and embedded fixtures. Particular care shall be taken to ensure that all concrete placed against the form faces and into corners of forms or against hardened concrete at joints is free from voids or cavities. The use of vibrators shall be consistent with the concrete mix and caution is to be exercised to not over vibrate the concrete to the point of segregation.

(xxi) Vibrators

Vibrators shall conform to IS specifications. The type of vibrators to be used shall depend upon the structure where concrete is to be placed. Shutter vibrators, to be effective, shall be firmly secured to the formwork which must be sufficiently rigid to transmit the vibrations and strong enough not to be damaged by it. Immersion vibrators shall have load frequency amplitude and acceleration as per IS 2505 depending on the size of the vibrator. Immersion vibrators, in sufficient numbers and each of adequate size shall be used to properly consolidate all concrete. Tapping or external vibrating of forms by hand tools or immersion vibrators will not be permitted.

The exact manner of application and the most suitable machines for the purpose shall be selected and be operated by experienced operatives. Immersion vibrators shall be inserted vertically at points not more than 450 mm apart and withdrawn when air bubbles cease to come to the surface. Immersion vibrators shall be withdrawn very slowly. In no case shall immersion vibrators be used to transport concrete inside the forms. Particular attention shall be paid to vibration at the top of lift in a column or wall.

When placing concrete in layers which are advancing horizontally as the work progress, great care shall be exercised to ensure adequate vibration, blending and melding of the concrete between the successive layers.

Immersion vibrators shall penetrate the layer being placed and also penetrate the layer below while the under layer is still plastic to ensure good bond and homogeneity between the two layers and prevent the formation of cold joints.

Care shall be taken to prevent contact of immersion vibrators against reinforcement steel. Immersion vibrators shall not come in contact with reinforcement steel after start of initial set. They shall also not be allowed to come in contact with forms or finished surfaces.

Form attached vibrators shall be used only with specific authorisation of Engineer.

The use of surface vibrators will not be permitted under normal conditions. However, for thin slabs, surface vibration by specifically designed vibrators may be permitted, upon approval of the Engineer.

Formation of stone pockets or mortar ponding in corners and against faces of forms shall not be permitted. Should these occur, they shall be dug out, reformed and refilled to a sufficient depth and shape for thorough bonding as approved by the Engineer.

(xxii) Placement Intervals

Each placement of concrete shall be allowed to set for a period of 48 hours or longer when required, before the start of subsequent placement. A time gap between the two adjoining pours in the horizontal plane and the two adjacent pours in the vertical plane shall be seven days and three days respectively.

Except when placing with slip forms, each placement of concrete in multiple lift work shall be allowed to set for at least 24 hours after the final set of concrete and before the start of a subsequent placement.

(xxiii) Special Provision in Placing

When placing concrete in walls with openings, in floors of integral slab and beam construction and other similar conditions, the placing shall stop when the concrete reaches the top of the opening in walls or bottom horizontal surface of the slabs as the case may be. Placing shall be resumed before the concrete in place takes initial set, but not until it has had time to settle as determined by Engineer.

(xxiv) Placing Concrete through Reinforcing Steel

When placing concrete through reinforcing steel, care shall be taken to prevent segregation of the coarse aggregate. Where the congregation of steel makes placing difficult, it may be necessary to temporarily move the top steel aside to get proper placement and then restore the reinforcing steel to design position.

(xxv) Bleeding

Bleeding or free water on top of concrete being deposited into the forms shall require stopping the concrete pour and the conditions causing this shall be corrected before any further concreting is resumed.

(xxvi) Rain or Wash Water

No concrete shall be placed in wet weather or on a water covered surface. Any concrete that has been washed by heavy rain shall be entirely removed, if there is any sign of cement and sand having been washed away from the concrete mixture. To guard against damage which may be caused by rain, the works shall be covered with tarpaulins immediately after the concrete has been placed and compacted before leaving the work unattended. Any water accumulating on the surface of the newly placed concrete shall be removed by approved means and no further concrete shall be placed thereon until such water is removed. To avoid water flowing over or around freshly placed concrete, suitable drains and sumps shall be provided.

(xxvii) Concreting in Hot Weather

The Contractor's methods shall comply with the recommendations ACI 305, Hot Weather Concreting, as modified and supplemented below.

The Contractor shall take great care during hot weather to prevent the cracking or crazing of concrete. The Contractor shall arrange for concrete to be placed in the early morning or late evening as directed by the Engineer.

The Contractor shall have particular regard to the requirements specified herein for curing.

Formwork shall be shaded from direct exposure to the sun both prior to placing of the concrete and during its setting. The Contractor shall take appropriate measures to ensure that reinforcement in and projecting from the section to be concreted is maintained at the lowest temperature practicable.

Concrete at placing shall have a temperature of not more than 32 oC. If necessary, the Contractor shall cool the aggregates and mixing water by methods approved by the Engineer.

Where necessary, the Contractor shall design, install and operate a cooling system by which cooling water is pumped through a piping system in order to decrease the heat of hydration during concreting. The proposal for such a cooling system shall be submitted to the Engineer for his approval two weeks prior to the concreting operations.

The temperatures of ambient air, concrete at various levels and at intervals not exceeding 5 metres and cooling water where applicable shall be measured by means of thermocouples and recorded with a Philips type PR 3210 A/00 recorder or similar approved.

(xxviii) Placing of Concrete Under Water

Under all ordinary conditions all foundations shall be completely dewatered and concrete placed in the dry. However, when concrete placement under water is necessary, all work shall conform to IS 456 and procedure shall be as follows:

Concrete shall be deposited under water by means of tremies or bottom-drop buckets of approved type.

All work requiring placement of concrete underwater shall be designed, approved and inspected with regard to the local circumstances and purposes. All under water concrete shall be placed according to the specifications and as approved by the Engineer.

(xxix) Protection

All concrete shall be protected against damage.

(xxx) Corrosion Resistant Lining

Where required, corrosion resistant linings shall be applied strictly according to the manufacturer's instructions. The work shall be performed by experienced personnel under the supervision of a qualified representative of the manufacturer. The completed lining shall be securely bonded to the substrate and provide the required corrosion resistant protection.

(xxxi) Installation of Pipes, Electrical Conduits etc Through Concrete Structures

Wherever required, the Contractor shall install in place, before concreting, any pipe, electrical conduit or other special item that passes through or terminates at any concrete wall. Alternatively the Contractor shall obtain the prior approval of the Engineer of shop drawings of the methods he proposes to adopt, particularly if he intends to leave an opening and install the special item later

After approval that a special item may be concreted in later, the opening shall be accurately fashioned to receive it. Pipes passing through walls or floors of water retaining or earth supporting structures shall be provided with welded puddle flanges and the opening provided shall take this into account.

1 The opening provided shall be of sufficient size to permit accurate final alignment of the embedded fitting without deflecting any part and allowing adequate space for satisfactory spacing where the pipe passes through openings so formed.

2 The box-outs shall be provided with continuous keyways to hold the concrete filling in place and ensure water-tightness.

3 The space left within the box-outs and around the special item positioned in place, shall be filled with non-shrink grout or non-shrink concrete as approved by the Engineer.

(xxxii) Mass Foundations

Mass foundations shall be poured in lifts not exceeding 1.5 m. in height unless otherwise approved by the Engineer.

(xxxiii) Treatment of Construction Joints on Resuming Concreting

All laitance and loose stones shall be thoroughly and carefully removed by wire brushing/ hacking and surface washed.

Just before concreting is resumed, the roughened joint surface shall be thoroughly cleaned and loose matter removed and then thoroughly wetted. The new concrete shall be well worked specially against the prepared face. Special care shall be taken to obtain thorough compaction and to avoid segregation of the concrete along the joint plane.

(xxxiv) Water

Clean water in pipes under pressure shall be provided by the contractor with all necessary equipment for giving a nozzle pressure of not less than 2.0 kg/cm2 for the convenient and effective jetting of rock foundations and concrete surfaces, for cooling aggregate required for concrete, for curing concrete and other requirements.

(xxxv) Protecting Fresh Concrete

Fresh concrete shall be protected from the elements, from defacement and damage due to construction operations by leaving forms in place for ample periods. Newly placed concrete shall be protected by approved means, such as tarpaulins, from rain, sun and winds. Steps, as approved by the Engineer, shall also be taken to protect immature concrete from damage by debris, excessive loading, vibration, abrasion or contact with other materials or otherwise disturbed. If it is necessary that workmen enter the area of freshly placed concrete, bridges shall be placed over the area.

14.6.2 Concrete for Large Pours

This clause applies to large concrete pours where measures need to be taken to deal with the generation of heat and attendant volume change to minimise cracking.

If available, coarse aggregate shall be of limestone or other aggregate with a low coefficient of thermal expansion and of angular shape.

Measures shall be taken to limit the effects of thermal movement in the concrete.

The maximum temperature during hydration shall not exceed 65 °C.

The concrete mix may include an approved type of water reducing /workability admixture.

Form-work for the sides shall be of minimum 19 mm thick plywood or equivalent thermal resistant to ensure that the maximum specified thermal gradient is not exceeded during curing.

All formwork for pits, ducts, rebates and holding down bolts shall be constructed so that it can be easily collapsed to facilitate removal after the initial set of the concrete. The top of formwork for holes shall be covered to prevent entry of excess grout or other substances.

Standby plant shall be available for all plant used for the construction of the foundations. For compressors, vibrators, cranes, concrete pumps, lighting equipment and the like, standby plant shall be on site before concreting commences.

Concrete shall be placed in single pours lasting no more than 16 hours. The sequence of placing shall be such, that exposed concrete shall be covered with fresh concrete within one hour of first mixing of the exposed concrete. Re-compaction of the original with the fresh concrete shall be undertaken to ensure a homogenous mass without a cold joint.

The concrete shall be placed and compacted in such a manner as to ensure that cracking due to plastic settlement does not occur.

On completion of a pour, the top surface shall be steel trowel finished and the exposed concrete shall be sprayed with an approved curing compound. Space shall be arranged around the pour to allow the free flow of air during curing.

The poured concrete shall be protected if necessary with insulation to limit the thermal gradient between the core and the surface to below 20 °C. The pour shall contain thermocouples distributed within the concrete in accordance with the Contractors design. The Contractor shall measure and record the internal and surface concrete temperatures daily until the formwork is stripped.

The formwork and insulation shall be left in place until the surface temperature is at the average ambient daily temperature.

The method statement for the construction of each large pour shall include the following information:

1. Details of the mix design and source of supply.
2. Full details of the formwork with particular reference to the installation of holding down bolt formers.
3. Details of the placing procedure including method of placing, standby arrangements, number of vibrators and number of supervisors and operatives.
4. Details of insulation for the pours and how the pours are to be cured.
5. Details of how the concrete is to be placed and compacted without cold joints and without cracking resulting from plastic settlement.

Within six weeks after construction of large pours, the Contractor shall issue a construction report containing full details of the construction, materials testing results and as-built drawings.

14.6.3 Concrete for Machine Foundations

Design and construction of machine foundations shall be carried out in accordance with IS 2974.

After commissioning rotating machines, the Contractor shall carry out a full vibration survey to record the vibrations of the foundations. The results of the survey shall be submitted to the Engineer.

14.6.4 Joints in Concrete

(i) General

Provision shall be made for expansion and contraction in concrete by the use of special joints located as necessary. Construction joint surfaces shall be as specified or as approved by the Engineer.

Concrete shall be placed without interruption until completion of the part of the work between predetermined construction joints. The time lapse between the pouring of adjoining units shall be as specified or as approved by Engineer.

Construction joints shall be avoided if possible or their number minimised. Concreting shall be carried out continuously up to construction joints the position and arrangement of which shall be indicated by the Contractor's designer. Construction joints shall comply with IS 11817.

Construction joints shall be placed at accessible locations to permit cleaning out of laitance, cement slurry and unsound concrete in order to create rough/uneven surface. Laitance and cement slurry shall be cleaned out by using wire brushes on the surface of the joint immediately after initial setting of the concrete. The prepared surface should be in a clean saturated surface dry condition when fresh concrete is placed against it. In the case of construction joints at locations where the previous pour has been cast against shuttering, the aggregate of the previously poured concrete shall be exposed using a high pressure water jet or by another appropriate means.

At least 3 weeks prior to commencement of concreting, the Contractor shall supply drawings to the Engineer indicating all expansion or other movement joints both vertical and horizontal including details of the type of joint to be provided, the method of concreting, the concreting lifts to be achieved in a single continuous operation and any other relevant details. One copy of the drawing, approved or modified, shall be returned to the Contractor.

Expansion joints shall be indicated on the Contractor's drawings. The width of the joint shall generally be 13 mm. Except where synthetic rubber (sealant) sealed joints are specified, joint filler and joint sealer shall be provided, with the filler to between 13 mm and 19 mm from the concrete face and then the sealer finished flush with surface. At synthetic rubber sealed joints, the filler shall be to 13 mm from the concrete face to receive sealant, unless otherwise specified.

All Construction joints shall be provided with suitable keyways or other keying methods. The old surface shall be roughened until the clean aggregate embedded in the mortar matrix is exposed, by chipping, sand-blasting or application of a surface mortar retardant followed by washing and scrubbing with a stiff brush. Reinforcement and water-stops shall be effectively protected. The prepared surface shall be kept wet for at least 24 hours before placing new concrete. Immediately prior to commencement of the new concreting, water shall be deposited on the prepared horizontal surface of the old concrete. If water-stops are not used, the coarseness amplitude of the prepared surface shall be at least 6 mm.

Roof and floor slabs shall be poured in alternating checker-board fashion between approved construction joints. Concreted sections shall be fully cured before adjoining sections are concreted. All construction joints in floor slabs and rafts shall be painted with a 230 mm wide strip of bitumen paint to be applied in two thick layers.

Fresh concrete should be thoroughly vibrated near construction joints so that mortar from the new concrete flows between large aggregates and develops a proper bond with old concrete.

Where high shear resistance is required at the construction joints, shear keys shall be provided.

Sprayed curing membranes and release agents should be thoroughly removed from joint surfaces.

If the stopping of concreting becomes unavoidable, a properly formed construction joint shall be made where the work is stopped. Joints shall be either vertical or horizontal. In the case of an inclined or curved member, the joints shall be at right angles to the axis of the member. Vertical joints in walls shall be kept to a minimum. Vertical joints shall be formed against a stop board, horizontal joints shall be level and wherever possible, arranged so that the joint lines coincide with the architectural features of the finished work. Battens shall be nailed to the formwork to ensure a horizontal line and if approved, shall also be used to form a grooved joint. For tank walls, similar work joints shall be formed as per IS 3370. Concrete that is in the process of setting shall not be disturbed or shaken by traffic either on the concrete itself or upon the shuttering. Horizontal and vertical construction joints and shear keys shall be located and shall conform in detail to the Contractor's approved drawings unless otherwise approved by Engineer. The joints shall generally be in accordance with the following:

(ii) Column Joints

In a column, the joint shall be formed 75 mm below the lowest soffit of the beams, including haunches if any. In flat slab construction, the joint shall be 75 mm below the soffit of column capital. At least two hours shall elapse after depositing concrete in column, piers or walls, before depositing in beams, girders or slabs supported thereon.

(iii) Beam and Slab Joints

Concrete in a beam shall be placed throughout without a joint but if the provision of a joint is unavoidable, the joint shall be vertical and at the centre or within the middle third of the span unless otherwise approved. Where a beam intersects a girder, the joints in the girder shall be offset a distance equal to twice the width of the beam and additional reinforcement provided for shear. The joints shall be vertical throughout the full thickness of the concrete member. A joint in a slab shall be vertical and parallel to the principal reinforcement. Where it is unavoidable at right angles to the principle reinforcement, the joint shall be vertical and at the middle of span.

(iv) Joints in Liquid Retaining Structures

Vertical construction joints in watertight construction will not be permitted. Where a horizontal construction joint is required to resist water pressure, special care shall be taken in all phases of its construction to ensure maximum water-tightness.

(v) Expansion and Movement Joints

Joint filler shall consist of a proven bituminous compound approved by the Engineer. Application of the filler shall be strictly in accordance with the manufacturer's instructions.

The Contractor shall supply, for the Engineer's approval, details of the proposed materials including the mechanical properties. The manufacturer shall design the width and thickness of the elastomeric compound to accommodate the maximum designed thermal shrinkage movement at the joint.

Joint Sealers shall be of impermeable ductile material providing a water-tight seal through the full joint movement range.

(vi) Expansion Joint Fillers

Materials

Materials for expansion joint filler boards shall be of best quality bitumen impregnated preformed non-extruding, resilient type of appropriate thickness in the standard sizes available.

The sealing compound to close the gaps at the edges shall be of best quality rubberized bituminous hot pour, made from special grades of bitumen and shall not show flowing tendency in hot weather and is resilient in the cold weather. The liquid primer shall be made from blown grade bitumen of approved quality.

The aluminium plates for fixing at floor level shall be of appropriate size and made out of extruded sections, free from any rolling defects.

The aluminium sheet for fixing on the underside of beams or the sides of columns shall be of appropriate size without any defects.

Preparation of Surfaces

All the concrete surfaces already cast and where the expansion joint is to be formed, shall be properly cleaned of all dirt, mortar/concrete, dust etc. One coat of primer shall be applied by brush to the entire concrete surface, just prior to the next concreting.

Workmanship

Soon after the primer is applied, the filler board shall be placed at the side and held tight with the concrete surface, by suitable means. Care shall be taken that the boards do not get damaged or warped during all the operations. Utmost care shall also be taken to ensure that the board is held tightly to the concrete surface and no stone chip, concrete etc shall enter between the board and the existing concrete surface against which the board is placed.

The aluminium plates shall have round holes at 300 mm c/c. of required diameter on one side of the joint through which screws shall be fixed into the concrete. On the other side, slotted holes at 300 mm c/c shall be provided so that when screwed, these shall render smooth movement of plates during expansion/contraction. The plates shall be fixed correctly to the required level, line, plumb etc and as approved by the Engineer.

In case of plates fixed on floors, they shall be fixed when the floor mortar screed is laid to the required level over the expansion joint duly filled up with sealing compound.

In case of roofs, the expansion joints in beams placed vertically, shall be extended upwards, when RC/brick masonry curbing is laid to the desired height (approximate 450 mm) over which horizontal flat board is laid to the extent of 150 mm, as per procedure laid down previously.

(vii) Water-Stops

Water bars or water stops shall be extruded from a polyvinyl chloride compound containing the plasticizers, resins, stabilizers and other ingredients needed to import the required characteristics or from synthetic rubber.

The Contractor shall supply to the Engineer, details of the thickness of the water-stop offered by him to indicate its adequacy to withstand the design pressures.

All water-stop interactions such as ells, tees, crosses etc shall be fabricated by the manufacturer and shall have sufficiently long legs to permit field butt splicing.

Water-stops shall be provided in all expansion and movement joints. Water-stops shall be continuous in joints, following offsets and angles in joints until spliced to water-stops at intersections and thereby completely sealing the structure. The flanges of water-stops shall be secured to the reinforcement with 18 gauge wire ties at a maximum spacing of 45 centimetres or with a PVC binding where that is specifically recommended by the water-stop manufacturer.

PVC water-stops shall be neatly fused and synthetic rubber water-stops vulcanized at joints and connections unless explicitly otherwise specified by the manufacturer.

Water stops shall be provided at all vertical construction joints in walls of water retaining structures and all expansion joints in water retaining structures and wherever specified or directed by the Engineer.

Water stops shall not be exposed to direct sunlight for long periods. Before being concreted, water stops shall be cleaned of all foreign materials. Wherever provided, water stops shall be placed in such a manner that they are embedded in the adjacent sections of the panels for equal width.

The storage, fixing in position, splicing of water stops shall be as per manufacturer's instructions.

Water stops shall be fully supported in the formwork, be free of nails and clear of reinforcement and other fixtures. Damaged water stops shall be replaced and during concreting care shall be taken to place concrete so that water stops do not bend or distort.

The different type of water stops to be used in liquid retaining structures shall be as follows:

	Type of Joint	Type of Water Stops
1.	Partial/ complete construction joint in walls and slabs	150 mm wide, ribbed with hollow centre bulb and 5 mm minimum thickness
2.	Expansion joints in walls and slabs	225 mm wide, ribbed with hollow centre bulb and 9 mm minimum thickness
3.	Construction joint in raft	225 mm wide, ribbed with hollow centre bulb and 5 mm minimum thickness
4.	Construction joint in wall	150 mm wide, ribbed with hollow centre bulb and 5 mm minimum thickness
5.	Partial/ complete constructiion joint in raft	225 mm wide, ribbed with hollow centre bulb and 5 mm minimum thickness

6.	Expansion joint in raft	225 mm wide, ribbed with hollow centre bulb and 5 mm minimum thickness

(viii) Dowels

Dowels for concrete work, not likely to be taken up in the near future, shall be wrapped in tar paper and burlap.

14.6.5 Curing

(i) Curing Formed Concrete

All concrete shall be cured by keeping it continuously damp for the period of time required for complete hydration and hardening to take place. Curing shall be by use of the water curing method, specified liquid membrane forming compound or concrete curing paper, the specified use of any method being subject to the approval of the Engineer.

Preference shall be given to the use of continuous sprays or ponded water, continuously saturated covering of sacking, canvas, hessian or other absorbent materials, or approved effective curing compounds applied with spraying equipment capable of producing a smooth, even textured coat. Extra precautions shall be exercised in curing concrete during hot weather. The quality of curing water shall be the same as that used for mixing the concrete.

Certain types of finish or preparation for overlaying concrete must be made at certain stages of the curing process and special treatment may be required for specific concrete surface finishes.

Curing of concrete made of high alumina cement and super-sulphated cement shall be carried out as approved by the Engineer.

The structural elements with concrete having water binder ratio less than or equal to 0.4 or partial replacement of cement by pozzolanic materials (5% or above replacement by silica fume or high reactivity metakaoline, or 15% or above by fly ash) shall be cured in two stages, initial curing and final curing.

The initial curing should be started not later than three hours or after the initial setting time, whichever is lower, after placement of concrete. The concrete surfaces exposed to the environment shall be covered by plastic sheet or other type of impermeable covers. The initial curing should be continued up to a minimum period of 12 hours or 2 hours plus final setting time of concrete, whichever is higher.

Final curing shall be with water and commence immediately after initial curing and continue for a minimum period of 14 days.

(ii) Continuous Spraying

Curing shall be assured by the use of an ample water supply under pressure in pipes, with all necessary appliances of hose sprinklers and spraying devices. Continuous fine mist spraying or sprinkling shall be used, unless otherwise specified or approved by Engineer.

(iii) Alternative Curing Methods

Whenever, in the judgment of the Contractor's designer and with the approval of the Engineer, it may be necessary to omit the continuous spray method, covering of clean sand or other approved means such as wet gunny bags, which will prevent loss of moisture from the concrete, may be used. Any type of covering which would stain or damage the concrete during or after the curing period shall not be used. The covering shall be kept continuously wet during the curing period.

For curing of concrete in pavements, side-walks, floors, flat roofs or other level surfaces, the ponding method of curing is preferred. The method of containing the ponded water shall be approved by Engineer. Special attention shall be given to edges and corners of slabs to ensure proper protection to these areas. The ponded areas shall be kept continuously filled with water during the curing period.

(iv) Curing Equipment

All equipments and materials required for curing shall be on hand and ready for use before the concrete is placed.

(v) Membrane Curing

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

For concrete containing Portland pozzolona cement, Portland slag cement or mineral admixtures, an increased period of curing may be required.

14.6.6 Repair and Replacement of Unsatisfactory Concrete

Immediately after shuttering is removed, the surfaces of concrete shall be very carefully inspected and all defective areas called to the attention of Engineer who may permit patching of the defective areas or else reject the concrete either partially or entirely. Rejected concrete shall be removed and replaced by the Contractor. Holes left by form bolts etc shall be filled and made good with mortar composed of one part of cement to one and half parts of sand, that passes through a 2.36 mm IS sieve, after removing any loose stones adhering to the concrete. Mortar filling shall be struck off flush at the face of the concrete. The concrete surface shall be finished as described under the particular item of work.

Superficial honey combed surfaces and rough patches shall be similarly made good immediately after removal of shuttering, in the presence of Engineer and superficial water and air holes shall be filled in. The mortar shall be well worked into the surface with a wooden float. Excess water shall be avoided. Unless instructed otherwise by Engineer, the surface of exposed concrete placed against shuttering shall be rubbed down immediately on removal of shuttering to remove fine or other irregularities. Care shall be taken to avoid damaging the surfaces. Surface irregularities shall be removed by grinding.

If reinforcement is exposed or the honey combing occurs at vulnerable positions. such as at the ends of beams or columns, it may be necessary to cut out the member completely or in part and reconstruct. The decision of Engineer shall be final. If in the opinion of the Engineer only patching is necessary, the defective concrete shall be cut out until solid concrete is reached (or to a minimum depth of 25 mm), the edges being cut perpendicular to the affected surface or with a small under cut if possible, anchors, tees or dowels shall be provided in slots whenever necessary to attach the new concrete securely in place. An area extending several centimetres beyond the edges and the surfaces of the prepared voids shall be saturated with water for 24 hours immediately before the patching material is placed.

(i) Use of Epoxy Mortar

The use of epoxy mortar for bonding fresh concrete used for repairs will be permitted upon written approval of Engineer. Epoxy mortar shall be applied in strict accordance with the instruction of the manufacturer.

(ii) Method of Repair

Small size holes having surface dimensions about equal to the depth of the hole, holes left after removal of form bolts, grout insert holes and slots cut for repair of cracks shall be repaired as follows:

The hole to be patched shall be roughened and thoroughly soaked with clean water until absorption stops.

A 5 mm thick layer of grout of equal parts of cement and sand shall be well brushed into the surface to be patched followed immediately by the patching concrete which shall be well consolidated with a wooden float and left slightly proud of the surrounding surface. The concrete patch shall be built up in 10 mm thick layers. After an hour or more, depending upon weather conditions, it shall be worked off flush with a wooden float and a smooth finish obtained by wiping with hessian. Steel trowels shall not be used for this purpose. The mix for patching shall be of the same materials and in the same proportions as that used in the concrete being repaired, although some reduction in the maximum size of the coarse aggregates may be necessary and the mix shall be kept as dry as possible.

Mortar filling by air pressure (guniting) shall be used for repair of areas too large and/ or too shallow for patching with mortar. Patched surfaces shall be given a final treatment to match the colour and texture of the surrounding concrete. White cement shall be substituted for ordinary cement, if so approved by Engineer, to match the shade of the patch with the original concrete.

(iii) Curing of Patched Work

The patched area shall be covered immediately with an approved non-staining water-saturated material such as gunny bags, which shall be kept continuously wet and protected against the sun and wind for a period of 24 hours. Thereafter, the patched area shall be kept wet continuously by a fine spray of water for not less than 10 days.

(iv) Approval by Engineer

All materials, procedures and operations used in the repair of concrete and also the finished repair work shall be subject to the approval of Engineer. All fillings shall be tightly bonded to the concrete and shall be sound and free from shrinkage cracks after the fillings have been cured and dried.

14.6.7 Finishing

This specification is intended to cover the treatment of concrete surfaces of all structures.

(i) Finishes for Formed Surfaces

The type of finish for formed concrete surfaces shall be as follows, unless otherwise approved by the Engineer:

For surfaces against which backfill or concrete is to be placed, no treatment is required except repair of defective areas.

For surfaces below grade, which will receive waterproofing treatment, the concrete shall be free of surface irregularities which would interfere with proper application of the waterproofing materials which is specified for use.

Surfaces which will be exposed to the weather and which would normally be level, shall be sloped for drainage. Unless a horizontal surface is specially specified or a particular slope required, the tops of narrow surfaces such as staircase treads, walls, curbs and parapets shall be sloped across the width at 1 in 30. Broader surfaces such as walkways, roads, parking areas and platforms shall be sloped at 1 in 50. Surfaces that will be covered by backfill or concrete, sub floors to be covered with concrete topping, terrazzo or quarry tile and similar surfaces shall be smooth, screeded and levelled to produce even surfaces. Surface irregularities shall not exceed 6mm. Surfaces which will not be covered by backfill, concrete or tile topping such as external decks, floors of galleries and sumps, parapets, gutters, sidewalks, floors and slabs shall be consolidated, screeded and floated.

Excess water and laitance shall be removed before final finishing. Floating may be done by hand or power tools and started as soon as the screeded surface has attained a stiffness to permit finishing operations and these shall be the minimum required to produce a surface uniform in texture and free from screed marks or other imperfections. Joints and edges shall be tooled as required or as approved by the Engineer.

(ii) Standard Finish for Exposed Concrete

Exposed concrete shall mean any concrete other than floors or slabs exposed to view upon completion of the job. Unless otherwise specified on the drawings, the standard finish for exposed concrete shall be of smooth finish.

A smooth finish shall be obtained with the use of lined or plywood forms having smooth and even surfaces and edges. Panels and form linings shall be of uniform size and be as large as practicable and installed with closed joints. Upon removal of forms, the joint marks shall be smoothed off and all blemishes, projections etc removed, leaving the surfaces smooth and unmarred.

(iii) Integral Cement Concrete Finish

When required, an integral cement concrete finish of specified thickness for floors and slabs shall be applied either monolithically or bonded, as specified in IS2571. The surface shall be compacted and then floated with a wooden float or power floating machine. The surface shall be tested with a straight edge and any high and low spots eliminated. Floating or trowelling of the finish shall be permitted only after all surface water has evaporated. Dry cement or a mixture of dry cement and sand shall not be sprinkled directly on the surface of the cement finish to absorb moisture or to stiffen the mix.

(iv) Rubbed Finish

A rubbed finish shall be provided only on exposed concrete surfaces as required. Upon removal of forms, all fins and other projections on the surfaces shall be carefully removed, offsets levelled and voids and/ or damaged sections repaired. The surfaces shall then be thoroughly wetted and rubbed with carborundum or other abrasive. Cement mortar may be used in the rubbing, but the finished surfaces shall not be brush coated with either cement or grout after rubbing. The finished surfaces shall present a uniform and smooth appearance.

14.6.8 Field Quality Control

All concreting shall be supervised by the Engineer and in order to enable the Engineer to make the requisite arrangements for checking reinforcement and formwork, the Contractor shall give him adequate notice of the proposed concreting operations which, except under special circumstances, shall not be less than 24 hours. Any concreting done in the absence of, or without the express permission of the Engineer is liable to rejection.

14.6.9 Tests

All tests specified in the Indian Standards shall be regularly carried out together with any additional tests the Engineer may require to satisfy himself regarding the quality of the work done.

If the results of any tests indicate the concrete in question is unsatisfactory in any respect, the Contractor shall take any steps indicated by the Engineer to rectify the same and if such rectification is not found to be satisfactory or adequate, the section in question shall be removed and re-concreted.

While all the tests stipulated in the Indian Standards are necessary, the carrying out of the field slump-tests and the making of the specified works test cubes from every batch of concrete, or as otherwise specified by the Engineer, shall be carried out as an invariable general rule.

The following requirements in respect of concrete testing will be rigidly applied throughout the duration of the Contract to all permanent works.

(i) Sampling Procedure

Sampling and testing shall be in accordance with IS 1199 and IS 516. Evaluation of the results and acceptance or rejection of the concrete will be done as described below.

Six cubes shall be obtained from each mix during each working period. Half the number in each sample shall be tested at 7 days and the balance at 28 days. Where the tests are carried out in the site laboratories, companion cubes shall be tested on the dates on which the representative samples are tested at site at an independent laboratory approved by the Engineer. If a significant difference is noticed between the two sets of results all further testing shall be done at the approved laboratory until the site equipment is rectified satisfactorily. No reduction in the frequency or number of samples taken shall be made without the explicit approval of the Engineer who, if agreeing to any reduction, shall have such a decision mainly on the consistency of good results achieved over an acceptable period. Any deterioration in quality will result in the more rigorous schedule being re-implemented.

The values given in the table below may be taken for general guidance in the case of concrete made with ordinary cement. In all cases, the 28 day compressive strength specified shall alone be the criterion for acceptance or rejection of the concrete. If however, from tests carried out for a particular job over a reasonably long period, it has been established to the satisfaction of the Engineer that a suitable ratio between the 28 days compressive strength and the modulus of rupture at 72 ± 2 hours or 7 days, or compressive strength at 7 days may be accepted, the Engineer may suitably relax the frequency of 28 day compressive strength tests, provided the expected strength values at the specified early age are consistently met.

Optional Tests Requirements of Concrete:

Grade of Concrete	Compressive strength on 15cm cubes min. at 7 days N / mm^2	Modulus of rupture by beam test min.	
		At 72 ± 2 hours N / mm^2	At 7 days N / mm^2
M 10	7.0	1.2	1.7
M 15	10.0	1.5	2.1
M 20	13.5	1.7	2.4
M 25	17.0	1.9	2.7
M 30	20.0	2.1	3.0
M 35	23.5	2.3	3.2
M 40	27	2.5	3.4

(ii) Test Specimen

Three test specimens shall be made from each sample for testing at 28 days. Additional cubes may be required for various purposes such as to determine the strength of concrete at 7 days or at the time of striking the form work or to determine the duration of curing or to check the testing error. Additional cubes may also be required for testing cubes cured by accelerated methods as described in IS 9013 - 1978. The specimen shall be tested as described in IS 516 - 1959.

(iii) Frequency

The minimum frequency of sampling of concrete of each grade shall be in accordance with following table:

Quantity of Concrete m^3	Number of Samples
1 – 5	1
6 – 15	2
16 – 30	3
31 – 50	4
51 & above	4 + one per additional $50m^3$

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

(iv) Test Strength of Samples

The test strength of the samples shall be the average of the strength of three specimens. The individual variation should not be more than ± 15 percent of the average.

(v) Standard Deviation

This section should be read in conjunction with Sections 14.3 and 14.4.1 of this specification.

The standard deviation and coefficient of variation shall be computed for a set of any 10 consecutive tests. The probable minimum strength of the batch, as calculated from the results of the 10 tests, based on failure probability of 1 in 10, shall then be compared with the specified minimum strength for the relevant grade of concrete.

1 If the calculated minimum strength exceeds the specified minimum strength by 10 percent or more, the Contractor will be permitted to redesign the mix with a lower cement content, if feasible.

2 If the calculated strength exceeds the specified minimum strength by not more than 10 percent, the mix design shall be used for subsequent batches of concrete.

3 If the calculated strength falls short of the minimum specified strength but by not more than 10 percent, the decision to accept or reject the representative batch of concrete will be at the sole discretion of the Engineer. The location of the batch in the structure, the maximum stresses likely to occur therein, the calculated strength of the cubes and other relevant factors will be taken into consideration, but his decision, once given shall not be subject to question or dispute nor shall it be subsequently quoted as a precedent.

4 If the calculated minimum strength falls short of the specified minimum strength by more than 10 percent, the representative batch of concrete shall be rejected.

5 All water retaining structures shall be tested for water-tightness in conformance with the requirements of IS 3370 (Part I) – 1965, section 10 to the satisfaction of the Engineer.

14.6.10 Acceptance Criteria

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

(a) The mean strength determined from any group of four consecutive test results complies with the appropriate limits in column 2 of the table below

(b) Any individual test result complies with the appropriate limits in column of Table below.

Characteristic Compressive Strength Compliance Requirement:

Specified grade	**Mean of the group of 4 non-overlapping consecutive test results in N/mm² **	**Non-overlapping consecutive test results in N/mm² Individual test results in N/mm²**
M 15	= / > f_{ck} + 0.825 x established standard deviation (rounded off to nearest 0.5N/mm² Or = / >f_{ck} + 3N/mm² whichever is greater	= / > f_{ck} –3N/mm²
M 20 or above	= / > >f_{ck} + 0.825 x established standard deviation (rounded off to nearest 0.5N/mm² or = / > f_{ck} + 4N/mm² whichever is greater	= / > f_{ck} – 4N N/mm²

Note – In the absence of an established value of standard deviation, the values given in (assumed standard deviation) may be assumed and an attempt should be made to obtain the results of 30 samples as early as possible to establish the value of standard deviation.

(i) Flexural Strength

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

1 The mean strength determined from any group of four consecutive test results exceeds the specified characteristic strength by at least 0.3N/mm²

2 The strength determined from any test result is not less than the specified characteristic strength less 0.3N/mm²

(ii) Quantity of Concrete Represented by Strength Test Results.

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

For the individual test result requirements given in column 2 of above table or in item (b) of flexural strength , only the particular batch from which the sample was taken shall be at risk.

Where the mean rate of sampling is not specified the maximum quantity of concrete that four consecutive test results represent shall be limited to 60m3.

If the concrete is deemed not to comply pursuant to the above, the structural adequacy of the parts affected shall be investigated and any consequential action as needed shall be taken.

Concrete of each grade shall be assessed separately.

(iii) Alterations and Concreting against Surfaces

Existing concrete surfaces which are to receive new concrete shall be heavily sand-blasted to expose the coarse aggregate and produce a clean, coarse textured surface. Such prepared surfaces shall be coated with an epoxy bonding or other approved coating immediately prior to concreting. The compound shall be equal or superior to "Sikastix Adhesive" manufactured by the Sika chemical company and shall be mixed and applied strictly in accordance with the manufacturer's recommendations under different conditions.

14.7 Ready Mixed Concrete

14.7.1 General

Ready mixed concrete (RMC) shall comply with the requirements of IS 4926 or the latest Indian Standard and RMC plant shall be approved by the Engineer.

Concrete delivered at site shall be in a plastic condition and requiring no further treatment before being placed in the position in which it is to set and harden.

The continuing mixing of concrete during transport shall be at a reduced speed to prevent segregation.

Concrete shall be produced by completely mixing cement, aggregates, admixtures (if any) and water at a stationary central mixing plant and delivered in transit mixers.

Concrete may be produced in a transit mixer at the batching plant, with the mixing being carried out entirely in the transit mixer either during the journey or on arrival at the site of delivery. No water shall be added to the aggregate and cement until the mixing of concrete commences.

14.7.2 Manufacturing

The ready-mixed concrete shall be manufactured and supplied on either of the following bases:

1 Specified strength based on 28-day compressive strength of 15cm cubes tested in accordance with IS: 456-2000.

2 Specified mix proportion.

Where the contract requires using ready mix concrete of designated strength, the Contractor shall procure the same from approved suppliers only and Section 14.6 shall also apply to concreting done with ready mix concrete.

When the concrete is manufactured and supplied on the basis of specified strength, the responsibility for the design of mix shall be that of the manufacturer and the concrete shall conform to the requirements specified.

When the concrete is manufactured and supplied on the basis of specified mix proportions, the responsibility for the design of the mix shall be that of the mix designer and the concrete shall conform to the requirements specified.

14.7.3 Supply

Ready mix concrete prepared and transported will be as per IS 4926 of 1976 or the latest 1S. Code.

Water is not to be added to ready mixed concrete on site.

Ready mix concrete will be brought to the site from the RMC plant only by transit mixers (agitators).

Every transit mixer will carry a delivery ticket, stating the minimum following details:

a. Name of manufacturer and depot
b. Serial number of the ticket.
c. Date
d. Truck number
e. Name of Contractor to whom the RMC is being supplied
f. Location of contract
g. Grade of concrete.
h. Specified werkabi1ity
i. Cement content and grade of cement
j. Time of loading
k. Quality of concrete.

When the truck arrives on site, the drum, should always be rotating at about 10 to 15 rev/min, for at least three minutes, to ensure that the concrete is thoroughly mixed and uniform before discharge.

When a truck mixer or agitator is used for the mixing or transportation concrete, no water from the truck-water system or from elsewhere shall be added after the initial introduction of the mixing water for the batch,

Unless otherwise specified, when a truck or agitator is used for transporting concrete, the concrete shall be delivered to the site of the work and the discharge shall be complete within 1 ½ hour when the prevailing atmospheric temperature is above 20°C and within 2 hours when the prevailing atmosphere temperature is at or below 20°C of adding the mixing water to the mix of cement and aggregate or adding the cement to the aggregate whichever is earlier.

14.8 Plain Cement Concrete

For plain cement concrete work, the specification for cement, sand, fine and coarse aggregates and water shall be the same as that specified in reinforced concrete but the proportion of mix will be nominal and the ratio of fine and coarse aggregate may be slightly adjusted within limits, keeping the total value of aggregates to a given volumes of cement constant to suit the sieve analysis of both the aggregates. Cement shall not be measured by volume and shall always be used directly from the bags (i.e. 50 kg/bag).

The nominal maximum size of coarse aggregate for 1:2:4 mix shall be as specified for reinforced concrete and for 1:3:6 and 1:4:8 mix shall be 40 mm for concrete 300 mm and more thick and 25mm for concrete less than 300 mm thick.

The quantity of water used shall be such as to produce concrete of the consistency required by the particular class of work and shall be decided by the use of a slump cone. Sufficient care should be taken to ensure that no excess quantity of water is used.

Mix proportion	Cement in bags	Sand m^3	Coarse Aggregate m^3			Water
Ordinary mix in volume			40 mm	20 mm	12mm	
1:5:10	2.60	0.475	0.6623	0.2583	-	156
1:4:8	3.40	0.500	0.6883	0.6883	-	153
1:3:6 (with 40mm aggr.)	4.4	0.485	0.672	0.672	0.262	176
1:3:6 (with 20 mm aggr.)	4.4	0.485	-	0.727	0.242	162.5
1:2:4 (with 20 mm aggr.)	6.4	0.47	-	0.705	0.235	205
1:2:4 (with 40 mm aggr.)	6.4	0.47	0.544	0.241	0.126	235
1:1.5:3	8.0	0.441	-	0.6615	0.2205	240
1:1:2	12.20	0.45	-	0.675	0.225	330

The slump shall be specified for each class of work and shall in general be as follows:

Type of concrete	Max. slump (in mm)
Mass concrete	50
Concrete below water proofing treatment	50
Coping	25
Floor paving	50

All plain concrete shall be mixed in a drum type powder driven machine with a loading hopper which will permit the accurate measure of various ingredients. If hand mixing is authorised, it should be done on a watertight platform.

The mixing of each batch in the concrete mixer shall continue for not less than 1.5 minutes after the materials and water are in the mixer. The volume of mixed materials per batch shall not exceed the manufacturers rated capacity of the mixer. The mixer shall rotate at a peripheral speed of about 60 metres per minute.

14.9 Pre-Cast Concrete

14.9.1 General

Pre-cast concrete and pre-cast reinforced concrete shall comply with IS 456 and with the following requirements.

Pre-cast concrete units shall incorporate sufficient lifting points and reinforcement to ensure the safe handling, transport and erection.

Where necessary, the Contractor's shop drawings shall include details of the lifting inserts, methods to be adopted to join the pre-cast units to other structures or parts thereof and the allowances made to receive work of other engineering specialties employed on the works.

Pre-cast concrete cladding panels shall be cast in formwork capable of producing a uniform fair faced finish.

Where appropriate, indelible identification and orientation marks shall be put on pre-cast concrete components in such a position that the marks shall not show or be exposed in the finished work.

14.9.2 Execution

(i) Casting

The pre-cast units shall be cast to the size and configuration required or otherwise specified.

The units shall be reinforced as necessary for the stresses likely to be caused by the methods of handling, transport and installation envisaged by the Contractor.

The units shall be equipped with approved lifting devices for safe handling and easy installation.

Concrete used for pre-casting the units shall be thoroughly compacted by vibration or tamping to give a dense concrete free from voids and honeycombing.

The exposed surfaces shall be finished as specified or with dense, smooth trowel led finish free from flaws and irregularities and true to the required configuration.

All angles of the pre-cast units, with the exception of any angles resulting from the splayed or chamfered faces, shall be true right angles. The arises shall be clean and sharp except those specified or shown to be rounded. The wearing surface shall be true to the required lines. On being fractured, the interior of the units should present a clean homogenous appearance.

Pre-cast units shall be cured to the maximum compressive strength for the specified class of concrete before the units are handled or lifted for transport or installation.

(ii) Curing

After having been cast in the mould or form, the concrete shall be adequately protected during setting in the first stages of hardening from shocks and from harmful effects of sunshine and wind. The concrete shall be cured at least for 10 days from the date of casting.

All pre-cast work shall be protected from the direct rays of the sun for at least 7 days after casting and during that period each units shall be kept constantly watered or completely immersed in water if the size of unit so permits. Otherwise curing practices as given in clauses stated earlier shall be followed.

The pre-cast articles shall be matured for 28 days before being incorporated into the Works so that the concrete shall have sufficient strength to prevent damage when handled. Side shutters shall not be struck in less than 24 hours after depositing the concrete and no pre-cast unit shall be lifted until the concrete reaches a strength of at least twice the stress to which the concrete may be subjected at the time of lifting.

Pre-cast units shall be clearly marked to indicate the top of member and its location and orientation in the structure. The reinforced side of the units shall be distinctly marked.

Pre-cast units shall be stored, transported and placed in position in such a manner that they will not be overstressed or damaged. The lifting and removal of pre-cast units shall be undertaken without causing shocks, vibration or being put under bending stresses. Before lifting and removal takes place, the Contractor shall satisfy Engineer that the methods he proposes to adopt for these operations will not overstress or otherwise affect the strength of the pre-cast units.

(iii) Installation

The installation shall be fully coordinated with the works of the other engineering specialities comprising the Works and the units shall be installed and secured at such times as to prevent any delay in the progress of the works.

Pre-cast units shall be aligned and secured in accordance with the approved shop and working drawings.

The installation shall be in a neat, workmanlike manner. On completion, all surplus materials or debris arising out of the work shall be removed from the site.

14.10 Reinforcement

14.10.1 General

No re-rolled material shall be accepted. If instructed by the Engineer, the Contractor shall submit the manufacturer's test certificates for the steel. Random tests on steel supplied by the Contractor may be performed by the Employer as per relevant Indian Standards. Each steel bar shall be identified by the number duly moulded on the bar itself.

14.10.2 Submittals

Bar bending schedules for reinforced concrete works shall be provided by the Contractor. The submittals for extra or modified work shall also be made by the Contractor at least two weeks prior to commencement of bending. Dimensions shown on the submittals furnished by the Contractor shall be his responsibility and approval of the submittals shall not constitute approval of the dimensions thereon.

14.10.3 Tie Wire

Tie wire shall be of annealed steel, 16 gauge minimum.

14.10.4 Supports and Accessories

Support blocks shall be of concrete with embedded wire ties or dowels for placement on grade or on membranes. Reinforcement for footings, grade beams and slabs on sub-grade shall be supported on pre-cast concrete blocks as approved by the Engineer. The use of pebbles or stones shall not be permitted. The blocks are to be embedded.

Plastic coated spacers or accurately dimensioned concrete blocks shall be used in all water retaining surfaces, roofs of water retaining structures and in all interior or exterior surfaces exposed to weather after completion of the structure. Plastic cover blocks of approved manufacture will be permitted at the discretion of the Engineer.

14.10.5 Dowels

Where so required, reinforcing bar dowels shall be provided in new work and for anchorage to existing concrete. Where anchorage to existing concrete is required, a non-shrinking epoxy type grout or approved equal or deferred bolting devices shall be provided in each case, conforming to the relevant requirement specified in the section for cast-in-situ concrete.

14.10.6 Testing

Testing of materials shall be at the Contractor's expense and as instructed by the Engineer and when so tested, shall conform to the relevant standards. Tests may be ordered on bars as selected by the Engineer from material at the site or from any place of distribution. Each sampling selection shall include at least two pieces, each 500 millimetre long.

The Contractor shall submit the manufacturer's test certificates. Regular tests on the steel supplied shall be performed by the Contractor at an approved laboratory in the presence of the Engineers as per relevant Indian Standards. The Engineer may require the Contractor to perform tests of samples at random as per relevant Indian Standard. The quality, grade, colour coding embossing marks etc shall all be to the entire satisfaction of the Engineer. Steel not conforming to the above test criteria shall be rejected.

The chemical, physical and mechanical properties of the steel reinforcement bars shall be as per IS 1786. Unless otherwise specified, the selection and preparation of test samples shall be as per the requirements of IS 2062.

All test pieces shall be selected either from the cuttings of bars or from any bar after it has been cut to the required or specified size and the test piece taken from any part of it. In either case, the test piece shall be detached from the bar in the presence of the Engineer.

The test pieces shall be full sections of the bars and shall be subjected to physical tests without any further modifications. No reduction in size by machining or otherwise shall be permissible, except in case of bars of size 28 mm and above. No test piece shall be annealed or otherwise subjected to heat treatment. Any straightening which a test piece may require shall be done cold.

For the purpose of carrying out tests for tensile strength, proof stress, percentage elongation and percentage elongation at maximum force for bars of 28 mm in diameter and above, deformations of the bars only may be machined. For such bars, the physical properties shall be calculated using the actual area obtained after machining.

Title	IS No.	ISO No.
Mechanical testing of metals - Tensile testing	1608	6892
Methods for bend test	1599, 7438 & 1786	15630-1
Method for re-bend test for metallic wires & bars	1786	15630-1

Chemical Composition of the bars shall conform to the following requirement

Constituents	Maximum permissible percent							Permissible max. Variation
	Fe 415	Fe 415D	Fe 500	Fe 500D	Fe 550	Fe 550D	Fe 600	
Carbon	0.300	0.250	0.300	0.250	0.300	0.250	0.300	0.020%
Sulphur	0.060	0.045	0.055	0.040	0.055	0.040	0.040	0.005%
Phosphorus	0.060	0.045	0.055	0.040	0.050	0.040	0.040	0.005%
Sulphur & Phosphorus	0.110	0.085	0.105	0.075	0.100	0.075	0.075	0.010%

Notes:

1 For welding of deformed bars, the recommendations of IS 9417 shall be followed.

2 In case of deviations from the specified maximum, two additional test samples shall be taken from the same batch and subjected to the test or tests in which the original sample failed. Should both additional test samples pass the test, the batch from which they were taken shall be deemed to comply with this standard. Should either of them fail, the batch shall be deemed not to comply with this standard.

Mechanical Properties of High Strength Deformed Bars

Nominal Size in mm	Tolerance on the nominal mass in percent		
	Batch	Individual sample	Individual sample for coils only
Up to and including 10	± 7	-8	± 8
Over 10 up to and including 16	± 5	-6	± 6
Over 16	± 3	-4	± 4

Note: To satisfy Clause 26 of IS 456 -2000, no mixing of different types of grades of bars shall be allowed in the same structural members as main reinforcement, without prior written approval of the Engineer.

14.10.7 Fabrication and Delivery

Tagged reinforcement bundles which can be easily identified shall be stored at the site in sufficient quantities to enable uninterrupted progress of the work. These shall be so stored as to prevent damage or undue exposure to harmful weather conditions.

14.10.8 Stacking and Storage

Steel for reinforcement shall be stored in such a way as to prevent distorting and corrosion. The steel for reinforcement shall not be kept in direct contact with ground. Fresh / fabricated reinforcement shall be carefully stored to prevent damage, distortion, corrosion and deteriorations. Care shall be taken to protect steel from exposure to saline atmospheres during storage, fabrication and use. This may be achieved by treating the surface of the reinforcement with a cement wash or by other suitable methods. Bars of different classification, size and length shall be stored separately to facilitate their issue in such sizes and lengths to cause minimum wastage in cutting from standard lengths.

14.10.9 Bending and Forming

Bars shall be fabricated accurately to dimensions, forms and shapes indicated by methods that will not damage the bars. Heating for purposes of bending will not be permitted. Field-bending of bars that are partially embedded in concrete shall not be done unless such procedure is specifically approved by the Engineer.

All bars shall be accurately bent according to the sizes and shapes shown on the approved detailed working drawings and bar bending schedules. Bars shall be bent gradually by machine or other approved means. Reinforcing bars shall not be straightened and re-bent. Bars containing cracks or splits shall be rejected. Bars shall be bent cold unless specifically approved by the Engineer.

Where approved, bars bent hot shall not be heated beyond a cherry red colour (not exceeding 645 oC) and after bending shall be allowed to cool slowly with out quenching. Bars incorrectly bent shall be used only after straightening and re-bending, such as shall not, in the opinion of the Engineer, injure the material. No reinforcement bar shall be bent when in position in the work without approval of the Engineer, whether or not it is partially embedded in hardened concrete. Bars having kinks or bends other than those required by design shall not be used.

Where reinforcement bars are necessarily bent aside at construction joints and afterwards bent back into their original position, care shall be taken to ensure that, at no time, the radius of the bend is less than 4 bar diameters for plain mild steel or 6 bar diameters for deformed bars. Care shall also be taken when bending back bars to ensure that the concrete around the bar is not damaged.

14.10.10 Laps

Laps and splices for reinforcement shall be as shown on the approved Contractor's drawings. Splices in adjacent bars shall be staggered and the locations of all splices shall be subject to the approval of the Engineer. Bars shall not be lapped unless the length required exceeds the maximum available lengths of bars at site.

14.10.11 Reinforcing Bars for Masonry

Reinforcing bars for masonry shall be shop fabricated.

14.10.12 Exposure conditions

Exposure conditions are defined in the table below:

Environment	Exposure Conditions
Mild	Concrete surfaces protected against weather or aggressive conditions, except those situated in coastal areas.
Moderate	Concrete surfaces sheltered from severe rain Concrete exposed to condensation and rain Concrete continuously under water Concrete in contact or buried under non-aggressive soil/ground water Concrete surfaces sheltered from saturated salt air in coastal areas
Severe	Concrete surfaces exposed to severe rain, alternate wetting and drying or severe condensation. Concrete completely immersed in sea water Concrete exposed to coastal environments
Very severe	Concrete surfaces exposed to seawater spray or corrosive fumes Concrete in contact with or buried under aggressive sub-soil/ground water.
Extreme	Concrete surfaces in tidal zones Members in direct contact with aggressive liquid or solid chemicals Concrete exposed to sewage, sewage effluent, sewage sludge and digester gases.

14.10.12A Fusion Bonded Epoxy Coating

Where fusion bonded epoxy coating (FBEC) is to be applied to reinforcement bars, it shall conform to IS 13620.

The coating material shall conform to Annex A1 of IS 13620.

The surface of the steel reinforcing bars to be coated shall be cleaned by abrasive blast cleaning to near white metal.

The protective coatings shall be applied by the electrostatic spray method.

The film thickness of the coating shall be evaluated by bending production-coated bars around a mandrel as prescribed in IS 13620.

Tests, retests and permissible coating damage shall be in accordance with IS 13620. Coating damage shall be repaired with the repair compound supplied by the coating manufacturer

14.10.13 Nominal cover to reinforcement

Nominal cover is the design depth of concrete cover to all steel reinforcements, including links. The dimension shall be used in the design and indicated on the Contractor's detailing drawings. Cover shall be not less than the diameter of the bar. Unless otherwise specified, cover to reinforcement shall be provided generally as per guidelines of IS 456.

Minimum values for the nominal cover of normal weight aggregate concrete which should be provided to all reinforcement, including links depends on the condition of exposure. The nominal cover to meet durability requirements is shown in the table below:

Environment	**Nominal concrete cover in mm not less than**
Mild	20
Moderate	30
Severe	45
Very severe	50
Extreme	75

1 For main reinforcement of up to 12 mm diameter subject to mild exposure, the nominal cover may be reduced by 5 mm

2 Unless specified otherwise, the actual concrete cover should not deviate from the required nominal cover by +10 mm

3 For exposure conditions severe and very severe, a reduction of 5 mm may be made, where concrete grade is M 35 and above.

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

1 At each end of a reinforcing bar not less than 25mm or less than twice the diameter of the bar.

2 For a longitudinal reinforcing bar in a column, nominal cover shall in any case not be less than 40 mm or less than the diameter of such bar. In the case of column of maximum dimensions of 200 mm or less, whose reinforcing bars do not exceed 12 mm, a cover of 25 mm may be used.

3 For longitudinal reinforcing bars in a beam cover shall be not less than 25mm, or less than diameter of the bar.

4 For tensile, compressive, shear, or other reinforcement in a slab, cover shall be not less than 25 mm, or less than the diameter of the bar.

5 For any other reinforcement not less than 15 mm, or less than the diameter of the bar.

6 For footings and other principal structural members in which the concrete is deposited directly against the ground, the cover to the bottom reinforcement shall be 75 mm. If concrete is poured on a layer of lean concrete the bottom cover may be reduced to 50 mm.

7 For concrete surfaces exposed to the weather or the ground after removal of forms, such as retaining walls, grade beams, footing sides and tops etc, not less than 50 mm for bars larger than 16 mm diameter and not less than 40 mm for bars 16 mm diameter or smaller.

8 Increased cover thickness may be provided when surfaces of concrete members are exposed to the action of harmful chemicals (as in the case of concrete in contact with earth faces contaminated with such chemicals), acid, vapour, saline atmosphere, sulphurous smoke (as in the case of steam-operated railways) digester gases etc and such increase of cover may be between 15 mm and 50 mm beyond the figures given above (1 to 6) as may be specified by the Engineer. The interior of sludge digestion tanks will fall into this category.

9 For reinforced concrete members, totally immersed in sea water, the cover shall be 40 mm more than specified (1 to 6) above.

10 For reinforced concrete members, periodically immersed in sea water or subject to sea spray, the cover of concrete shall be 50 mm more than that specified (1 to 6) above.

11 For concrete of grade M 25 and above, the additional thickness of cover specified in (8), (9) and (10) above may be reduced to half. In all such cases the cover should not exceed 75 mm

12 Protection to reinforcement in cases where concrete is exposed to harmful surroundings may also be given by providing dense impermeable concrete with an approved protective coating. In such cases, the extra cover, as stated in (7) and (8) above, may be reduced with the approval of the Engineer.

13 The minimum clear distance between reinforcing bars shall be in accordance with IS 456.

The minimum values of nominal cover for normal-weight aggregate concrete to be provided to all reinforcement including links to meet specified period of fire resistance is shown in the table below:

Fire resistance	**Nominal cover**						
	Beams		**Slabs**		**Ribs**		**Columns**
	Simply Supported	**Continuous**	**Simply Supported**	**Continuous**	**Simply Supported**	**Continuous**	
Hr	mm	mm	mm	mm	mm	mm	mm
0.5	20	20	20	20	20	20	40
1	20	20	20	20	20	20	40
1.5	20	20	25	20	35	20	40
2	40	30	35	25	45	35	40
3	60	40	45	35	55	45	40

4	70	50	55	45	65	55	40

1 The nominal covers given relate specifically to the minimum member .

14.10.14 Placing of Reinforcement

Reinforcement shall be accurately fixed by any approved means and maintained in the correct position by the use of blocks, spacers and chairs as per IS 2502 to prevent displacement during placing and compaction of concrete.

Any steel not conforming to the specifications shall be rejected. All reinforcement shall be clean, free from grease, oil, paint, dirt, loose mill scale, loose rust, dust, bituminous material or any other substances that will destroy or reduce the bond. All rods shall be thoroughly cleaned before being fabricated. Pitted and defective rods shall not be used.

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

1 For effective depth, 200 mm or less ±10 mm

2 For effective depth, more than 200 mm ±15 mm

The correct cover shall be maintained by cement mortar blocks or other means approved by the Engineer, as described in Section 14.10.4.

(i) Cleaning

Before placing reinforcement and again prior to concrete placement, the reinforcement shall be cleaned of loose mill scale, rust, oil or other coating that would reduce strength or bond. Steps shall be taken to ensure that the reinforcement shall not contact form coatings, release agents, bond breaker or curing compounds.

(ii) Positioning of Reinforcement

Reinforcement shall be kept in the correct position using the following methods:

For beam and slab construction, pre-cast cover blocks in cement mortar 1:2 (1 cement : 2 coarse sand) about 4 x 4cm section and of thickness equal to the specified cover shall be placed between the bars and shuttering, to secure and maintain the requisite cover of concrete over reinforcement.

For cantilevered and doubly reinforced beams or slabs, the vertical distance between the horizontal bars shall be maintained by introducing chairs, spacers or support bars of steel at 1.0 metre or shorter spacing to avoid sagging.

For columns and walls, the vertical bars shall be kept in position by means of timber templates with slots accurately cut in them; or with 1:2 cement mortar blocks (1 cement : 2 coarse sand) of the required size suitably tied to the reinforcement to ensure that they are in correct position during concreting.

For other RCC structures such as arches, domes, shells, storage tanks etc a combination of cover blocks, spacers and templates shall be used as approved by Engineer.

(iii) Tying in Place

The reinforcement shall be accurately placed and tied securely with tying wire at all points where bars cross. Stirrups shall be tied to bars at both the top and bottom. The loose ends of the tying wire shall be bent inwards to prevent them projecting out of the concrete cover provided, taking special care at surfaces where a form finish has been specified. Bars and fabric shall be supported as described in Section 14.10.4.

Bars intended to be in contact at crossing points shall be securely bound together at all such points with 16 gauge annealed soft iron wire. When epoxy coated reinforcement is used, the wire shall be plastic coated. The vertical distances required between successive layers of bars in beams or similar members shall be maintained by the provision of spacer bars at such intervals that the main bars do not perceptibly sag between adjacent spacer bars.

(iv) Splices

Unless otherwise approved, splices shall be wired contact lap splices and conform to the relevant local standard or to IS 2502.

No splicing of vertical bars will be allowed except at approved horizontal construction joints.

Splices in horizontal bars shall be lapped with at least one continuous bar between adjacent splices. The minimum spacing of splices in any one run of bar shall be 6m and in slabs which contain two layers of reinforcement, splices in opposite layers shall be offset by at least 1.5 m.

(v) Welding

Welding of reinforcement shall not be permitted unless specifically approved. If welding is approved, the work shall be carried as per IS 2751, according to best modern practices and as approved by the Engineer. Where permitted, the bars shall be shop or field welded by experienced welders by the direct electric arc process, using low hydrogen electrodes. In all cases of important connections, tests shall be made to prove that the joints are of the full strength of bars welded. The completed weld shall develop a minimum strength of 125 percent of the bar yield strength.

All surfaces close to the weld shall be cleaned free of loose mill scale or other foreign material. The same precautions shall be taken each time an electrode is charged. Chip burned edges shall be cleaned before welds are deposited.

When wire-brushed, completed welds shall exhibit uniform section, smoothness of welded metal, feather edges without undercuts or overlays, freedom from porosity and clinker and good fusion, with penetration into the base metal. Defective welds or parts of welds shall be cut out and re-done satisfactorily. Defective welds or parts thereof shall not be removed by using a cutting torch.

(vi) Welded Wire Mesh

Welded fabric shall be placed on approved supports to hold it in place during concreting. The fabric shall be laid flat in one plane and bent as required to fit the work. Laps shall be a minimum of one mesh. At laps, alternate wires shall be tied with tying wire.

(vii) Additional Reinforcement

Additional reinforcement shall be provided at sleeves and openings as required.

(viii) Inspection

Erected and secured reinforcement shall be inspected and approved by the Engineer prior to placement of concrete.

14.10.15 Field Quality Control

The Contractor shall appoint an experienced officer to make continuous inspections of the reinforcement during cutting, bending, placing in position, tying and cleaning before the pouring of concrete. He shall effect any corrections or irregularities noted or requested by the Engineer.

Welding for all shop and field welded reinforcing steel bars shall be inspected by the assigned Contractor's officer and regular inspections may be required by the Engineer who shall be given the fullest opportunity to witness the welding operations.

14.11 Formwork

14.11.1 General

The Contractor shall submit to the Engineer sufficient details of the proposed shoring and formwork to enable the Engineer to satisfy himself about their general adequacy and effectiveness. Forms, shoring and false work shall be adequate for imposed live and dead loads, including equipment, the height of concrete drop, concrete and foundation pressures, stresses, lateral stability and other safety factors during construction.

The formwork used in the works shall, unless otherwise specified herein, or approved or permitted by the Engineer, comply with IS 14687.

14.11.2 Materials

All formwork shall be constructed of timber, sheet metal or other approved materials, capable of providing the required finish. Where a special finish is required, the Contractor shall provide, before commencement of fabrication, all details of the materials and means he proposes to adopt to obtain the finish. All materials used shall be dimensionally stable on exposure to extremes of weather. Sliding forms and slip forms may be used with the approval of Engineer.

14.11.3 Formwork Requirements

The design of formwork shall take into account all the vertical and lateral loads that the forms will be carrying including live and vibration loadings.

Forms shall conform to the shapes, lines, grades and dimensions including camber of the concrete as necessary. Ample studs, waler braces, straps, shores etc shall be used to hold the forms in proper position without any distortion whatsoever until the concrete has set sufficiently to permit removal of the forms. Forms shall be strong enough to permit the use of immersion vibrators. In special cases, form vibrators may also be used. The shuttering shall be close boarded. Timber shall be well seasoned, free from sap, loose knots, worm holes, warps or other surface defects in contact with the concrete. Faces coming in contact with concrete shall be free from adhering grout, plaster, paint, projecting nails, splits or other defects. Joints shall be sufficiently tight to prevent loss of water and fine material from the concrete.

Plywood shall be used for exposed concrete surfaces, where called for. Sawn and wrought timber may be used for unexposed surfaces. Inside faces of forms for concrete surfaces which are to be rubbed finished shall be planed to remove irregularities or unevenness in the face. Form work with lining will be permitted.

All new and used form lumber shall be maintained in a good condition with respect to shape, strength, rigidity, water tightness, smoothness and cleanness of surfaces. Form lumber unsatisfactory in any respect shall not be used and if rejected by Engineer shall be removed from the site.

Shores supporting successive stories shall be placed directly over those below or be so designed and placed that the load will be transmitted directly to them. Trussed supports shall be provided for shores that cannot be secured on adequate foundations.

Formwork, during any stage of construction, showing signs of distortion or distorted to such a degree that the intended concrete work will not conform to the exact contours required, shall be repositioned and strengthened. Poured concrete affected by faulty formwork shall be entirely removed and the formwork corrected prior to placing new concrete.

Excessive construction cambers to compensate for shrinkage settlement etc that may impair the structural strength of members will not be permitted.

Forms for substructure concrete may be omitted when, in the opinion of Engineer, the open excavation is firm enough to act as the form. Such excavations shall be slightly larger than required by the drawings to compensate for irregularities in excavation and to ensure the design requirements are met.

Forms shall be so designed and constructed that they can be stripped in the order required and their removal does not damage the concrete. Face formwork shall provide true vertical and horizontal joints conforming to the architectural features of the structure as to location of joints and be as approved by Engineer.

The formwork shall be so constructed that up and down vertical adjustment can be made smoothly. Wedges may be used at the top or bottom of timber shores, but not at both ends, to facilitate vertical adjustment or dismantling of formwork.

Where exposed smooth or rubbed concrete finishes are required, the forms shall be constructed with special care so that the desired concrete surfaces can be obtained which require a minimum finish.

14.11.4 Form Coating

Form coating shall be non-grain raising and non-staining resin type coating or other suitable non-staining mould oil which will not leave residual matter on the surface of the concrete or adversely affect bonding to concrete of paint, plaster, mortar, protective coatings, waterproofings or other applied materials. The coatings shall not contain any mineral oils, paraffin, waxes or other non-drying ingredients, nor, in the case of surfaces in contact with potable water, any toxic ingredients of any type whatsoever.

14.11.5 Metal Forms

Metal forms shall be true to detail in condition, clean, free from dents, bends, rust and oil or other defects likely to impair the specified finish.

14.11.6 Round Column Forms

Forms for round columns shall be of metal tubes of materials described for metal forms, fibre glass reinforced plastic or other approved material.

14.11.7 Tie Bolts

Only tie bolts which avoid embedding any metal parts permanently within 50 mm of the concrete surface, shall be permitted. Voids remaining after the removal of all or part of each tie bolt shall be filled flush with the surrounding concrete using a freshly prepared non-shrink cement and fine aggregate paste.

In the case of structures designed to retain an aqueous liquid, the Contractor shall ensure that the measures adopted shall not impair the water tightness of the structure. Tie bolts which form a continuous hole through a structure designed to retain an aqueous liquid shall not be used.

14.11.8 Form Joint Sealers

Effective precautions shall be taken to ensure that joints between form panels are sufficiently water tight to prevent honey combing resulting from the escape of mortar during the placing and vibration of concrete. The joints shall be sealed with resilient foam rubber strips, non hardening plastic type caulking compound free from oil or other such material or compound as may be approved by the Engineer. Form tie holes shall be plugged with plastic caulking compound, tight fitting rubber plugs or equal.

14.11.9 Moulds

Moulds for grooves, drips, rebates, profiles, chamfers and other similar items shall be of a smooth-milled approved timber or standard extruded polymer plaster units of the required shapes.

14.11.10 Bracing Shuttering and Props

Shuttering shall be braced, strutted, propped and so supported that it shall not deform under weight and pressure of the concrete and also due to the movement of men and other materials. Bamboos shall not be used for props or cross bracings.

The shuttering for beams and slabs shall be so erected that the shuttering on the sides of beams and under the soffits of slabs can be removed without disturbing the beam bottoms.

Re-propping of beams shall not be done except when props have to be reinstated to support construction loads anticipated to be in excess of the design load. Vertical props shall be supported on wedges or other measures shall be taken whereby the props can be gently lowered vertically while striking the shuttering.

If the shuttering for a column is erected for the full height of the column, one side shall be left open and built upon sections as placing of concrete proceeds, or windows may be left for pouring concrete from the sides to limit the drop of concrete to 1.0 m. or as otherwise approved by Engineer.

14.11.11 Chamfers & Fillers

All corners and angles exposed in the finished structure shall be formed with mouldings to form chamfers or fillers on the finished concrete. The standard dimensions of chamfers and fillets, unless otherwise specified, shall be 20 x 20 mm. Care shall be exercised to ensure accurate mouldings. The diagonal face of the moulding shall be planed or surfaced to the same texture as the forms to which it is attached.

14.11.12 Vertical Construction Chamfers

Vertical construction joints on faces which will be exposed at the completion of the work shall be chamfered as above except where not permitted by Engineer.

14.11.13 Form Types for Surface Finishes

Concrete surface finishes shall generally be of the following types

1 All interior faces of walls and exposed roofs of structures of above and below grade and exterior surfaces above finished grade shall have a smooth form finish.

2 All exterior walls below finished grade and other surfaces not included in category (1) above, shall have a rough finish, unless otherwise specified.

3 Metal, plywood or forms of other approved material shall be used to provide a smooth finish.

4 Plywood or board forms of lesser quality may be used to provide rough finishes.

14.11.14 Shoring and Falsework

Shoring and false work shall be designed to distribute loads safely over the base area on which the shoring is erected. Adequate precautions shall be taken against undermining or settlement particularly against wetting of soils, when cleaning forms or curing concrete or by any other cause.

(i) Alignment and Camber

All forms shall be constructed to produce the required lines, grades and camber as required, in the finished structure. The tolerance on line and level shall not exceed 3 mm. In the absence of any specific camber, the forms for soffits of beams, other than pre-stressed beams, shall under normal circumstances be constructed to provide an upward camber of 6 mm for every 3 metres of clear span.

(ii) Means Adopted

S-Jacks, wedges or similar approved means shall be used to induce the required camber in the forms and to correct any settlement which may occur either before or during the placing of concrete.

14.11.15 Construction

Form windows shall be provided as necessary to provide access for placement and vibration of concrete. The windows shall be adequately sized to admit chutes and vibrators and should generally be spaced at 2 metre intervals. The windows shall be firmly closed and braced before placing concrete at higher levels.

Temporary openings shall be provided in wall and column forms for inspection and cleaning. All inner surfaces of forms shall be cleaned before any concrete is poured.

Reglets and rebates to receive flashing, frames and other equipment shall be properly formed. Dimensions, details and precise positions of all such reglets and rebates shall be ascertained from the suppliers of the flashings, frames or equipment, if supplied under a separate contract.

If form materials are found to be fit for reuse, they shall be cleaned and re-conditioned before re-erection.

14.11.16 Embedded Piping and Other Hardware

Before the commencement of fabrication of the formwork, all trades requiring openings for the passage of pipes, electrical conduits and other inserts shall be consulted and the necessary pipe sleeves, anchors or other inserts shall be properly and accurately installed by the representative trades or adequate details obtained which would enable the requisite openings to be correctly positioned. Pipes and conduits, when embedded shall not weaken the construction and no pipes, other than electric conduits, shall be permitted to be embedded within a slab not exceeding 12cm thick. Conduits placed in a concrete slab shall not have an outside diameter exceeding 1/3 the thickness of the slab and shall be placed between the upper and lower layers of reinforcement. Conduits may be embedded in walls if the outside diameter is less than 1/3 the wall thickness and they are not spaced closer than at three diameters centre to centre and do not otherwise weaken the wall.

14.11.17 Field Quality Control

Tell-tale devices or other methods shall be adopted, where approved, to detect movements and deflection of forms during concrete placement. The required slab and beam cambers and verticality and the specified batter of column sides shall be regularly checked, corrected and maintained as concrete loads are applied on the forms. Workmen shall be assigned to check forms and seal all mortar leaks discovered during concreting.

14.11.18 Inspection of Formwork

Any member which is to remain in position after the general dismantling is completed should be clearly marked.

Material used should be checked to ensure that, wrong items / rejects are not used.

If there are any excavations nearby which may influence the safety of the formwork, corrective and strengthening action shall be taken.

The bearing soil must be sound and well prepared and sole plates shall bear well on the ground and;

1 Sole plates shall be properly seated on their bearing pads or sleepers.

2 The bearing plates of steel props shall not be distorted.

3 The steel parts on the bearing members shall have adequate bearing areas.

Safety measures to prevent the impact of traffic, scour due to water etc should be taken. Adequate precautionary measures shall be taken to prevent accidental impacts etc.

Bracing, struts and ties shall be installed along with the progress of formwork to ensure the strength and stability of the formwork at intermediate stages. Steel sections (especially deep sections) shall be adequately restrained against tilting, over turning.

When adjustable steel props are used, they shall:

1 Be undamaged and not visibly bent;

2 Be complete with the steel pins provided by the manufacturers;

3 Be restrained laterally near each end; and

4 Have means for centralising beams placed in the fork-heads.

Screw adjustment of adjustable props shall not be over extended.

Double wedges shall be provided for adjustment of the form to the required position wherever any settlement / elastic shortening of the props may occur. Wedges should be used only at the bottom end of single props. Wedges should not be too steep and one of the pair should be tightened / clamped down after adjustment to prevent shifting.

The number of nuts and bolts shall be adequate.

All provisions of the design shall be complied with.

Cantilever supports shall be adequate.

Props shall be directly under one another in multistage constructions as far as possible.

Guy ropes or stays shall be properly tensioned.

There shall be adequate provision for the movement and operation of vibrators and other construction plant and equipment.

The required camber shall be provided over long spans.

Supports shall be adequate and in plumb within the specified tolerances.

14.11.19 Removal of Forms and Shoring and Striking

Contractors shall record on the drawings or a special register, the date upon which the concrete is placed in each part of the work and the date on which the shuttering is removed there from.

In no circumstances shall forms be struck until the concrete reaches a strength of at least twice the stress due to self-weight and any construction erection loading to which the concrete may be subjected at the time of striking the formwork.

The striking of formwork shall be as approved by the Engineer. Generally, however, the following table gives the minimum periods that must elapse before the formwork is removed, reckoned from the time the pouring of concrete was completed.

Position of Formwork and Props	Minimum days for Removal
Walls	1
Sides of beams and columns	1
Slabs (props left under)	3
Props to slabs (spans not exceeding 4 1/2 metres)	7
Props to slabs (spans exceeding 4 1/2 metres)	14
Beam soffits (props left under)	7
Props to beams (spans not exceeding 6 metres)	14
Props to beams (spans exceeding 6 metres)	21

The stripping time recommended above may be modified subject to the approval of the Engineer.

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

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

Striking shall be done slowly with utmost care to avoid damage to arises and projections and without shock or vibration, by gently easing with wedges. If, after removing the formwork, it is found that timber has been embedded in the concrete, it shall be removed and made good.

Reinforced temporary openings shall be provided, as approved by Engineer, to facilitate removal of formwork which otherwise may be in-accessible.

Tie rods, clamps, form bolts etc which shall be entirely removed from walls or similar structures shall be loosened not sooner than 24 hours nor later than 40 hours after concrete has been deposited. Ties, except those required to hold forms in place, may be removed at the same time. Ties withdrawn from walls and grade beams shall be pulled towards the inside face. Cutting ties back from the faces of walls and grade beams will not be permitted.

14.11.20 Restrictions

No permanent load or loads from construction equipment shall be imposed on columns, supported beams or supported slabs until the concrete has attained at least twice the compressive strength necessary to sustain the imposed loads.

14.12 Surface Finishes

14.12.1 Surface Finishes Produced Without Formwork

(i) Screeded Finish

The concrete shall be levelled and screeded to produce a uniform plain or ridged surface as required. No further work shall be applied to the surface unless it is a first stage for a wood float or steel trowel finish.

(ii) Wood Float Finish

The screeded finish shall be wood floated under light pressure to eliminate surface irregularities.

(iii) Steel Trowel Finish

When the moisture film has disappeared and the concrete has hardened sufficiently to prevent laitance from being worked to the surface, the surface to the wood float finish shall be steel-trowelled under firm pressure to produce a dense, smooth, uniform surface free from trowel marks.

(iv) Power float finish

Power floating shall be undertaken by steel floating the concrete to an even finish with no ridges or steps. When the concrete has taken a primary set it shall be power trowelled to a uniform smooth polished surface free from trowel marks or other blemishes. Once power floating is complete the surface finish must be adequately protected from construction traffic.

Where the type of finish is not specified it shall be wood float finish.

14.12.2 Surface Finishes Produced With Formwork

(i) Rough Finish

This finish shall be obtained by the use of moulds or properly designed forms of closely jointed sawn boards. The surface shall be free from substantial voids, honeycombing or other large blemishes.

(ii) Fair Finish

This finish shall be obtained from forms designed to produce a hard smooth surface with true, clean arises. Only very minor surface blemishes shall be permitted and there shall be no staining or discolouration. Any projections shall be removed and the surface made good.

(iii) Fair Worked Finish

This finish shall be obtained by first producing a fair finish and then filling all surface blemishes with a fresh, specially prepared cement and fine aggregate paste whilst the concrete is still green, where possible. After the concrete has been properly cured the faces shall be rubbed down, if required to produce a smooth and even surface. If the surface is to be exposed in the final work, every effort shall be made to match the colour of the concrete.

Liquid retaining surface and other surfaces exposed in the completed Works shall receive a fair worked finish. All other structural concrete surfaces shall receive a fair finish.

14.13 Construction Tolerances

14.13.1 General

Tolerances are a specified permissible variation from the designed lines, grade or dimensions as approved by the Engineer. No tolerances specified for horizontal or vertical building lines or footings shall be constructed beyond the legal boundaries. Unless otherwise approved by the Engineer, the following tolerances shall be permitted:

14.13.2 Tolerances for Reinforced Concrete Buildings

(i) Variation from plumb

In the line and surfaces of columns, piers, walls and in buttresses: 5 mm per 2.5 m, but not more than 25 mm.

For exposed corner columns and other conspicuous lines.

In any bay or 5 m maximum:	± 5 mm
In 10 m or more:	± 10 mm

(ii) Variation from the design levels or grades

In slab soffits, ceilings, beam soffits and in arises.

1	In 2.5 m.:	± 5 mm
2	In any bay or 5 m. maximum:	± 8 mm
3	In 10 m. or more:	± 15 mm

For exposed lintels, sills, parapets, horizontal grooves and other conspicuous lines.

4	In any bay or 5 m. maximum:	± 15 mm
5	In 10 m or more	± 10 mm

(iii) Variation in linear building lines

In any bay or 5 m. maximum:	± 10 mm
In 10 m. or more:	± 20 mm

(iv) Sizes and locations of sleeves, openings in walls and floors

Allowable tolerance	± 5mm (excludes anchor bolts)

(v) Variation in cross-sectional dimensions of columns, beams slabs and walls

Allowable tolerance	+10mm/-5mm

(vi) Footings

Variation in dimensions in plan: +50mm/-5mm

Misplacement or eccentricity: 2% of footing dimension within the direction of misplacement but not more than 50 mm

Reduction in thickness: (-) 5% of specified thickness subject to maximum of 50 mm

(vii) Variation in steps

Rise in a flight of stairs	± 3.0mm
Tread in a flight of stairs	± 5.0mm
Rise in consecutive steps	± 1.5mm
Tread in consecutive steps	± 3mm

14.13.3 Tolerances in other Concrete Structures

(i) All structures:

Variation of the constructed linear outline from established position in plan.

In 5 m.:	± 10mm
In 10 m. or more:	± 15mm

Variation of dimensions to individual structure features from established positions in plan.

In 20 m. or more:	± 25mm
In buried constructions:	± 150mm

Variation from plumb, from specified batter or from curved surfaces of all structures.

In 2.5 m.:	± 10mm
In 5.0 m.:	± 15mm
In 10.0 m. or more:	± 25mm
In buried constructions: (+/-)	Twice the above limits.

Variation from level or grade indicated on drawings in slabs, beams, soffits, horizontal grooves and visible arises.

In 2.5 m.:	± 5mm
In 7.5 m. or more:	± 10mm
In buried constructions:	± Twice the above limits.

Variation in cross-sectional dimensions of columns, beams, buttresses, piers and similar members.

Allowable tolerance (+)12mm/(-) 6mm

Variation in the thickness of slabs, walls, arch sections and similar members.

Allowable tolerance (+)12mm/(-) 6mm

(ii) Footings for columns, piers, walls, buttresses and similar members:

Variation of dimensions in plan: (+)50mm/(-)12mm

Misplacement or eccentricity: 2% of footing within the direction of misplacement but not more than 50 mm

Reduction in thickness: 5% of specified thickness subject to a maximum of 50mm

(iii) Other Tolerances

Tolerances in other types of structures shall generally conform to those given in Clause 2.4 of Recommended Practice for concrete form work IS 14687.

14.14 Cement Grouting

14.14.1 General

These specification clauses refer to grouting where required in excavated rocky strata.

14.14.2 Requirements

The Contractor shall furnish all tools, equipment, materials and labour for furnishing and placing grout to stop leaks and permanently control the inflow of water through rock faces when necessary for the proper construction of the Works or if instructed to do so by the Engineer.

The Contractor shall carry out the works in accordance with the requirements of IS 6066 – 1971,

14.14.3 Construction Plant and Products

(i) Equipment

The equipment used shall be of type, capacity and mechanical condition suitable for satisfactorily completing the work. The power and equipment and their layouts shall conform to all relevant regulations and safety codes applicable to the Mumbai Sewage Disposal Project- Stage II. All motors shall be equipped with suitable mufflers and scrubbers.

Standard drilling equipment of the rotary type shall be used to perform the drilling. Rotary percussion drills of any type will not be permitted to be used. The drilling equipment utilized within subsurface structures shall be capable of drilling at any orientation to a maximum depth of 7.5 metres.

Holes shall be grouted using the shortest practicable length of line. Fouling of the equipment shall be prevented by maintaining a continuous flow of grout and by periodically flushing with water. A water supply shall be directly connected into the grout supply line. Pressure gauges and adequate valves required for by-pass and shut-off shall be attended constantly by qualified operators at the collar of the hole being grouted.

Additional grout headers, to a maximum of six, shall be available to interconnect holes. Such interconnected holes shall be grouted simultaneously as long as the capacity of the mixing and pumping system permits the design grouting pressure to be maintained.

The Contractor shall be equipped to continuously flush with fresh water, as approved by the Engineer, those interconnected holes he is not able to grout, if the grout take in a series of interconnected holes exceeds the pump capacity.

The general requirements for the cement grout plant shall include two independent, operational grout pumps connected to allow switching from one to the other in the event of mechanical failure without interrupting the grout flow, operational stand-by equipment for each element of the operation shall be available at the job site.

(ii) Materials

Mixes consist of cement, water, sand and an approved fluidifier in the proportions as designated by the Contractor's designer and approved by Engineer. The mix may, from time to time, be amended to suit the conditions encountered in particular locations. The water cement ratio by volume shall be varied to meet the characteristics of each holes as revealed by the grouting operation and may range between 10.0 and 0.6. If after mixing, the grout cannot be placed for any reason whatsoever, it shall be wasted.

The proportions of grout shall produce a flowable mixture consistent with a minimum water content and shrinkage. The grout proportions shall be limited as follows:

Use	**Grout thickness**	**Mix. proportions**	**W/C. Ratio in (Max.)**
a) Fluid mix	Under 25mm	One part Portland cement to one part sand.	0.44
b) General	more than 25mm but less than 50mm	One part Portland cement to 2 parts of sand.	0.53
c) Stiff mix.	50mm and over	One part Portland cement to 3 parts of sand.	0.53

Variations in grout mixes and procedures shall be permitted if approved by the Engineer.

Special grout shall be provided in strict accordance with the manufacturer's instructions.

1. Cement Water and Sand

All cement, water and sand shall be as that used in concrete.

2. Fluidifier

Fluidifiers shall be compounds possessing characteristics which will improve the fluidity of the mixture and assist in dispersing shrinkage of the grout. Bentonite or other clay like materials are not acceptable as fluidifiers. Fluidifiers shall be furnished in moisture resistant sacks, shipped in dated sealed containers and shall be handled and stored to avoid absorption of moisture, damage or waste. Material which has become caked due to moisture absorption shall not be used in the work. No fluidifier shall be used that has exceeded the manufacturer's recommended shelf life.

3. Pipes

All metal pipes and fittings required for grouting operations shall be furnished, cut, threaded, fabricated and embedded by the Contractor. The pipes shall conform to IS 6631 – 1972.

14.14.4 Execution

(i) General

All holes for cement grouting shall be drilled at the locations, in the directions and to the depths approved by the Engineer, as the grouting operations proceed. Grouting shall be performed in the presence of the Engineer. The actual number, depth sequence and spacing of holes and the pressures, pumping rates and grout mixes to be used for grout injections will depend upon the nature of the rock, the results of the water pressure tests or observations and the results of previous grouting operations. They will be determined by the Contractor and subject to the approval of the Engineer.

(ii) Supervision

The Contractor shall have an experienced supervisor directing his grouting operations. The supervisor shall be experienced in cement grouting in rock.

(iii) Grout Hole Drilling and Preparation

The holes at the maximum required spacing are referred to as primary holes, hereafter. The number of grout holes shall be increased progressively by split spacing between the primary holes as approved by the Engineer. The type of bit used for drilling shall be at the discretion of the Contractor. The minimum diameter of the hole shall be 38 mm at the point of maximum penetration. Only clean water may be used as a circulating medium when drilling grout holes. Recirculated water shall not be used. Grout hole drilling ahead of the grouting operation shall be limited to the extent that can be grouted within two calendar weeks.

Grout pipes shall be installed in a workman like manner and shall be thoroughly cleaned of all dirt, grease, oil grout and mortar immediately before embedment. All grout pipes shall be sealed to the rock. On completion of grouting, grout pipes shall be cut off flush with the rock line and the holes shall be thoroughly washed before grouting, to the approval of the Engineer. Drill cuttings, fragments and slurry shall be removed from the hole by an air/water jet applied at the bottom of the hole and returned through the hole to the surface. Washing shall continue until all debris is removed from the hole and the return water is clear.

Surfaces to be grouted shall be thoroughly roughened and cleaned of all foreign matter and laitance. Prior to grouting, hardened concrete surfaces to be grouted shall be saturated with water.

The cleaning of bedding planes, joints and fractures shall be accomplished by pumping water through the grout connection at the anticipated grouting pressure. Such pressure washing shall continue at the desired pressure as long as there is an increase in the rate of water intake.

Holes in which the optimum pressure cannot be reached shall be washed for as long as the fracture filling is being removed, as will be revealed by the escape of muddy water through nearby openings and for not less than five minutes unless otherwise approved. Open holes in which no pressure can be built up shall be washed for a minimum of five minutes or for such a period as fractures or joint filling, as determined by the Engineer.

Each grout hole shall be water pressure tested immediately prior to grouting. Water shall be injected through the test apparatus and through the grout connection. All holes shall be tested at pressures to be determined by the Engineer, but not to exceed 7 kgf/cm2. Water tests shall consist of water absorption under designated grouting pressures for a maximum of 10 minutes. This procedure is designated as the water pressure check. Expandable rubber packers shall be provided to seal off the portion of the hole to be tested as instructed. Atmospheric or open hole testing may be required in addition to the pressure testing. A selected number of holes will be utilized for water pressure check holes to determine the grouting effectiveness after the primary holes are grouted.

(iv) Grouting under equipment and base plates

Anchor bolts, anchor bolt holes and the bottom of equipment and column base plates shall be cleaned of all oil, grease, dirt and loose material. The use of hot, strong, caustic solution for this purpose shall be permitted.

Water in anchor bolt holes shall be removed before grouting is started.

Forms around base plates shall be tight to prevent leakage of the grout.

Adequate clearance shall be provided between forms and base plates to permit grout to be worked properly into place.

(v) Grouting

Unless specifically approved by the Engineer, each grout hole shall be grouted individually. Approval may be given to simultaneously grout adjacent holes penetrating the same geologic stratum up to a maximum of six, if communication is established between the holes during grouting and if the water pressure test results in each hole have revealed similar requirements for grout mix and pressure.

Grouting, once started, shall be done quickly and continuously to prevent segregation, bleeding and breakdown of initial set. Grout shall be worked from one side of one end to the other to prevent entrapment of air. To distribute the grout and to ensure more release from entrapped air, link chains shall be used to work the grout into place.

Grouting through holes in base plates shall be by pressure grouting.

Grouting pressure to be used in the work will vary with conditions encountered in different holes and the pressures used for each holes will be as approved by the Engineer. It is anticipated that pressures will range from 0.7 to 7 kgf/cm^2, but in no event will pressures exceeding 10.5 kgf/cm2 be required.

(vi) Grout Inspection

Once started, the grouting of a hole shall not be interrupted without approval of the Engineer. If necessary to prevent premature stoppage, periodic applications of water under pressure shall be made. Under no conditions shall the pressure or rate of pumping be increased or decreased suddenly. The grouting of any hole shall not be considered complete until refusal. Refusal is defined as a grout injection rate of zero litres per minute measured over a five-minute interval at 100 percent grouting pressure, although in no case will the Contractor be required to pump into a hole in which the grout takes below 30 litres per hour for more than four hours.

The Contractor shall caulk all grout leaks as they develop, as approved by the Engineer. Caulking shall begin on the leaks with the highest volume and progress to those of lesser volume until all leaks are caulked. Prior to grouting, the Engineer may require caulking of leaks which have shown high volume during water pressure testing. If due to the size and continuity of fractures, it is found impossible to reach the required pressure after pumping a reasonable volume of grout at the minimum workable water-cement ratio, or a mortar grout with the maximum volume of sand at the minimum workable water-cement ratio, the speed of pumping shall be reduced or pumping shall be stopped temporarily and intermittent grouting shall be performed, allowing sufficient time between grout injections for the grout to stiffen. If the desire result is still not obtained, grouting the hole shall be discontinued when approved. In such an event, the hole shall be cleaned, the grout allowed to set and additional drilling and grouting shall then be continued to the hole or in the adjacent area as approved until the desired resistance is developed.

After grouting refusal is reached, the pressure on the hole shall be maintained by means of a stop-cock or other suitable device until the grout has set.

Grout check holes shall be drilled after the primary hole has been grouted to assess the grouting effectiveness. Additional grouting and drill holes shall be placed between the primary holes as approved by the Engineer.

(vii) Clean-up

During grouting operation, the Contractor shall take such precautions as may be necessary to prevent drill cuttings, equipment oil, wash water and grout from defacing or damaging the permanent structure. The Contractor shall furnish such pumps as necessary to care for waste water and materials from his operations and clean up waster water and materials from his operations. The clean-up procedure shall be to the satisfaction of the Engineer.

(viii) Records

The Contractor shall keep records of all grouting operations including:

1 logs of grout holes;

2 hole locations and depths;

3 results of washing and pressure testing operations;

4 time of each change of grouting operation;

5 pressure;

6 rate of pumping;

7 amount of cement for each change of water cement ratio; and

8 any other data which he considers pertinent and important.

All records shall be in a form approved by the Engineer and shall contain all data as required by the Engineer.

14.15 Damp Proof Courses

The surface to receive a damp proof course shall be cleaned and carefully swept to remove all dust, laitance etc and shall be approved by the Engineer. Damp proof courses shall be cement concrete. An approved waterproofing compound at 3% by weight of cement or as otherwise approved by the manufacturer shall be mixed into the cement mortar for this concrete.

The damp proof course shall be laid to the full width of the wall and the edges shall be straight, even and truly vertical. Wooden forms shall be used to obtain good edges. No masonry work shall be commenced onto a freshly laid damp proof course until it has cured for 48 hours but the curing of cement concrete shall be continued along with the masonry work. Specifications for cement, sand, aggregate and water shall be as described for concrete works.

The concrete of ground floors shall be laid in two layers. The top of the lower layer of concrete shall be painted with two coats of A-90 grade bitumen (conforming to IS: 1580) applied at the rate of 1.5 kg/m2. The top surface of the lower layer shall be finished smooth while laying the concrete so that the bitumen can be applied uniformly. The bitumen shall be applied after the concrete has set and is sufficiently hard. Bitumen felt conforming to IS: 1322 shall be sandwiched in the sub-floor laid in two layers.

14.16 Testing of Structures

14.16.1 Inspection of Structures

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

In case of doubt regarding the grade of concrete used or results of cube strength are observed to be lower than the designed strength as per specifications at 28 days, compressive strength test of concrete based on core test, ultrasonic test and/or load test shall be carried out by the digital ultrasonic concrete tester as approved by the Engineer.

The Contractor shall also conduct conclusive tests such as ultrasonic pulse test, core test etc to prove the suitability of concrete, in case cube tests give unsatisfactory results.

14.16.2 Core Test

The points from which cores are to be taken and the number of cores required, shall be at the discretion of the Engineer and shall be representative of the whole of the concrete concerned. In no case shall fewer than three cores be tested. Cores shall be prepared and tested as described in IS 516

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

In case the core test results do not satisfy the requirements as above, or where such tests have not been done, load testing may be resorted to.

14.16.3 Load Tests on Parts of Structures

Load tests should be carried out as soon as possible after expiry of 28 days from the time of placing of concrete. The structure should be subjected to a load equal to the full dead load of the structure plus 1.25 times the imposed load for a period of 24 hours and then the imposed load shall be removed.

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

If the maximum deflection in mm during 24 hours under load is less than 40L2/D, where L is the effective span in metres and D the overall depth of the section in mm, it is not necessary for recovery to be measured and the recovery provision as above will not apply.

14.16.4 Other Non-destructive Test Methods

Other non-destructive test methods may be adopted, in which case the acceptance criteria shall be agreed upon between the Engineer and the Contractor and the test shall be done under expert guidance.

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

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

Members other than flexural members should be investigated by analysis.

15.0 GENERAL ARCHITECTURAL SPECIFICATIONS

15.1 Pre-Cast Cement Concrete Block Masonry

15.1.1 Manufacturing

Pre-cast cement concrete blocks shall be of best quality locally available or manufactured at site and should be approved by the Engineer before incorporation in the work. The ingredient and the cement concrete used shall conform to the relevant IS as stipulated in specification for cement concrete works.

Minimum crushing strength of the solid blocks shall be 40 Kg/ cm^2 28 days after curing. The type of the bond to be adopted will be decided by the Engineer but vertical joints shall be staggered. The size of the blocks shall be 390 x 190 x 140 mm and 390 x 190 x 100 mm.

Concrete blocks, whether made on or off site shall be manufactured to the shapes, sizes and finishes as approved by the Engineer and shall comply with the requirements of IS: 2185. Concrete for blocks shall be made generally in accordance with Section 14.0 except that the combined aggregate shall have a fineness modulus lying between 3.6 and 4 and shall conform with the following grading:

IS Sieve	**Percentage passing by weight**
12.5 mm	100
10 mm	>85
4.75 microns	>60
300 microns	>10

Concrete for blocks shall be minimum Class M-20. Hand mixing shall not be permitted. When ordered by the Engineer, sample blocks from any batch shall be tested as specified in IS: 2185.

The Contractor shall submit full details of his proposed manufacturing arrangements to the Engineer for his approval before making any blocks for use in the works and shall submit such samples as may be needed to demonstrate the quality of the finished product. Production of blocks shall be of equal standard to the approved sample blocks.

The blocks shall be cured for at least for 14 days before incorporation in the work. The cement mortar for concrete blocks masonry shall be 1:4 and joints shall not be more than 10 mm thick.

Finished blocks shall be neatly stacked for storage on a firm dry support and shall be covered to protect them from dirt, sun and rain. Damaged blocks shall not be used in the works.

15.1.2 Workmanship

Concrete blockwork shall be laid generally as specified or as directed by the Engineer. The construction of hollow block masonry shall be generally in accordance with IS: 2572. Blockwork for partition walls shall be laid in stretcher bond. Fair face blockwork which is not to be plastered shall be neatly pointed.

15.2 Brickwork

15.2.1 Manufacturing

Bricks provided for common brickwork shall be whole, sound, well burnt clay bricks free from cracks and shall comply with the requirements of IS: 1077. Clay engineering bricks shall comply with the requirements of IS: 2180. Samples of the proposed bricks to be used shall be submitted to the Engineer for his approval.

Bricks shall be class designation 35 of size 22.5 x 11.1 x 7 cm. Permissible tolerance on dimensions shall not be more than (+/-) 8%.

The minimum crushing strength shall not be less than 35 kg/cm2 and water absorption shall not be more than 25% by weight.

15.2.2 Workmanship

Brickwork shall be built in accordance with the requirements of IS: 2212.

Bricks shall be carefully stacked by hand in separate stacks. Broken or damaged bricks shall not be used.

Every brick shall be thoroughly soaked in water before use until the bubbles cease to come up. No broken bricks shall be used except as closures.

All the courses shall be laid truly horizontal and where required all vertical joints shall be truly vertical. Joints shall be broken vertically and they shall not exceed 12 mm in thickness.

Bricks shall be thoroughly bedded and flushed with mortar. Specified mortar of good and approved quality shall be used. Lime shall not be used where reinforcement is provided in brick work. The mortar shall completely cover the bed and sides of the bricks. Proper care shall be taken to obtain a uniform mortar joint throughout the construction.

The brickwork shall not be raised by more than 12 single courses per day.

The walls shall be raised uniformly in a proper approved bond. The walls shall be uniformly raised in all cases not leaving any part one metre lower than another. When circumstances render it necessary to carry on the same section of a building in uneven courses, the bricks shall be raked back to maintain a uniform and effectual bond.

In construction of a wall, firstly the two end corners shall be carefully laid to line and level and then the interim portion shall be built using a cord stretching along the headers or stretchers held in position at the ends to keep the correct alignment and level of the courses. Care shall be taken to keep the perpendiculars properly aligned within following maximum permissible tolerances:

1 Deviation from vertical within a storey shall not exceed 6 mm per 3 m height.

2 Deviation in verticality in total height of any wall of building more than one storey in height shall not exceed 12.5mm

3 Deviation from position shown on plan of any brick work shall not exceed 12.5 mm

4 Relative displacement between load bearing wall in adjacent storeys intended to be vertical alignments shall not exceed 6 mm

5 A set of tools comprising of a wooden straight edge, a masons spirit level, square, a 1 metre rule, line and plumb shall be kept on the site of work for every three masons for proper checking during the progress of work.

String courses, cornices and mouldings shall be straight and true by projecting brick work with properly cut and shaped bricks wherever necessary with as fine joints as possible.

In all brick arches and other curved work, the bricks shall be shaped to the slope, joints radiating correctly to the centre, from front to back of walls and not smaller than 10 cm thick.

The adhesion between brick masonry and the concrete surfaces of columns, beams, chajjas, lintels etc shall be ensured by the concrete being hacked/ chipped/keyed, cleaned and with a cement slurry applied so that a proper bond is achieved.

The joints of all surfaces which are to be finished in plaster shall be raked out to depth of 20 mm as the work progresses and before the cement mortar has set. All joints shall be thoroughly flushed with mortar at every course. Care shall be taken to ensure that the bricks are bedded effectively and all joints completely filled to the full depth.

Newly laid brickwork shall be protected from the harmful affects of sunshine, surface water and impacts. The work shall be watered three times a day for 14 days and afterwards twice a day for a month.

In the event that cracks in the brickwork appear, they shall be made good by cement grouting or epoxy putty grouting/ polysulphide compound grouting or as otherwise approved by the Engineer.

15.2.3 Half Brick Work

Materials and workmanship for a half brick or brick on edge partition wall shall be as specified above. The wall shall be stiffened by RCC stiffeners 115 mm wide x 80 mm thick to the full length of the wall and shall be provided with two 6 mm diameter mild steel bars or as otherwise approved by the Engineer. These bars shall be securely anchored at their end where the partition ends. The free ends of the reinforcement shall be keyed into the mortar of the main brick work to which the half brick work is joined. Overlaps in reinforcement, if any, shall not be less than 30 cm.

15.3 Plaster

The joints of all masonry work shall be raked out to 20mm. The surface of all concrete and reinforced concrete work shall be roughened in the manner specified for reinforced concrete work before plaster is applied. All the surfaces shall be thoroughly washed and well watered before plaster is applied.

A long straight edge shall be freely used to ensure an even surface. All corners and angles shall be plumb and true and soffits of arches shall be true arcs of circles. All exposed angles with door and window frames shall be carefully finished. Internal angles shall be rounded and arises shall be rounded, splayed or beaded as required and as approved by the Engineer.

A sample of plaster shall be approved by the Engineer as regards the texture etc before proceeding with the work. All subsequent work shall generally conform to the approved sample panel. The finished work shall be cured for a minimum period of seven days.

15.3.1 Sand Faced Plaster

Cement mortar shall consist of 1 part of cement to 3 parts of screened and washed sand and shall be placed in 2 coats. The undercoat shall be similar to the undercoats for cement plaster.

The surface of the undercoat shall be scratched by special wire tools for forming the key for the finishing coat before the mortar has set and hardened.

The second or finishing coat shall be 1 part of white cement, 3 parts of properly graded washed sand to give a grained texture. The finishing coat shall be 6 mm thick, uniformly applied and surface finished with special cork thapies and tools recommended for coloured cement plaster work. When finished the surface shall be even and shall have a grained texture.

Adequate time interval shall be allowed between the applications of successive coats for hardening. The coats shall be kept moist by watering for 7 days and shall not be allowed to dry out.

Three coats of approved cement paint shall be applied on the finished surface of sand faced plaster. Cement paint application shall be in accordance with the manufacturer's specifications.

15.3.2 Cement Plaster

Blended cement, sand and water required for the work shall conform to Section 14.2, except that sand for the finishing coat shall be fine sand conforming to IS 1542. The plastering works shall generally conform to IS 1661 (Pt. III) (Code of practice for cement and cement plaster finish on walls and ceilings). All general precautions as specified in IS 1661 (Pt. III) clause-8, shall be taken and preparation of the background shall be as laid down in IS 1661 clause 12 and IS 2402 shall be followed for rough cast and sand faced plaster work.

15.3.3 Preparation of Surface

The surface to be plastered shall first be thoroughly cleaned. All joints shall be raked out in case of brick work / stone masonry and closely hacked in case of concrete, under the relevant masonry / concrete items. The surface to be plastered shall be well wetted for a minimum period of 6 hours before commencing the work.

The surface to be plastered shall first be dubbed out with cement mortar to cover all irregularities and faces up to the proudest part. The dubbing coat which shall be 12 mm thick and be applied/scored and keys shall be formed on the surface by thoroughly combing it with heavy horizontal lines about 12 mm apart and about 3 mm deep when mortar has just set.

The cement mortar for sand faced plaster shall have washed and approved sand with slightly larger proportions of coarse materials, but not exceeding 3 mm. The water shall be gradually added to make the mixture homogenous. The thickness of the finishing coat excluding the key shall be 8mm. After application, the surface shall be finished with a wooden float lined with cork closely pricked on with a wet sponge tapped gently to bring sand particles into prominence.

Any other horizontal portions shall be cleaned of any mortar splashes. Junctions between walls and chajjas shall be rounded off simultaneously as approved by the Engineer.

The Contractor shall ensure that all service pipes, electrical conduits, boxes, switch boxes etc have been installed in position and the plastering surface is duly approved by the Engineer.

In order to avoid the formation of cracks and for the dispersion of cracks at the junctions between concrete surfaces and brick masonry work and between junction of windows/door frames and brick masonry works, cautionary measures such as fastening and lapping of chicken mesh over the junction areas shall be carried out over which the plastering work shall be taken up as required by the Engineer.

Gaps between window/door frames with cills and jambs shall be filled up/caulked by plaster of Paris/epoxy putty/silicon sealants, rubber based sealants by caulking guns or by approved methods as approved by Engineer.

Before plastering work is taken up, all the ceilings and walls etc shall be marked indicating the thickness of plaster required and which shall be in true line, level and plumb and shall be approved by the Engineer.

15.3.4 Grooves

The grooves shall be of required dimensions. The same shall be made to turn wherever necessary. The finish, inside, shall be of the same finish as that of the plaster. The lines of the grooves shall be well defined and rounded. The grooves shall be provided in plastering in internal and external surfaces.

15.3.5 Mixing

Cement and fine aggregates shall be mixed dry in the required proportions to obtain a uniform colour. Water shall then be added to get the required consistency for the plaster.

Mixing shall be done mechanically. Manual mixing may be allowed only in exceptional circumstances at the discretion of the Engineer. Manual mixing, where adopted, shall be carried out on a clean watertight platform. After water is added during mixing, the mix shall be mixed for 10 to 15 minutes.

In machine mixing, the mixer shall run at least five minutes after placing all the ingredients in the drum. Only so much quantity of mortar which can be used within half an hour after the addition of water shall be prepared at a time. Any mortar for plaster which is set or partially set shall be rejected and shall be removed forthwith from the site.

15.3.6 Application

The plaster on walls shall consist of two coats. The undercoat shall be 20 mm thick and be of one part cement and 4 parts coarse sand and shall be dashed against wall. It shall be uniformly applied and shall be floated and the surface shall be made even. The surface of the undercoat shall be scratched by wire brush to form a key for the finishing coat, before cement has set or hardened. The second coat or finishing coat shall be a thin coat to produce a smooth and even surface.

Plaster to concrete ceilings may be finished in two coats, the first coat of 1 part cement and 4 parts of sand dashed and floated to make the surface uniform and even. The surface shall be scratched as above to form a key for the finishing coat. The second or finishing coat shall be a thin coat of cream of lime putty evenly applied and trowelled smooth to producea smooth and even surface.

Rough cast plaster shall be carried out in two coats. The first coat shall consist of 1 part of cement to 3 parts of clean sand or as specified otherwise. The finished thickness of the first coat shall be 12mm and shall be laid by throwing the mortar (by using strong whipping motion) on the prepared surface with a trowel in a uniform layer but shall not be smooth. The second coat shall consist of 1 part of cement and 3 parts of 6 mm to 10 mm gravel all as approved by the Engineer. The gravel shall be thoroughly cleaned with water removing all dirt and organic materials. All these ingredients shall be mixed into a paste which shall be flung upon the first coat with large trowels to form an even protective coat. The thickness of this coat shall be 10 mm. Due care shall be taken to avoid concentration of either large size or small size of gravel in one place.

Plaster to other concrete surfaces shall be as for walling.

An adequate time interval shall be allowed between the applications of successive coats for hardening. The coats shall be kept moist by watering and shall not be allowed to dry out for seven days.

The finished plastered surface shall be free from cracks, fissures, crevices, hair cracks, blisters, local swellings and flakes. The finished surface shall be true to line, level, plumb and be plain and durable.

16.0 PIPEWORK, SHAFTS AND MANHOLES

16.1 Pipework Materials

16.1.1 General

All pipes to be laid by open trench excavation shall be solid walled concrete and in accordance with this Specification. The particular type, size, class and jointing system of pipes and fittings for each part of the Works shall be as specified below or as approved by the Engineer.

Pipeline materials shall be capable of withstanding all the loads and pressures to which they will be subjected. The Contractor shall consider compatibility with existing networks and other operational considerations. Structural design shall be carried out based on soil classifications and operating conditions such as internal pressures and external loads both temporary and permanent.

The installed pipes and their joints shall be resistant to the corrosive effects of the fluid being carried and the ground conditions in which they are placed.

Pipes and fittings must support loads coming from earth weight, traffic or other special forces, as well maximum pressures that can arise during service.

16.1.2 Fabrication tolerances

Tolerances for straight pipes and fittings shall conform to IS 3589.

(i) Straightness

Finished pipe sections shall be truly straight with walls parallel to the axis of the pipe and shall not be out of the alignment by more than 5mm for every 3m of length.

(ii) Length

Straight pipe shall not vary from the specified overall length or effective length by more than plus or minus 1.0 percent; where exact or cut lengths are specified the tolerance on length shall not exceed plus 15mm or minus 10mm.

(iii) Circumference

The outside circumference of the pipe shall not vary by more than 0.5 percent.

(iv) Outside Diameter

The outside diameter of a pipe of nominal diameter of over 500mm shall not vary by plus or minus 0.5 percent.

The diameter of plain end of a pipe of nominal diameter over 500mm shall not vary by more than plus or minus 0.5 percent. Notwithstanding these tolerances and the surface irregularities permitted, any dimensional variation or surface irregularity which permits leakage past the joints shall be cause for rejection.

16.1.3 Concrete pipes

All concrete pipes to be laid in open trenches, and their fittings, shall comply with IS 458.

The concrete shall be in accordance with Section 14.0 of this document.

Installation and testing of RCC pipes shall be in accordance with IS 783.

16.1.4 Concrete Pipe Joints

Concrete pipe joints shall be either spigot and socket or sleeve joints. Joints shall be sealed by elastomeric joint rings complying with IS 5382. Caulked joints shall not be used.

16.1.5 Glass Fibre Reinforced Plastic (GRP) pipes

Except where otherwise specified, glass-fibre reinforced plastic pipes and fittings shall be in accordance with IS 14402. Pipes shall have dense, void-free walls and be manufactured using the centrifugally-spun or externally-wound filament method.

The materials used in the manufacture of the pipes shall be resistant to abrasion and to chemical and biological attack and shall not react with or be soluble in the liquid being conveyed, or the surrounding ground or groundwater, within the temperature range to which they are exposed. The composition of the pipe materials shall be such as to avoid deterioration during transport or storage due to ultra-violet radiation.

16.1.6 Steel Pipework

(i) General

Steel pipes, fittings and joints shall conform to IS 3589 and IS 6631.

Pipes and specials shall be manufactured from seamless or welded carbon steel pipes made from materials with mechanical properties and weldability at least equivalent to those required by IS 3589.

The pipe thickness shall be suitable to comply with the required normal working pressure. Suitable thicknesses and recommended test pressures are given in IS 3589 for pipes up to 2,540 mm outside diameter.

All pipework and fittings shall be new and entirely fabricated and corrosion protected at the maker's works.

Steel pipelines shall have at least:-

a. an external coating comprising 3 layers: fusion bonded epoxy, fusion bonded epoxy adhesive primer and 3mm of hot applied polyethylene or polypropylene
b. Additional external protection for regions of contaminated / aggressive ground
c. Additional wall thickness and external protection for any tunnel sections and pipe bridges.
d. an internal coating comprising a minimum of 500 microns of fusion bonded epoxy
e. an effective means of repair to the internal coating subsequent to welding
f. an effective means to repairing external coating using heat shrink sleeving / wrapping with an overlap onto undamaged external protection of at least 150mm.

The Contractor shall prepare a method statement for repair of the pipeline specific to the chosen range of pipe materials, diameters, coating systems and pipe depths.

(ii) Fusion Bonded Epoxy Coated Steel Pipe

All pipes and fittings shall be satisfactorily hydraulically pressure tested, prior to coating at the manufacturer's works, to a pressure of 1.5 times the design pressure.

Prior to coating, the pipes shall be degreased, blast cleaned to IS 3589 and if seam welded, the welds shall be ground smooth. Any grit or dust shall be removed by air blast.

Before any visible surface corrosion has occurred, the pipes shall be heated to a temperature not exceeding 245 °C and then epoxy powder applied inside and out either by immersion in a fluidised bed or by spraying. The coating shall then be cured.

The coating material shall be a semi-flexible thermosetting dry powder fusion-bonded amine-cured epoxy as approved by the Engineer.

The resulting coating shall have a minimum thickness of 0.3 mm. Spark testing shall be employed to check for any imperfection and any defects found shall be repaired using a compatible two-pack epoxy and the area re-tested.

In the event of a fusion-bonded epoxy coating being damaged after leaving the factory, the item shall be returned to the factory for repair or be repaired at Site. Repairs shall be effected in accordance with the following requirements:

a. repair materials shall be compatible with the original factory-applied coating materials
b. the edges of the original factory-applied coating shall be ground off to a taper or feather edge
c. exposed metal shall be treated
d. the relative humidity of the atmosphere in which the repair is to be effected shall be maintained (if necessary, by the use of hot air blowers and tenting) at less than 85%
e. the surface temperature of the exposed metal shall be raised to at least 3°C above dew point and the coating shall then be applied in stages, as recommended by the manufacturer, to achieve a total thickness in accordance with Section 16.1.6(ii).

All repairs shall be checked with a holiday detector and any holidays shall be repaired, after which the repairs shall be re-checked.

16.1.7 Protective Cement Mortar Coating to External Surfaces

Where specified for steel pipeline to be laid underground, the external surfaces of pipes, specials and fittings shall be provided with a minimum of 40 mm thick cement mortar coating by guniting. A length of 150 mm at each end of the pipe shall be left un-coated to facilitate site welding. This portion shall be lined after laying, welding and field testing of the pipeline is completed satisfactorily.

Where the pipes/ specials are to be gunited externally or encased in concrete, the external surface of the pipe shall be given a coat of cement wash. The pipe surface shall be blast cleaned to the Engineer’s satisfaction. Immediately after the pipe/special is blast clean, the Contractor shall commence coating of the surface with cement wash.

(i) Mix Proportion

The proportion of cement and shall be 1: 3.5 by volume.

(ii) Reinforcement

The welded fabric used shall be BRC fabric conforming to IS 1566 or equivalent MS reinforcement. The welded fabric used shall be bent to proper shape to conform to the surface of the pipe to be coated and shall be securely held 20 mm away from the surface of the pipe by means of spacer blocks made from cement mortar (1:1) and binding wire. Spacers shall be placed at least 30cm centre to centre both ways. Adjacent sheets of fabric shall lap at least 80 mm and shall be securely fastened together by binding wire at intervals not exceeding 300 mm

(iii) Preparation for Surfaces

The interior surfaces of all pipes to be lined with Portland cement mortar shall be thoroughly cleaned by sand or steel grit blasting.

(iv) Hand Cleaning

Before blasting, all oil and grease on the surface of the metal shall be removed thoroughly by flushing and wiping using suitable solvents and clean rags. The use of dirty or oily rags will not be permitted. All other foreign materials shall be removed by buffing or by scraping and wire brushing. After cleaning, the pipe shall be protected and maintained free of all oil, grease and dirt that might fall upon the plate from whatever source until the plate has received its cement mortar coating.

(v) Mechanical Cleaning

All metal surfaces shall be thoroughly sandblasted to bright metal. Sandblasted surfaces which acquire a coat of rust shall be reblasted. Adequate air separators shall be used to remove all oil and free moisture effectively from the air supply to the blaster. Any plate showing pits or structural defects shall be kept aside during examination.

(vi) Rust Preventive Coating.

Immediately upon completion of sandblasting, surfaces at the end of fittings which are to be left bare shall be given a brush coat of a suitable rust preventive material. Rust preventing coating shall be applied and shielded and maintained during the subsequent application and curing of mortar lining and application of the exterior coating to protect, from corrosion. Rust preventive material used shall be of such character that the quality of the weld and other functions of the steel plate will not be impaired by its presence.

(vii) Application of Mortar Lining by Guniting

The compressor used shall be of an adequate capacity to maintain a pressure of at least 2.8 kg/sq.cm at the gun end. The nozzle shall be held at such a distance (65 to 100 cm) and position that the stream of flowing materials shall impinge as nearly as possible at right angles to the surface being gunited. All deposits of loose sand shall be removed prior to placing any layer of gunite. Gunite shall be shot in one coat to the specified thickness. Every precaution shall be taken to prevent the formation of sand pockets and if any develop, they shall be cut out and replaced with satisfactory machine placed material. No hand patching will be allowed. The Contractor shall apply the coating in such manner that no sloughing shall occur at any time during or following its application.

Gunite shall be placed in the top and sides of the pipe, then screeded to a uniform thickness and the ground lines or blocks removed. All rebound and waste materials shall then be removed by air blowing and gunite placed in the bottom of the fittings and screeded. When completed, the lining shall be concentric with the barrel of an even thickness. The entire surface shall then receive a final flash coat of gunite and shall be steel trowelled to a true surface equal in smoothness to the spun lining in such a manner not to impair the bond between mortar and steel plate. The guniting and surface finishing shall complete in set and shall be applied continuously without the fuse of construction joints. In case, for any reason whatsoever, the cement does not adhere to the walls of pipes and sloughs off, swabbing the pipe with cement slurry shall not be permitted.

If for any reason it is necessary to interrupt the placing of the gunite for a length of time that will result in the material taking a permanent set, a square shoulder shall be formed at the ends of the sections and or elsewhere by shooting against a backing up strip or by cutting back with a trowel or other suitable tool the irregular edges of the material last place to a clean unbroken surface perpendicular to the face that will provide a suitable connection or construction joint between such material and the material to be placed subsequently. When performing this work, care shall be taken not to shatter or disturb the material remaining in place or disturb the embedded wire mesh. Before placing fresh material against the surface of such joints, the joint shall be carefully cleaned and wetted to ensure a good bond between the fresh material and that previously applied. The joint shall be thoroughly wetted by sprinkling and maintained in a moist condition.

The un-gunited portion at the ends of the pipe lengths left for the purpose of field welding or bolting shall be encased with M15 concrete after the connection is made and hydraulic testing is completed.

(viii) Curing of Lining and Coatings

Immediately upon the completion of lining of special fittings, the fittings shall be closed tightly at each end by bulkheads. After the mortar has set, but not later than twelve hours after the application of the lining, curing shall be commenced by the water spray method and continued thereafter for fourteen days. The water spray method shall consist of sprinkling the mortar lining with water by means of sprinkled heads placed within the barrel of fittings, of such capacity as to keep the entire surface of mortar lining continuously wet throughout the entire period of curing.

The application of the exterior coating shall begin not less that seventy two hours after the completion of interior lining but in any event, such water spray curing shall be continued inside without interruption during the application of exterior coatings and thereafter until the fitting is loaded for transportation to the trench, regardless of the lapse of time after loading. Each fitting shall be closed at both ends during transportation and storage and the Contractor shall continue the interior water spraying. All the fittings will be laid within 24 hours after such water spray has been discontinued.

The Contractor shall protect all cement mortar from damage during handling and transportation. After the internal mortar has been cured, internal bracings shall be placed at the ends of the fitting and elsewhere, if necessary, without damaging the mortar lining to preserve the roundness of the barrel of the pipe. All such bracings, except those that may interfere with the jointing operation, shall remain in position until the fitting has been installed and back filled.

16.1.8 Cast Iron Drainage/Vent Pipe and Fittings

Cast iron drainage/vent pipes and fittings shall generally comply with IS 1536:2001, IS 3114:1994, IS 1538:1993, ANSI/AWWA C110/A21.10, ANSI B16.12.

Joints (exposed or below ground) shall be self-locking neoprene gasket joints.

For plain end pipe connections, couplings shall comprise a continuous sleeve around the pipe with stainless steel sheath and gear clamps for exposed piping. Mechanical type couplings shall be used for below ground piping.

16.1.9 Flange Adaptors and Couplings

Flange adaptors and plain-end to end couplings shall conform to AWWA C-219, with materials conforming to IS 2062:2011 Grade C, BS EN 10025 Grade S275. Each flange adaptor assembly shall be coated with thermoplastic anti-corrosion protection coating applied by hot dipping in a powder tank to an average thickness of 250 microns or epoxy coated to AWWA C-213, with an EPDM rubber seal which shall be in accordance with BS EN 681 – 1 and complete with all necessary, nuts, bolts, studs and washers.

16.2 Shafts and Manholes

16.2.1 General

Backfilling around manholes shall be carried out as construction proceeds. On no account shall the concrete work be built up so far ahead of backfilling as to impede proper compaction of the backfill material.

All shafts and manholes shall be watertight on completion. If any leaks appear in the manholes at the inside joints they shall be sealed.

All shafts and manholes shall be cleaned of any accumulation of silt, mortar, debris or any other foreign matter and shall be free of any accumulation at the time of final inspection.

16.2.2 Pre-cast Concrete Manholes

Pre-cast concrete circular manhole sections and cover slabs shall be manufactured from sulphate resisting cement.

All pre-cast cover slabs shall be heavy duty and shall be provided with a tapered opening over which the manhole cover will be set. The slabs shall be provided with built-in lifting rings.

16.2.3 Manhole Covers and Fittings

All access covers or opening covers shall to the dimensions given on the Drawings. The covers shall be capable of safe operation by two people and shall be fitted with locking devices and be secure against vandalism.

Unless otherwise stated in the Employer's Requirements, the covers and frames for manholes shall conform to IS 1726 or IS 12592.

16.2.4 Deleted

16.2.5 Chemical Resistant Resin Mortar

(i) General

The mortar shall be an intimate mixture of liquid resinous material and a setting agent and may contain appropriately selected filler materials. When mixed these components shall form a mortar, with a workability suitable for the proposed method of application that subsequently hardens.

(ii) Composition

The liquid resin shall be any solvent free resinous material capable of forming a chemical resistant mortar when mixed with a suitable catalyst and, if required, a filler material. The filler material if used, shall be compatible with the liquid resin, of the chemical resistance required and of a size that will permit the preparation of a minimum joint thickness of 3.0mm. The mixed mortar shall not adversely affect or be affected by other construction materials with which it will properly come into contact, including fixtures and fittings.

(iii) Colour

The colours of individual components of the chemical resistant resin mortar shall be sufficiently different from each other that complete, homogeneous mixing of the components will be apparent by visual inspection.

(iv) Packaging

The components of the chemical resistant resin mortar shall be pre-measured and packaged by the manufacturer in units sized to suit the method of application. All packages shall be clearly marked as to size, contents, mixing instructions, safety precautions, storage requirements and date of expiration of the contents.

(v) Shelf Life

The unmixed components of the chemical resistant resin mortar shall have a minimum shelf life after delivery to the site of 12 months when stored at a temperature between 5°C and 50°C.

(vi) Pot life

Where it is proposed to apply the mortar by trowel, the working time after initial mixing of the resin, filler material and hardener shall be a minimum of 60 minutes at a temperature of 20 °C and 30 minutes at 50 °C. The pot life of the mortar shall be considered exceeded when the mortar can no longer be applied to a prepared surface without curling behind the trowel. If it is proposed to apply the mortar by some other method (eg by gun), the working time after mixing shall be of a length suitable for the proposed method of application. Mortar applied at any time during the pot life shall have the specified properties when cured.

(vii) Bond Strength

The chemical resistant resin mortar shall form a bond with brick, tile or concrete or with a cured surface of itself, with a minimum strength subject to substrate cohesive capacity, of 3 N/mm2. This bond strength shall be achieved regardless of whether the mortar is applied to a dry, a damp or wet surface without priming or other form of surface preparation. The bond strength shall be tested and measured using samples of the actual construction materials.

(viii) Compressive Strength

The chemical resistant resin mortar shall have a minimum compressive strength of 15 N/mm2 when tested and measured.

(ix) Tensile Strength

The chemical resistant resin mortar shall have a minimum tensile strength of 5 N/mm2 when tested and measured.

(x) Modulus of Elasticity

When tested and measured, the chemical resistant resin mortar shall have a maximum elastic modulus of 9kN/mm^2.

(xi) Chemical Resistance

The cured chemical resistant resin mortar shall be capable of resisting attack by any constituents that may normally or occasionally be present in sewage or which may form within the system by a combination of physical, chemical and biological reactions. In particular, the mortar shall be capable of resisting attack from extended exposure to sulphuric acid in concentrations up to 15%, oils, greases and petrol. The chemical resistance of the mortar shall be tested and measured.

(xii) Shrinkage

The chemical resistant resin mortar shall have a shrinkage not exceeding 0.5% when tested and measured.

(xiii) Absorption

The cured chemical resistant resin mortar shall have an absorption not exceeding 3.0%.

(xiv) Thermal Compatibility

The cured chemical resistant resin mortar shall have properties of shrinkage and thermal expansion to withstand prescribed tests.

16.2.6 Coal Tar Epoxy Paint

Containers of epoxy paint shall be of a pack-size suitable for complete usage when thoroughly mixed by one operator within the pot life of the material at the highest likely ambient temperature. A mechanically operated mixer shall be used of a design which does not entrain air in the paint. Except where otherwise specified, epoxy resin paints shall be formulated so that the epoxy resin content together with its curing agent shall not be less than 40% by weight of the solid binder.

The coal tar epoxy paint shall have the following properties as a minimum:

1	Pot life at 50 ^{o}C	1 Hr
2	Touch free time	8 Hrs at 35 ^{o}C
3	Initial cure	24 Hrs at 35 ^{o}C
4	Final cure	96 Hrs at 35 ^{o}C
5	Finished Film Thickness	300 microns per coat

16.2.7 Granular Bedding and Surround Material

Material for granular bedding and surround shall be broken stone or irregular shaped gravel with coarse sand and shall be inert to ground water, acids and sulphates. It shall have a compaction fraction value of less than 0.15 and shall be nominal single size complying to the following gradings:

1	Pipe Diameter	Nominal Size
2	DN 100	10mm
3	DN 150	10 or 14mm
4	DN 200 – 300	10, 14 or 20mm
5	DN 375 – 525	14 or 20mm
6	DN 600 & above	14, 20 or 40mm

The material shall be tested and shall have a 10% fines value greater than 50kN. Material retained on a 7mm sieve shall have an index of flakiness less than 25% and an index of elongation less than 45%.

Whenever necessary, the test for compaction shall be carried out on the material for granular bedding.

16.2.8 Geotexile Fabric

Geotextile fabric shall be a pervious sheet of non-woven polyester, polyethylene, nylon, or polypropylene filaments and formed into a uniform pattern. The material shall be resistant to all naturally occurring acids and alkalis present in the soil and shall be resistant to biological degradation. The fabric shall be strong enough to withstand stresses occurring during placement and any subsequent pipe or soil movement.

The grade of the fabric shall be such that O95 (pore size) shall be smaller than D85 of the native soil as established by the Particle Size Distribution Analysis.

The geotextile fabric shall have the following minimum properties when measured in accordance with the reference standards:

Test	**Minimum Property**	**Standard**
Weight	125 g/m²	IS 14716
Thickness under 2kN/m^2 load	4 mm	IS 13162
CBR test	4750 N	
Tensile Strength:		
Longitudinal direction	22kN/m	IS 15060
Transverse direction	36kN/m	
Elongation at rupture	50% - 80%	IS 13162
Grab strength	1500 N	IS 14293
Water permeability at 10cm head	45 litres/m^2/sec	IS 14324

16.2.9 Benching

Internal shaft benching shall be formed with plain concrete class M 30. The surface of benching and flow channel shall be protected with chemically resistant resin mortar, minimum thickness of mortar shall be 12mm.

16.3 Workmanship

16.3.1 Storage

Pipes and fittings shall be stored raised at least 75mm from the ground and shall be carefully supported, cushioned and wedged. Pipes shall not rest directly on one-another and shall not be stacked more than four pipes high, or two pipes high in the case of pipes larger than DN 500.

Any period during which the pipes are strung out along the pipeline route or placed alongside, the Works shall be kept to a minimum. Jointing parts and materials shall in any case be stored under cover and jointing elements forming parts of the pipes shall be adequately protected to prevent accidental damage. Subject to the foregoing and to any restrictions on the duration of temporary occupation of parts of the Site, pipes may be strung out along the pipeline route prior to installation providing that any necessary temporary fencing has first been erected.

Storage areas shall be carefully set out to facilitate unloading, loading and checking of materials with different consignments stacked or stored separately with identifications marks clearly visible.

End covers and protection shall not be removed until incorporation into the works.

16.3.2 Transportation of Pipes and Fittings

Any vehicle on which pipes are to be transported shall have a body of such length that the pipes do not overhang. The pipes shall be transported and handled in accordance with the manufacturer's recommendations.

Approved slings shall be used and all hooks and dogs and other metal devices shall be padded. Hooks engaged on the inner wall surface at pipe ends shall not be used.

Under no circumstances shall pipes be dropped, be allowed to strike one another, be rolled freely, or dragged along the ground.

16.3.3 Inspections of Pipes and Fittings

Before incorporation into the pipeline, each pipe shall be brushed out and carefully examined for soundness.

Damaged pipes which, in the opinion of the Engineer, cannot be satisfactorily repaired shall be rejected and removed from the Site.

If the Engineer considers that an unacceptable proportion of the pipes supplied by the Contractor within a test length has failed the Contractor may be required to hydraulically pressure test each pipe and joint on-site before pipe laying.

In this event, test results shall be submitted to and approved by the Engineer before any further pipes are laid.

In addition to any inspection and tests made when delivery is taken, pipeline materials, including lining or protective paintwork, pipeline and manhole construction shall be inspected after installation and all damage identified shall be repaired.

Any special material required for the repair of pipe lining or necessary repairs shall be made using materials obtained from the appropriate supplier and shall be used in accordance with their recommendations.

16.3.4 Trench Preparation

Trench excavation and backfilling shall be co-ordinated with the construction of the pipeline as a whole to ensure expeditious completion of the whole operation and shall comply with Section 6.7 of this Specification.

For pipelines the bottom of the trench shall be finished smooth and be free from irregularities, so that the pipes bear uniformly and are supported throughout their length. The holes required at each joint shall be made as small as possible.

Trench design shall comply with the standard trench details given in IS 3114 (steel pipes) and IS 5822 (concrete pipes) and other material specific pipe standards. Exceptions may be permitted where ground conditions dictate in which case the Contractor shall submit trench embedment details to the Engineer for review prior to works on site.

Details of layered compaction shall be given, including proposed compaction layer thicknesses, with a view to ensuring minimal post construction surface settlement.

16.3.5 Installation of Pipelines

Pipes shall be laid in accordance with IS 783, IS 3114, IS 5822 and other relevant Indian standards unless otherwise specified herein.

No metal tools or heavy objects shall be permitted to come into contact with the pipes or fittings.

Externally coated pipes shall be handled at all times with wide non-abrasive canvas, rubber, or leather belts or other equipment designed to prevent damage to the coating. The use of chains, wire slings, or any other handling equipment found to be injurious to the coating shall not be permitted. The timbers or skids used to support the coated pipe prior to installation shall be properly padded for the purpose of protecting the coating. Pipes and fittings shall be lowered into the trench with equipment suitable for the weight of pipes and fittings. Pipes and fittings shall be carefully cleaned before jointing. Any injury to the protective coating from any cause must be repaired before the pipes are tested.

Every precaution must be taken to prevent foreign material from entering the pipes or fittings. Whether installed or when in storage, the pipeline ends shall be capped at all times when not being worked on. During laying operations no debris, tools, cloth, or other material shall be placed in the pipe. The Contractor shall provide sufficient ends caps for this purpose and shall instil the practice of "If you leave it (unattended), seal it, no matter how brief the period is".

The equipment for checking and controlling the pipe alignment shall be robust and simple to use and check and installed in such a way that it is not liable to accidental disturbance and shall incorporate features to show whether any disturbance has taken place.

Pipes shall be laid accurately to the designed lines and levels within a tolerance of +/- 5 mm. Pipe alignments shall be straight between bends.

Pipelines on which work is being undertaken shall be kept thoroughly cleaned. Except when cleaning or water testing, water shall not be allowed to flow through the pipes.

16.3.6 Cutting of Pipes

Pipes which are required to be cut to form closing pieces in any portion of the pipeline or to terminate in manholes of other parts of the Works shall not be cut until after all adjacent pipes have been installed and jointed and shall be cut to allow a 20mm gap between adjacent pipe ends.

Pipes shall be cut in accordance with the manufacturer's recommendations, by a method which provides a clean, square profile, without splitting or fracturing the pipe wall and which causes minimal damage to any protective coating.

Where necessary, the cut ends of pipes shall be formed to the tapers and chamfers suitable for the type of joint to be used. Any protective coatings shall be made good, the ends sealed and the external face of the pipe made smooth for a suitable distance.

16.3.7 Precautions against Flotation

When the pipeline laid underground or above ground in a long narrow cutting gets submerged in water collected in the trench of cutting it is subjected to an uplift pressure due to buoyancy and is likely to float if completely or partly empty. In the design of pipelines, provision is made to safeguard against flotation by providing sufficient overburden or by providing sufficient dead weight by means of blocks etc.

In the case of works extending over one or more monsoon seasons however, special care and precautions are necessary during the progress of work. The work of providing blocks, refilling the earth to the required level, compacting the same etc shall always be done as soon as the pipeline in the cutting has been laid.

The Contractor shall ensure that water shall not be allowed to accumulate in open trenches. Where work is in an incomplete stage, precautionary work, such as blank-flanging in the open ends of the pipeline and filling the pipeline with water etc shall be taken up as directed by the Engineer.

Protection of the pipeline against flotation during the Contract period shall be the responsibility of the Contractor.

16.3.8 Installation of Gravity Pipelines

Sight rails or other suitable methods shall be used to control the accuracy of pipe laying. If used then strong sight rails shall be fixed and maintained at each change of gradient and at as many intermediate points as may be necessary, but not more than 20 m apart. Sight-rails shall be clearly painted in contrasting colours and be not less than 1 metre long and 150mm deep, straight and level, rigidly supported by stout wooden posts at each end. Any pipes placed on end for affixing the base of the posts shall be not less than 225mm in diameter and shall be filled and rammed solid with earth or sand. Posts shall otherwise have their bases concreted. Boning rods or travellers for use with sight rails shall be of robust construction, clearly painted and accurately made to the various lengths required, the lower ends being provided with shoes with sufficient projection to rest on the pipe inverts. A third sight-rail shall be used wherever possible for ease of checking against accidental displacement.

Where pipelines are to be bedded on concrete, pre-cast concrete bedding blocks shall be set to a level allowing for the thickness of the pipe barrel and side string lines shall be used for checking alignment.

16.3.9 Concrete Bedding and Surround

Concrete bedding and surrounds shall not be placed until the joints at each end of the pipe have been completed. The full width and depth of bedding concrete shall be placed and carefully vibrated beneath the pipe followed at once by the addition of any haunching and surround concrete. Unformed surfaces shall be of spade finish. The pipe shall be prevented from floating or other movement during concreting.

Wherever pipes are provided with concrete protection, they shall be supported temporarily on pre-cast concrete blocks cast to the shape of the bedding and where they have a concrete surround the depth of the pre-cast concrete block shall be increased to suit. The pre-cast concrete blocks shall be positioned behind each socket. The width of the pre-cast concrete blocks shall be half the diameter of the supported pipe subject to a minimum and maximum of 115mm and 300mm, respectively. The blocks shall be left in and incorporated in the in-situ concrete.

To ensure flexibility of the pipeline, a divider of fibreboard or other suitable material cut to shape shall be placed at each pipe joint to make a complete break in the continuity of the concrete protection.

Where two or more pipelines are laid in the same trench the joints shall coincide at the points where the continuity of the concrete surround is broken, ie at the joints in the pipeline with the longest pipe. Any intermediate joints in the other pipelines with shorter pipes shall be surrounded in concrete.

16.3.10 Granular Bedding and Surround

Pipes shall be provided with a bed, embedment and surround in the locations and to the dimensions as recommended by the pipe manufacturer. Where required, granular pipe bedding and surround shall be wrapped in a geotextile fabric to prevent migration of fine material into the granular surround.

Granular bedding shall be well compacted to the correct levels so that pipes are given full support along the entire barrel length. Recesses shall be formed in the granular bedding to accommodate sockets, collars or other pipe joints.

Bedding, pipe surround and backfill shall be compacted to at least 95% maximum dry density except at road crossing where the compaction shall be at least 98%.

Pipes shall not be supported on timber wedges pre-cast concrete blocks, or similar materials. After pipes have been correctly laid further granular material for haunching or surround shall be placed and carefully compacted so no disturbance of the pipe occurs.

Compaction of backfill shall be suitably controlled to ensure that backfilling does not adversely affect the integrity of the pipeline.

Following pipe laying, further granular material shall be placed in the trench with special care being taken to fill under the sides of the pipe to ensure full contact with the barrel of the pipe. The granular material shall then be compacted evenly on both sides of the pipe.

16.3.11 Manhole covers

The covers shall be carefully set to the slope of the ground or road surface. In open areas, manhole covers shall be set 150mm above the surrounding general ground level.

After setting in position the lifting and prising holes provided in the cover shall be cleaned out and refilled with tarred hemp.

16.3.12 Brickwork

All brickwork shall be uniformly bedded, bricks always being laid frog upwards and each brick floated, rubbed in or hammered down upon such a sufficient quantity of mortar that the mortar may be squeezed up into the joints and each joint not already full shall be flushed up with the mortar of the next succeeding bed. The whole of the beds and joints shall be completely filled and compressed to ensure the greatest possible density. Horizontal weathered jointing shall be provided to all external faces. Bricks with a very high suction may be wetted, but not saturated, immediately before laying. Engineering brickwork shall not be laid in wet weather.

All engineering brickwork shall be carried out using cement mortar.

16.3.13 Cement Mortar

The ingredients shall be thoroughly mixed while dry by machine or hand until the cement colour can no longer be distinguished from the fine aggregate in any part of the mass and then shall be uniformly wetted by means of a rose while undergoing further thorough mixing.

The mortar shall be prepared and used at such places and times and in such quantities that a longer time than thirty minutes shall not elapse between the first wetting and its completed use upon the Works. If mixed by hand, no single mixing shall exceed a quarter of a cubic metre.

The fine aggregate for cement mortar shall comply with IS 383, the grading being in accordance with IS 2386.

16.3.14 Welded Joints for Steel Pipelines

Welding of joints in steel pipes shall be carried out manually by the metal arc welding process complying with AWWA Standard C206 and in accordance with IS 816:1969 arc welding, or BS 2633 to suit the pressure rating of the pipework. Before starting the welding of any pipe joints in the Works, the Contractor shall submit for the Engineer approval details of the plant, methods and materials he proposes to use, including make and size of electrodes, number of runs, current strength and arrangements for air testing of individual joints.

Pipework shall be radio-graphed as required in accordance with IS 1182:1983 or BS EN 1435, the technique number to be subject to the approval of the Engineer.

All parts to be welded shall have loose scale, slag, rust, paint and other foreign matter removed by means of a wire brush and shall be left clean and dry. All scale and slag shall be removed from each weld run when it is completed. Pipes manufactured with longitudinal or spiral welds shall be lined up before jointing so that these welds are at least 15° apart around the joint circumference.

Sealing of cable entries shall only take place after the satisfactory testing of joints for which the cable entry is required. Cable entries shall be closed with the screwed plug provided and the plug welded in place. Lining and coating shall be applied to the area of the entry to the same standard as the pipe.

16.3.15 Butt Welded Joints

Unless otherwise agreed by the Engineer, welded joints shall be of the butt welded type. The Contractor must submit his proposals and his welding procedures for butt welding to the Engineer for approval and shall not commence any butt welding jointing work until he receives the Engineer's approval.

Butt welded joints shall be single groove or double groove welded and shall be full penetration butt welds. Unless otherwise approved by the Engineer, welds shall be single run welds.

Pipe ends for butt welding shall be plain end pipe in accordance with API Spec 5L (Addendum). They shall be bevelled to an angle of 30° measured from a line drawn perpendicular to the axis of the pipe and with a root face of 1.6 mm ± 0.8 mm. The root face shall be located to suit whether the pipes will be welded from the inside or from the outside.

Any internal backing rings used shall be removed after the welding operation.

16.3.16 Lap Welded Sleeve Joint

Lap welded sleeve type joints shall be welded inside and outside. The internal weld shall be a full depth structural weld, whilst the exterior weld shall be a small fillet weld to seal the joint and to allow gas testing of the joint.

For pipes larger than 900 mm diameter, a triple run convex fillet weld shall be used. For pipes of 900 mm diameter or less, a double run convex fillet weld shall be used.

The minimum length of the fillet, as deposited, is to be equal to the full thickness of the pipe wall. The actual throat depth shall not be greater than 9/10 and not less than 7/10 of the minimum leg lengths as deposited. The depositing of the weld metal shall be carried out in such a manner as to ensure that all the welds have adequate root fusion and are of good clean metal free from cracks, gas holes, slag inclusions and all other impurities. The surface of the weld shall have an even contour with regular finish and shall indicate proper fusion with the parent metal. All slag shall be thoroughly removed after depositing each run of welding by light hammering with a chipping hammer followed by wire brushing. Any welds showing cracks or other cavities or in which the weld metal tends to overlap onto the parent metal without proper fusion or containing any other defects whatsoever shall be cut out and re-welded to the satisfaction of the Engineer.

16.3.17 Lap Welded Collar Joint

Where the Engineer permits two plain-ended pipes to be jointed by a welded collar joint, the gap between the two ends shall not exceed 75 mm. An external steel sleeve collar, of a thickness not less than that of the pipe itself and approximately 300 mm in length, shall be placed centrally over the two ends to be jointed. The end of each pipe shall then be fillet welded to the sleeve collar, inside and outside, in accordance with the above procedure for a lap welded sleeve joint.

16.3.18 Welder Performance Test

The Contractor shall submit for the Engineer's approval, the names of the proposed welders together with evidence that they have passed appropriate qualifying tests and possess certificates from an independent testing authority. Weld specimens from each of the welders shall be submitted for the approval of the Engineer, who may also require satisfactory test welds to be carried out under Site conditions and on materials similar to those for use in the Works. The Contractor shall maintain an up-to-date list of welders that have been approved by the Engineer.

The Contractor shall remove from the approved list any welder whose workmanship is, in the opinion of the Engineer, below a reasonable standard of quality or consistency.

16.3.19 Inspection and Testing

(i) General

Testing of welded joints shall be done as per relevant Indian standards IS 3600:1985 Part 1 to 2, IS 3600:2009 Part 3, IS 3600: 1984 Part 4, IS 3600:1983 Part 5 to 6, IS 3600:1985 Part 7 to 9, IS 3613:1974, IS 7307:1974 Part 1, IS 2595:2008, IS 4260:1986 or British standards BS Codes BS EN 1321:1997, BS EN 895:1995, BS EN 10208:2009 Part 1 to 2, BS EN 10208-2:2009, BS EN ISO 15614-1:2004+A1:2008, BS 4871:1985 Part 2, BS 4872:1985 Part 1.

All inspection and testing shall be carried out by certified inspectors appointed by the Contractor. Reports on inspections and tests shall be submitted to the Engineer promptly.

All welds shall be visually inspected.

The first 10 joints made by each welder shall be 100% tested; thereafter 10% of the joints made by the welder shall be tested. If a weld is found to be defective, the welder concerned will have his previous and subsequent weld 100% tested, if a further defect is found the next three welds will be 100% tested.

Non-destructive testing methods:

Weld Type	Testing Method
Butt welds	radiographic testing
Part penetration and fillet welds	magnetic particle testing

Radiographic inspection of welds shall be made by the Contractor, in the presence of the Engineer, in accordance with IS 4853:1982, IS 1182:1983 or IS 2595:2008 to a maximum of 10% of the total run of weld. Each joint to be radiographed shall be cleaned and any weld spatter removed. Any defective weld shall be repaired by approved means or cut out if necessary. If, in the opinion of the Engineer, excessive repair work is necessary, the radiographic inspection may be increased beyond 10% of the total run.

Spherical and other forms of sleeve welded joints shall be gas tested.

(ii) Gas Testing

The Contractor shall carry out nitrogen tests on a number of completed welded sleeve/collar type joints, at the discretion of the Engineer.

A tapped hole (approximately 6 mm diameter) made in the socket end of the pipe to be tested shall be fitted with a suitable non-return valve. Moisture free nitrogen gas, at a pressure of 1 bar shall then be pumped into the annular space between the spigot and socket and the pump disconnected.

If no drop in pressure occurs over the ensuing test period the test shall be deemed to be successful. The duration of this test period shall be 30 minutes unless otherwise approved by the Engineer. If the test pressure cannot be maintained for 30 minutes, all defects in the weld shall be cut back and re-welded and the test reapplied until successful. Once the joint has successfully passed a gas test, the tapped hole shall be sealed with a threaded steel plug, which is tack welded in place.

The Contractor shall provide all items necessary for the nitrogen gas tests including compressor, gas bottles, valves, gauges, tubing and so forth.

16.4 Construction Tolerances

For pipes installed by open trench excavation the final location of the completed pipeline shall not deviate from the position detailed in the Contract by more than:

1 Line ± 10mm

2 Level ± 5mm

3 Max. lipping between edges of adjacent pipes ± 2.5% of nominal internal diameter

No reverse gradient will be accepted on gravity pipelines.

Finished concrete surfaces shall not deviate from the positions detailed in the Contract by more than:

1	Screeded finish or rough formwork	± 10mm
2	Any other finish	± 5mm

17.0 STRUCTURAL STEELWORK AND FLOORING

17.1 General

Safe access, including flooring, handrails, staircases, ships ladders, ladders and step-irons, as appropriate, shall be provided as necessary to all areas and items of plant and equipment requiring any attention for operation and/or maintenance.

Any small areas of chequer plating or similar covering that are necessary to cover gaps between items of plant and the surrounding structure and any access ladders, platforms and handrails that must be attached to items of plant to facilitate operation, inspection or maintenance, shall be supplied and erected by the Contractor.

The Contractor shall provide adequate means of access to all hand-wheels, sight glasses, gauges, lubrication points and any other items to which access is necessary for routine operation and maintenance.

In damp and/or corrosive environments, flooring, handrails etc shall be of GRP or Stainless Steel.

Unless otherwise specified all areas of the Works shall be considered permanently damp and/or corrosive.

All items supplied under this section shall be permanently stamped with the manufacturer's identification markings and the manufacturer shall be ISO Certified.

17.2 Open Grid Flooring (Open Mesh/Grating)

Open mesh decking shall be in accordance with IS 15836:2008 Part 1 & 2 / IS 2062:2006. The panels shall be constructed with bearer bars, depths to suit the span but not less than 38mm deep. Adjacent panels and panels at the same level shall span in the same direction, unless specifically required for frequent access and shall be secured together by stitching bolts with a minimum of two fixing clips when supported on structural steelwork. The top edge of the bearer bars shall be serrated and shall be in addition to the bearer bar minimum depth.

Each panel shall be designed for a uniformly distributed load of 10kN/m2 with a maximum deflection of 1/240th of the span.

Open grid flooring (open mesh/grating) shall be structural grade stainless steel alloy AISI Type 316L. The stainless steel open grid flooring (open mesh/grating) shall be of the welded or pressure-locked style. Squeeze-locked or riveted styles are not acceptable." Where grid flooring (grating) is to be installed for openings in concrete slabs or across concrete channels, the grid flooring (grating) shall rest on continuous 'L' shaped angles of stainless steel AISI 304 cast-in-place complete with anchors at 450mm c/c. The 'L' shaped angle shall provide a minimum bearing surface width of 25mm each direction."

17.3 Walkway Platforms, Access Steps, Ladders and Handrailing

17.3.1 Walkways and Access Platforms

Standard structural steel sections shall be used for supporting structures.

Toe plates shall be fitted along the outer edges of all walkways and shall be part of the structure and not the floor panels. Toe plates shall extend 100mm above the top level of the floor panels. Floor panels shall be sized so that each panel does not weigh more than 50 kg.

The support structure shall be constructed so that it can readily be dismantled. Provisions shall be made in the design for adjustment to eliminate irregularities in structural floor levels.

All components including floor fixings shall be hot-dip galvanised after fabrication to IS2629:1985.

All assemblies shall be marked at the factory with distinguishing numbers, letters or marks corresponding to those of Approved Drawings or parts lists. Such marks if impressed before painting shall be clearly readable afterwards. Any temporary bolts for field erection shall be readily distinguishable from any bolts used for permanent connections.

Where dissimilar materials come into contact with each other, an insulating membrane or paint coating shall be applied to minimise direct contact.

17.3.2 Access Ladders

The cross-section of stringers shall be suitable for the weight of the ladder, taking into consideration the spacing of the points at which they are fixed to supporting steelwork or floors. The minimum thickness of the stringers shall be 13mm. The stringers shall be drilled to take 25mm diameter rungs, which shall be uniformly spaced at 250mm centres. The rungs shall pass through and be welded to the stringers at each side of each stringer and each weld shall be continuous. Supports shall be arranged to allow a minimum clearance of 230mm behind the rungs to the wall or other obstruction.

All components of the access ladders shall be structural grade stainless steel alloy AISI Type 316L.

17.3.3 Hand-railing

Hand-railing shall be double rail 1 100mm high and 900mm high on stairs measured vertically from the nose of the tread.

Standards shall be continuous 38mm minimum nominal OD x 3.7mm thick structural grade stainless steel alloy AISI 304L tube/pipe with 60mm diameter solid stainless steel AISI 304L balls. Balls shall be drilled to give 1.5mm clearance to handrails. Each ball shall incorporate a concealed grub-screw with Allen-type head to secure the rails. Standards shall have a minimum base width of 65mm, drilled for M16 fixing bolts and be set at maximum 1800mm centres. Handrails shall be 33.7mm OD x 3.2mm thick structural grade stainless steel alloy AISI 304L tube/pipe. Joints shall be arranged to coincide with the spacing of standards and shall have mitred type joints with a tubular ferrule, plug welded or fixed with a 5mm diameter countersunk head pin.Removable sections of handrail shall have half-lap joints secured with a countersunk head pin.

Chains across openings shall be oval shaped proof coil chain links with inside dimensions 12mm x 28mm x 4.7mm thick of stainless steel alloy AISI 304L. The chains shall have 304L SS snap-hooks. 304L SS eye-lets shall be securely fixed to the balls of the standards.

17.3.4 Chequer Plating

Chequer plating complete with cut-outs and in sizes suitable for removal by hand shall be structural grade stainless steel alloy AISI 316L plate of minimum 6mm thickness to carry a uniformly distributed loading of 10kN/m2. Deflections shall not exceed 1/240 of the span and if the spans are over 1m stiffeners shall be used.

Plating top surface shall be of non-slip, raised oval/diamond, self draining pattern securely fixed to the supporting structure. The sections shall fit without gaps and squarely on the supporting structure.

The weight of each removable section shall not exceed 50 kg.

Each length shall have two formed holes for lifting keys. Two pairs of lifting keys shall be supplied for every 50 m2 of plating. Where a single area is covered by several pieces of plating, the direction of the pattern on all plates shall be the same and the pattern shall be continuous.

Kerbing shall be built-in so as not to reduce the width of the opening and it shall provide a minimum of 25mm bearing surface for the chequer plating. It shall be supplied with fixing lugs at centres, not exceeding 1 m. kerbing and chequer plating shall be finished flush with the surrounding finished floor.

Chequer plating shall be screwed to its kerbing or supporting steelwork by countersunk screws so that individual plates cannot rattle or move. At the edges of raised floors, gangways and platforms, toe plates 100mm high shall be provided.

Where chequered plate is to be installed for openings in concrete slabs or across concrete channels, the plate shall rest on continuous inverted 'L' shaped angles of stainless steel AISI 304 cast-in-place complete with anchors at 450mm c/c. The angles shall provide a minimum bearing surface width of 25mm each direction.

17.3.5 Step Irons

Step irons shall be provided to provide access to all manholes and chambers without alternative means. Vertical spacing between step irons shall be 225mm.

Step irons shall be manufactured from 12mm diameter stainless steel bar incorporating a non slip tread.

18.0 PILING

18.1 General

Pile foundations may be necessary for supporting structures where the subsoil is considered to have insufficient bearing capacity. The Contractor shall carry out the detailed design of these structures in accordance with the Contract Conditions and Employer's Requirements and shall determine the type of foundation required, the number of piles and their working loads and the optimum arrangement of piles required for supporting the structures.

Piles shall be designed, constructed and tested in accordance with the relevant sections of IS 2911, IS 14593 or any other relevant IS code.

Excavation, concrete, steel reinforcement and steel casing, where applicable, shall conform to the relevant Clauses of the Specification. At least 21 days before the Contractor intends to commence piling work on the Site, the Contractor shall submit for the Engineer's approval full details of his proposed piling system including the type and dimensions of piles, reinforcement details and full design and driving calculations. The details to be submitted shall include the Contractor's proposals for equipment, temporary works and construction methods.

No work on piling shall commence on the Site until the Engineer's approval to the Contractor's proposal has been received.

Notwithstanding the requirements outlined in this section, the design shall be entirely the Contractor's responsibility.

18.2 Types of Piles

Bearing piles shall be driven reinforced pre-cast concrete or cast in-situ concrete piles.

All concrete for piles shall be in sulphate resisting cement, unless the Contractor can document that a lesser quality complies with the actual aggressiveness of soil and ground water. The use of a lower quality is subject to the approval of the Engineer.

18.3 Design of Piles

Piles shall be designed to sustain the required loads with settlements not exceeding those specified. Allowance shall be made in the design for the incidence of negative skin friction where appropriate and for resisting the necessary tensile forces due to the swelling and heave of any soil stratum.

Piles shall be designed to have a bearing capacity of at least 2.5 times the working load (working load = design load).

The permissible loading of piles shall be modified where necessary to allow for particular conditions: piles in close proximity or in groups, soil strength, groundwater level and other relevant factors.

The piles shall be of sufficient cross-section and length, and configured in a way to sustain the loads designed or specified without settlement (of single piles combined with additional settlements due to group action) exceeding the following:

- Working load allowable settlement 8 mm
- 1.5 × Working load allowable settlement 10 mm
- 2 × Working load allowable settlement 12 mm

These settlements shall include both permanent and elastic deflections. Measurement of the settlement shall be made on first achieving the specified load. Measurement of the settlement shall be made at the point of application of the load.

Where piles in place are subjected to handling, stacking and pitching or bending moments and/or shear forces, these shall be combined with the vertical loads (either in compression or tension) to satisfy the design requirements of BS 8110 Parts 1, 2 and 3.

The average compressive stress in the concrete of bearing piles under working load shall not exceed 25% of the characteristic cube strength at 28 days, calculated on the total cross sectional area of the pile shaft.

18.4 Lengths and Tolerances

The Contractor shall determine the approximate lengths of piles by examination of the available geotechnical information.

In case the available geotechnical information does not describe the ground conditions to a sufficient depth to ensure safety, additional soil investigations shall be carried out by the Contractor to the Engineer's approval.

Piles shall be constructed within the following tolerances:

- in plan, at the working level of the piling rig 0.15 × B in any direction from the designed position; B = pile dimension (diameter or side);
- 1 in 75 from the vertical for a vertical pile;

The cross-sectional dimensions of the pile shall not be less than those proposed by the Contractor nor shall they exceed them by more than 0.015 × B (B = pile dimension, diameter or side).

No face of a pre-cast pile shall deviate by more than 6 mm from a straight edge 3 m long joining two points on that face, nor shall the centre of area of the pile at any cross section deviate more than 1/500 of the pile length from a line joining the centres of area of the ends of the pile.

18.5 Sequence for Constructions

The sequence of construction of piles shall be to the approval of the Engineer and shall be arranged to minimise the vertical and lateral displacement of piles already installed. Levels of the tops of adjacent piles or the structures founded upon them or any other structures shall be measured at intervals while a pile is being installed. Driven piles which have risen, shall be re-driven or forced down to the original resistance.

18.6 Driving Piles

The Contractor shall submit for the Engineer's approval, details regarding the suitability, efficiency and energy of his driving equipment.

Pre-cast concrete piles shall not be driven until the concrete has achieved the specified characteristic strength.

Cast-in-situ piles driven with steel casing shall be bottom driven using a casing that shall not distort or buckle during driving. Concrete casing shall be driven on the pile shoe using a mandrel.

Each pile shall be driven continuously until the approved set and/or depth has been reached except that the Engineer may permit the suspension of driving if he is satisfied that the rate of penetration prior to cessation of driving will be substantially re-established on its resumption or if he is satisfied that the suspension of driving was beyond the control of the Contractor.

A follower (long dolly) shall not be used except with the approval of the Engineer who will then require the set to be revised to take into account the reduction in the effectiveness of the hammer blow.

The final set of each pile shall be recorded either as the penetration in millimetres per 10 blows or as the number of blows required to produce a penetration of 25 mm.

When a final set is being measured the following requirements shall be met:

1. The exposed part of the pile shall be in good condition without damage or distortion;
2. The dolly and packing, if any, shall be in sound condition;
3. The hammer blow shall be in line with the pile axis and the impact surfaces shall be flat and at right angles to the pile and hammer axis;
4. The hammer shall be in good condition, delivering adequate energy per blow and operating correctly; and
5. The temporary compression of the pile shall be recorded, if required by the Engineer.

The Contractor shall give adequate notice and provide all facilities to enable the Engineer to check driving resistances. A set for purposes of the Contract shall only be taken in the presence of the Engineer unless otherwise agreed.

At the start of the work and in new areas or sections, a detailed driving record shall be obtained over the full length of the first pile and during the last 3 m of driving of subsequent piles to establish the behaviour of the piles.

The Contractor shall inform the Engineer without delay if an unexpected change in driving characteristics is noted. A detailed record of driving resistance over the full length of the nearest available pile shall be taken.

Re-drive checks, if required, shall be carried out by a procedure to be agreed by the Engineer.

Piles shall be driven in an approved sequence to minimise the detrimental effects of heave and lateral displacement of the ground.

Measurements shall be taken to determine the movement of ground or any pile resulting from the driving process when required by the Engineer.

Where piles have risen as a result of driving adjacent piles, the Contractor shall submit to the Engineer his proposals for correcting detrimentally affected piles and for avoidance or control of heave effects in subsequent work

Jetting may be carried out only when approved by the Engineer and the Contractor shall submit detailed proposals and it shall not normally be undertaken over the last 3 m of penetration.

18.7 Repair and Lengthening of Piles

In preparation for repairing the head of a pile, the concrete shall be cut off square at sound concrete to expose the reinforcement and all loose particles shall be removed by wire brushing followed by washing with water.

If the pile is to be subjected to further driving the head shall be replaced with concrete of an approved class.

If the pile has been completely driven but the sound concrete is below cut-off level, the pile shall be made good to cut-off level with concrete of a class not inferior to that of the concrete of the pile.

In preparation for lengthening a normal reinforced pile, the concrete shall be cut off square to expose a sufficient length to ensure that the full strength of the bars will be developed across the joint.

For lap or splice joints, sufficient link bars shall be provided to resist eccentric forces.

If the pile is to be subjected to further driving the additional length shall be of an approved grade of concrete.

Other methods of lengthening shall be subject to approval by the Engineer.

Repaired or lengthened piles shall not be driven until the added concrete has reached the specified characteristic strength of the concrete of the pile.

18.8 Reinforcement

Unless otherwise required by the design, cast in situ piles shall be reinforced over the whole of their length.

The minimum longitudinal reinforcement shall be 1.0% of the gross concrete area in the top 3 m of the pile and 0.8% of the gross concrete area in the remainder of the pile. Lateral ties shall be provided to maintain the alignment of the longitudinal reinforcement at centres not closer than 150 mm.

Unless otherwise required by the design, reinforcement in pre-cast concrete piles shall comply with the following minimum requirements:

Area of longitudinal reinforcement of 12 mm diameter minimum shall be at least 1% of the gross concrete area (cast in-situ and pre-cast concrete piles);

Lateral reinforcement shall be in the form of hoops or links not less than 6 mm diameter. Over a distance of 3 times the width of the pile measured from each end of the pile the volume of lateral reinforcement shall be not less than 0.6% of the gross volume. In the body of the pile, the lateral reinforcement shall not be less than 0.4% spaced at not more than half the width of the pile. The transaction between the close spacing near the ends and the maximum spacing shall be made gradually over a length equal to 3 times the width.

Piles of rectangular cross section shall have a minimum of 4 longitudinal reinforcement bars and piles of circular cross section shall have a minimum of 6 longitudinal reinforcement bars. Bars shall be 12 mm diameter minimum. The main longitudinal bars shall be level at the top of the pile and fit tightly into the shoe if one is used.

Hoops and links shall fit tightly against longitudinal bars and be bound to them by welding or soft iron wire with the free ends turned inwards. The longitudinal bars shall be held apart by spreader forks not more than 1.5 m apart.

The main longitudinal reinforcing bars in piles not exceeding 12 m in length shall be in one continuous length unless otherwise required. In piles exceeding 12 m in length, joints will be permitted in main longitudinal bars at 12 m nominal intervals. Joints in adjacent bars shall be staggered at least 1 m apart along the length of the pile. Joints shall be such that the full strength of the bar is effective across the joint.

The cover to the outermost reinforcement, including binding wire shall not be less than 60 mm measured to the inside of the casing. Lap or splice joints shall be provided with sufficient link bars or other elements to resist eccentric forces. Laps shall have a minimum length of 40 times the diameter of the main longitudinal reinforcement.

Main longitudinal reinforcement shall project a minimum of 40 times the bar diameter above the cut-off level of the pile. For pre-cast piles, compliance with this requirement will necessitate breaking down of the pile head after driving.

18.9 Pile Shoes

Driven piles shall be provided with flat or pointed co-axial shoes of cast iron if driving is liable to damage the concrete at the tip of the pile.

18.10 Records

The Contractor shall maintain a complete record of all piling works that shall include the following where relevant:

- pile type and number
- nominal diameter or dimension, pile length
- date of casting and date driven
- depth from ground level to toe of pile
- depth from ground level to bearing stratum
- set of pile or pile tube in mm per 10 blows or blows per 25 mm of penetration for first piles in new areas or sections, sets taken at intervals during the last 3 m of driving for subsequent piles
- final set, weight and drops of hammer
- details of any obstructions observed.
- ground level at pile position at commencement of pile installation
- pile cut-off level
- length of temporary or permanent casing
- length and details of reinforcement
- concrete mix
- volume of concrete supplied to pile where this can be measured in practice

All records shall be accurately kept in duplicate as the work proceeds and one copy shall be handed to the Engineer at the completion of each day's work.

18.11 Pre-cast Reinforced Concrete Piles

Pre-cast reinforced concrete piles shall be designed cast and cured to develop the strength necessary to withstand the transporting, handling and driving stresses without damage. Square piles shall have chamfered corners.

18.12 Cast-In-Situ Piles

18.12.1 Driven or Bored Cast-in-situ Piles

Driven or bored cast-in-situ piles shall comprise a temporary or permanent casing of steel, or a permanent casing of pre-cast concrete, augured or driven to a set and completely filled with dense concrete reinforced with steel bars.

All joints in the casing and between the casing and shoes, where applicable, shall be watertight during driving and completion of driven cast-in-situ piles.

Drilling mud shall not be used unless otherwise approved by the Engineer.

18.12.2 Casing for Cast-in-situ Piles

The casing shall be suitable for the method of installation and for the purpose of jointing piles. The casing may either be permanent or temporary.

Steel casing shall be delivered to Site in as a long length as can be conveniently handled. Ends shall be prepared for butt-welding and designed to maintain true alignment of the pile.

Joints between steel casings shall be made by butt-welding so that the full strength of the original section is developed. Welded joints shall be watertight.

18.12.3 Concreting Cast-in-situ Piles

Concrete in cast-in-situ piles shall be in accordance with the requirements. The slump for the concrete shall be agreed with the Engineer prior to concreting preliminary test piles. Concrete filling in cast-in-situ piles shall be placed continuously. Removal of temporary casings must be complete before the placed concrete loses its workability to ensure that the concrete is not lifted, but placing of concrete shall keep in advance of withdrawal of casing to prevent necking.

Pile heads shall be stripped down and bonded into the pile caps as specified for pre-cast concrete piles.

18.13 Testing of Piles

18.13.1 Testing frequency

Pile testing shall be undertaken at the following frequencies:

- Preliminary Pile Tests
  - The Contractor shall undertake one static preliminary load test for each type of pile to be constructed.
  - The Contractor shall identify the ground and groundwater conditions in different areas to be piled and shall undertake additional preliminary pile tests for each characteristic set of ground conditions.
- Static Load Testing of working piles –2%
- Dynamic Load Testing of working piles – 10%
- Impulse Response or Sonic Echo Integrity Testing of working piles – 100%
- Installation of tubing for cross-hole sonic logging – 100% of cast in situ piles

- Cross-hole sonic logging – a minimum of 20% of cast in situ piles. Additional tests may be required if the impulse response or sonic echo results are inconclusive).

18.13.2 Method Statements

The Contractor shall provide a method statement for the pile testing that includes details of the following general matters:

- Method of test
- Number, Type and Location of elements to be tested
- Age of piles at the time of testing
- Method of preparing the pile for testing
- Safety and Supervision of the testing organization including details of qualifications and accreditation
- Method of interpreting the test data
- Details of reports to be produced
- Timing of submission of testing reports

In addition, the method statement shall include details of the following:

- Integrity Testing
  - Confirmation of the testing method and identification of those piles for which cross-hole sonic logging will be undertaken
- Dynamic testing
  - Confirmation of the testing method
  - Special Requirements for pile testing equipment and arrangement
  - Interface with temporary works
  - Details of the test pile head / cap
  - Details of the proposed measuring devices and arrangement
  - Details of the proposed hammer or propellant
  - Specific details of the analyses to be undertaken
- Static testing
  - Loads to be applied for each test stage and criteria for length of each test stage
  - System for providing reaction e.g. reaction piles, ground anchors, kentledge etc.
  - Maximum reaction capacity
  - Identification of tension or compression test
  - Special materials e.g. low friction sleeving
  - Special requirements for pile testing
  - Pile installation criteria
  - Details of the proposed measuring devices and arrangement
  - Interface with temporary works

- Work required at the pile head upon completion of the test

18.14 Preliminary Test Piles

After the Engineer has approved the Contractor's proposals and calculations for the piling system, preliminary test piles shall be constructed to the approval of the Engineer. Preliminary test piles shall be constructed and tested prior to the commencement of any piling activity.

These shall be loaded to two and half times the working load to prove the design and system and to demonstrate that the safe load requirements can be achieved by the piling method proposed.

The preliminary test piles shall be located in places proposed by the Contractor and approved by the Engineer.The Contractor shall construct and test adequate preliminary test piles as per proposed design, in each zone/area where a major structure or facility is being sited; where a change in loading is proposed; and where the ground conditions change within the Site. The Engineer shall be given at least 48 hours notice of commencement of construction of the preliminary pile which is to be test-loaded.

The preliminary test piles shall be constructed and installed in a manner similar to that to be used for the construction of the working piles by the use of similar equipment and materials. Any variation will only be permitted with the prior approval of the Engineer.

For the preliminary piles that are to be test loaded, a detailed record of the progress during construction/installation shall be made and submitted to the Engineer daily.

The pile shafts shall be terminated at the normal cut-off level or at some other level as required by the Engineer.

The pile shafts shall be extended where necessary above the cut-off level of working piles so that gauges and other apparatus to be used in the testing process will not be damaged by water or falling debris and to permit exposure of the reinforcement.

Where the pile shaft is extended above the cut-off level of the working piles in soils that would influence the load bearing capacity of the pile, a sleeve shall be left in place during testing to eliminate friction that would not arise in working piles.

If the cut-off level is below ground level and the shaft is not extended and there is a risk of the borehole collapsing, a sleeve shall be left in place or inserted above the pile shaft or other means satisfactory to the Engineer shall be employed. Adequate clearance shall be given between the top of the pile shaft and the bottom of the sleeve to permit unrestricted movement of the pile.

For a pile that is tested in compression, the pile head or cap shall be formed to give a plane surface, which is normal to the axis of the pile and sufficiently large to accommodate the loading and settlement measuring equipment. The pile head or cap shall be adequately reinforced or protected to prevent damage due to the concentrated application of load from the loading equipment.

The pile cap shall be concentric with the test pile and the joint between the cap and the pile shall have a structural strength equivalent to that of the pile.

A sufficient clear space shall be made under any part of the cap projecting beyond the section of the pile so that at the maximum anticipated settlement, load is not transmitted to the ground except through the pile.

The connection between the pile and the loading equipment shall be constructed in such a manner as to provide strength equal to the maximum load that is to be applied to the pile during the test with an appropriate factor of safety on the structural design.

If the preliminary test pile fails to meet the requirements, the piling system proposed will be considered unsatisfactory. The Contractor shall then submit revised proposals and calculations for the approval of the Engineer. Unless otherwise agreed by the Engineer, any test pile that has failed the preliminary test will be rejected and the Engineer and the Contractor shall provide one or more further test piles and tests to prove his modified system.

18.15 Pile load tests

18.15.1 General

Pile load tests shall be carried out in the following situations:

- when using a type of pile or installation method that is outside comparable experience and which has not been tested under comparable soil and loading conditions;
- when using a piling system which is outside the experience of the operatives carrying out the work;
- when the piles will be subject to loading for which theory and experience do not provide sufficient in the design. The pile testing procedure should then provide loading similar to the anticipated loading; and
- when observations during the process of installation indicate pile behaviour that deviates strongly and unfavourable from the behaviour anticipated on the basis of the site investigation or experience when additional ground investigations do not clarify the reasons for this deviation.

Load test can be as a static test or a dynamic test.

If one pile load test is carried out, it shall normally be located where the most adverse ground conditions are believed to occur. If this is not possible, an allowance shall be made when deriving the characteristic value of the bearing resistance.

If load tests are carried out on two or more test piles, the test location shall be representative of the site of the pile foundations, and one of the test piles shall be located where the most adverse ground conditions are believed to occur.

Between the installation of the test pile and the beginning of the load test, adequate time shall be allowed to ensure that the required strength of the pile material is achieved and the pore pressures have regained their initial values.

18.15.2 Static Load Tests

(i) Loading procedure

The pile load test procedure, particularly with respect to the number of loading steps, the duration of the loading steps and the application of load cycles, shall be such that conclusions can be drawn about the deformation behaviour, creep and rebound of a pile foundation from the measurements on the pile. For trial piles, the ultimate loading shall be such that conclusions can also be drawn about the ultimate failure load.

Devices for the determination of forces, stresses or strains and displacements shall be calibrated prior to the test.

The direction of the applied force to compression or tension pile tests shall coincide with the longitudinal axis of the pile.

In general, pile load tests for the purpose of designing a tensile pile foundation should be carried out to failure. Extrapolation of the load-displacement graph for tension tests should normally not be used, especially in the case of transient loading.

(ii) Trial piles

The number of trial piles required to verify the design shall be selected on the following aspects:

- the ground conditions and their variability across the site;
- type of structure;
- documented evidence of the performance of the same type of pile in similar ground conditions; and
- the total number and types of piles in the foundation design.

The ground conditions at the test site shall be investigated thoroughly. The depth of borings or files tests shall be sufficient to ascertain the nature of the ground both around and beneath the pile tip. It shall include all strata likely to contribute significantly to pile deformation behaviour, at least five times the diameter beneath the pile tip, unless sound rock or very hard soil is found at a lesser depth.

The method used for installation of the trial piles shall be fully documented.

(iii) Working piles

The number of working pile load tests shall be selected on the basis of the recorded findings during construction.

The load applied to working test piles shall be at least equal to the design load governing the design of the foundation.

18.15.3 Dynamic Load Tests

(i) General

The results of dynamic load tests may be used for design provided an adequate site investigation has been carried out and the method has been calibrated against static load tests on the same type of pile of similar length and cross-section, and under comparable soil conditions.

Dynamic test results shall always be considered in relation to each other.

Dynamic load tests may be used as an indicator of the consistency of the piles and to detect weak piles (integrity testing).

In a dynamic load test the pile is instrumented with accelerometers and strain gauges within two pile diameters of the top of the pile.

The gauges are connected to a recording and data processing device. During blows on the pile signals from the gauges are recorded and processed for assessment of pile bearing capacity. The data processing will be of two kinds: one simple (CASE or likewise method) and one more exact method based on signal matching (CAPWAP or likewise program).

In the CASE method or likewise the following data shall be registered and reported:

- bearing capacity;
- toe resistance and skin friction;
- maximum compression stress, acceleration, velocity and displacement;
- maximum tension stress in pile;
- pile structural integrity; extent and location of damage;
- maximum energy transferred to the pile;
- blows per minutes for hammer check;
- blow number;
- input and reflection of force, velocity, upward and downward force waves; and
- load versus deflection of cushions and of pile toe bearing'

CAPWAP or likewise program determines that set of soil resistance parameters which produces the best match between measured and computed pile top force and velocity. After CAPWAP analysis, additional information produced than from CASE is:

- deformation properties, ultimate capacities and soil damping parameters for each soil segment of normally 1 m length;
- unit skin friction for each segment and end bearing;
- maximum of tension and compression forces and stresses;
- pile structural damping;
- dynamic pile toe displacement; and
- graph on bearing capacity and pile stresses versus blow count.

An introductory program (WEAP) can be utilised before pile driving to assess preliminary combinations of sets and bearing capacities for specified pile driving equipment and soil conditions.

Well-experienced experts shall carry out the data processing.

(ii) Dynamic Load Test Procedure

The Contractor shall notify the Engineer at least two weeks prior to dynamic testing

The Contractor shall submit a qualified testing consultant and his experience to the Engineer for approval.

The Engineer shall determine if the test is to be performed or if some pile waiting periods at the proposed site is required before a decision will be made.

The Engineer will establish a date for the tests and will also determine the location of all piles to be dynamically load tested.

(iii) Dynamic Load Test Procedure on Driven Piles

The Contractor shall supply all personnel and equipment needed to strike the test pile with the hammer.

The Contractor shall provide the hammer (drop, diesel, etc) or the crane to lift a steel ram weight by a single non-twisting cable and be able to strike the pile top by means of full-gravity-fall.

The testing consultant personnel will drill holes into the pile to be tested so that transducers (two accelerometers and two strain gauges) can be attached.

When the transducers have been placed in position and the recording and processing equipment has been made ready to receive the acceleration and strain measurement, the Contractor shall strike the driven pile with the hammer as many times as is required to obtain adequate measurements as determined by the Engineer.

The Engineer may ask the Contractor to provide surveying instrument to monitor the pile set after each strike.

After the dynamic testing measurements have been obtained and analysed the Contractor shall prepare and submit a complete report to the Engineer.

(iv) Dynamic Load Test Procedure on Bored Piles.

The Contractor shall prepare the pile top and, if necessary, improve the structural integrity of the pile top to resist a sharp impact force. All loose concrete at the pile top shall be removed. The top portion of the bored pile shall be extended a length of at least two times the diameter of the bored pile with the same diameter as the bored pile. The extended portion of the bored pile shall be cast with concrete having a minimum compressive strength of 40 MPa.

Additional shear reinforcement such as spiral hoops at the pile top is recommended for the impact force. The Contractor shall provide the windows for the installation of instruments by means of burring 0.35×0.35 m² to the steel casing using a cutting torch.

On top of the bored pile, a timber cushion shall be placed under a steel plate to act as a hammer cushion. Adhesive material may be applied between the pile top and the timber.

The Contractor shall provide an additional steel casing inserted into the pile top. This casing shall act as a guide for the steel ram weight, having a length not less than the summation of the drop height and the length of the steel ram weight. A vibrating hammer shall be used to secure and stabilise the steel casing.

The Contractor shall supply all personnel and equipment needed to strike the test pile with the steel ram weight. The Contractor shall provide a crane which has the capability to lift the steel ram weight by a single non-twisting cable and be able to strike the pile top by mean of full-gravity-fall.

The testing consultant personnel will drill holes in the windows of the left-in-place steel casing into the pile to be tested so that transducers (two accelerometers and two train gauges) can be attached.

When the transducers have been placed in position and the recording and processing equipment has been made ready to receive the acceleration and strain measurement, the Contractor shall strike the driven pile with the hammer as many times as is required to obtain adequate measurements as determined by the Engineer.

The Engineer may ask the Contractor to provide surveying instrument to monitor the pile set after each strike.

After the dynamic testing measurements have been obtained and analysed the Contractor shall prepare and submit a complete report to the Engineer.

(v) Load Test Report

The Contractor shall, within 24 hours of the completion of the tests, submit to the Engineer a complete record of each pile test. Where appropriate, this report shall include:

- a description of the site;
- the ground conditions with reference to ground investigations;
- the pile type;
- a description of the loading and measuring apparatus and the reaction system;
- calibration documents of the load cells, the jacks and the gauges;
- the installation record of the test piles;
- photographic records of the pile and the test site;
- test results in numerical form;
- time settlement plots for each applied load when a step loading procedure is used;
- the measured load-settlement behaviour; and
- justification of the reasons for any departures from the recommendations.

18.15.4 Piles in Compression

(i) Ultimate Bearing Resistance from Static Pile Load Tests

Trial piles to be tested shall be installed in the same manner as the piles that will form the foundation and shall be founded in similar stratum.

In the case of a very large diameter pile, it is often impractical to carry out a load test on a full size trial pile. Load tests on smaller diameter trial piles may be considered provided that:

- the ratio of the trial pile/working pile diameter is not less than 0.5;
- the smaller diameter trial piles are fabricated and installed in the same way as the piles used for the foundations; and
- the trial pile is instrumented in such a manner that the base and shaft resistance can be derived separately from the measurements.

In the case of a pile foundation subjected to down drag, the pile resistance at failure or at a displacement which equals the criterion for the verification of the ultimate limit state determined from the load test results shall be corrected by subtracting the measured or the most unfavourable design positive skin friction force in the compressible stratum from the forces measured at pile head.

When deriving the ultimate characteristic bearing resistance Rcc from values Rcms measured in one or several static pile load tests, an allowance shall be made for the variability of the ground and the variability of the effect of pile installation. As a minimum, both conditions of the table below shall be satisfied using the equation:

$$R_{cc} = \frac{R_{cms}}{\gamma_{ns}}$$

- Factors γ_{ns} to derive R_{cc}:

Number of load tests	1	2	>2
γ_{ns} on average R_{cms}	1,5	1,35	1,3
γ_{ns} on lowest R_{cms}	1,5	1,25	1,1

In order to derive the ultimate design bearing resistance, the characteristic value, Rcc, should be divided into components of base resistance, Rcbc, and shaft resistance, Rcsc, such that:

$$R_{cc} = R_{cbc} + R_{\mathrm{csc}}$$

The design bearing resistance, Rd, shall be derived from

$$R_{cd} = \frac{R_{cbc}}{\gamma_{bs}} + \frac{R_{\mathrm{csc}}}{\gamma_{ss}}$$

whereγbs and γss are taken from the table below.

Values of γbs, γss and γts:

Component factors	γ_{bs}	γ_{ss}	γ_{ts}
Driven piles	1,3	1,3	1,3
Bored piles	1,6	1,3	1,5
CFA piles	1,45	1,3	1,4

Normally the load test only provides the pile load test versus settlement and time versus settlement diagrams without distinction between point and shaft resistance. Therefore, it is often not possible to distinguish between partial factors for the assessment of the design value of base resistance and shaft resistance. Instead a partial factor on the ultimate characteristic pile resistance Rcc may be taken as the γts values given in the table above.

(ii) Ultimate Bearing Resistance from Pile Driving Formulae

If pile-driving formulae are used to assess the ultimate bearing resistance of individual compression piles in a foundation, the validity of the formulae shall have been demonstrated by previous experimental evidence of good performance or static load tests on the same type of pile of similar length and cross-section and in the similar ground conditions.

Pile driving formulae shall only be used if the stratification of the ground has been determined.

In the design, the number of piles to be re-driven shall be specified. If re-driving gives lower results, these shall be used as the basis for ultimate bearing resistance assessment. If re-driving gives higher results, these may be taken into consideration.

Re-driving should usually be carried out in silt soils, unless local comparable experience has shown it to be unnecessary.

(iii) Ultimate Bearing Resistance from Dynamic Load Tests

Dynamic load tests and their evaluation can be used to assess pile-bearing resistance of individual compression piles. The validity of the evaluation shall have been demonstrated by previous evidence of acceptable performance or static load tests on the same pile type of similar length and cross-section and in similar soil conditions. The input energy level during the dynamic load testing shall be high enough to allow for an appropriate interpretation of the pile capacity at a correspondingly high enough strain level.

When deriving the ultimate characteristic bearing resistance Rcc from values Rcmd measured in two or several dynamic pile load tests, an allowance shall be made for the variability of the ground and the variability of the effect of pile installation. As a minimum, both conditions of the4 table below shall be satisfied using the equation:

$$R_{cc} = \frac{R_{cmd}}{\gamma_{nd}}$$

Factors γnd to derive Rcc:

Number of load tests	2	4	>4
a) γ_{nd} on average R_{cmd}	1,5	1,35	1,3
b) γ_{nd} on lowest R_{cmd}	1,5	1,25	1,1

In order to derive the ultimate design bearing resistance, the characteristic value, Rcc, should be divided into components of base resistance, Rcbc, and shaft resistance, Rcsc, such that

$$R_{cc} = R_{cbc} + R_{\text{csc}}$$

The design bearing resistance, Rcd, shall be derived from

$$R_{cd} = \frac{R_{cbc}}{\gamma_{bd}} + \frac{R_{\text{csc}}}{\gamma_{sd}}$$

whereγbd and γsd are taken from the table below.

Values of γbd, γsd and γtd

Component factors	γ_{bd}	γ_{sd}	γ_{td}
Driven piles	1,4	1,4	1,4
Bored piles	1,7	1,4	1,6

In case Rcbc and Rcsc are not known the design bearing resistance Rcd is derived from

$$R_{cd} = \frac{R_{cc}}{\gamma_{td}} .$$

18.15.5 Piles in Tension

(i) Ultimate tensile resistance from static pile load tests

Pile load tests to determine the ultimate tensile resistance Rtc of an isolated pile shall be carried out in accordance with Clause 18.13.

When deriving the ultimate characteristic resistance Rtc from values Rtm measured in one or several static pile load tests, an allowance shall be made for the variability of the ground and the variability of the effect of pile installation. As a minimum, both conditions of the table below shall be satisfied using the equation:

$$R_{tc} = \frac{R_{tms}}{\gamma_{nt}} .$$

Factors γnt to derive Rtc:

Number of load tests	1	2	>2
a) γ_{nt} on average R_{tms}	1,5	1,35	1,3
b) γ_{nt} gnt on lowest R_{tms}	1,5	1,25	1,1

Normally when piles are loaded in tension, more than one pile shall be tested. In the case of a larger number of tension piles, at least 2% shall be tested.

The design tensile resistance, Rtd, shall be derived from

$$R_{td} = \frac{R_{tc}}{\gamma_m}$$

Where γ_m= 1.6.

18.15.6 Supervision of construction

A pile installation plan shall be the basis for the construction work.

The plan should give the following design information:

- the pile type with designation if standardised or technical approval otherwise;
- the location and inclination of each pile and tolerances on position;
- pile cross-section;
- pile length;
- number of piles;
- required pile load carrying capacity;
- pile toe level or the required penetration resistance;
- installation sequence;

- known obstructions; and
- any other constraints on piling activities.

The installation of all piles shall be monitored and records shall be made at site and as the piles are installed. A record signed by the supervisor of the work and the pile manufacturer shall be kept for each pile.

The record for each pile shall include the following, where appropriate:

- pile type and installation equipment;
- pile number;
- pile cross-section, length and reinforcement;
- data and time of installation (including interruptions to the construction process);
- concrete mix, volume of concrete used and method of placing for cast-in-situ piles;
- pumping pressures of the grout or concrete, internal and external diameters, pitch of screw and penetration per revolution (for continuous flight auger piles or other injection piles);
- for driven piles, the values of driving resistance measurements such as weight and drop or power rating of hammer, blow frequency and number of blows for at least the last 0.25 m penetration;
- the power take-off of vibrators (where used);
- the torque applied to the drilling motor (where used);
- for bored piles, the strata encountered in the borings and the condition of the base, if the performance of the base is critical;
- obstructions encountered during piling; and
- deviations of positions and directions and as-built elevations.

Records shall be kept for period completion of the contract. As-built record plans shall be compiled after completion of the piling and be kept with the construction documents.

If site observations or inspection of records reveal uncertainties with respect to the quality of installed piles, additional investigations shall be carried out to determine the as-built conditions of the piles and whether remedial measures are necessary. These investigations shall include either re-driving or pile integrity tests, in combination with soil mechanics field tests adjoining the suspected piles and static pile load tests.

Tests shall be used to determine the integrity of piles for which the quality is sensitive to the installation procedures if the procedures cannot be monitored in an alternative reliable way.

Dynamic low-strain integrity tests can be used for a global evaluation of piles that might have severe defects or that may have caused a serious loss of strength in the soil during construction. Since defects like insufficient quality of concrete and thickness of concrete cover, affecting the long-term performance of a pile, often cannot be found by dynamic tests, other tests such as sonic tests, vibration tests or coring may be needed in supervising the execution.

19.0 Materials, Workmanship and Design

19.1 Introduction

This section sets out the general standards of materials, workmanship and design to be used by the Contractor for the manufacturing and installation of the Mechanical Works, and reference to any specific material or equipment does not necessarily imply that such material or equipment is included in the Works.

All component parts of the Works shall, unless otherwise specified, comply with the provisions of this section or be subject to the approval of the Engineer.

19.2 Castings

The structure of the castings shall be homogeneous and free from non-metallic inclusions and other defects. All surfaces of castings which are not machined shall be smooth and shall be carefully fettled to remove all foundry irregularities (special attention should be given to flanged faces).

Minor defects not exceeding 2.5 mm in depth or 12% of total metal thickness, whichever is less and which will not ultimately affect the strength and serviceability of the casting, may be repaired by approved welding techniques and subsequent heat treatment for stainless steel. The Engineer shall be notified of larger defects and no unauthorised repair welding of such defects shall be permitted. The Engineer shall be invited to perform FAT of castings.

If the removal of metal for repair should reduce the stress resisting cross-section of the casting by more than 25%, or to such an extent that the computed stress in the remaining metal exceeds the allowable stress by more than 25%, then that casting shall be rejected.

Castings repaired by welding for major defects shall be stress-relieved after such welding, or as otherwise instructed in writing by the Engineer.

Non-destructive tests may be required for any casting containing defects whose effect cannot otherwise be established or to determine that repair welds have been properly made.

Unless otherwise specified, castings shall be produced to the following standards or equal:

1. Grey-iron	IS 3005 Part 1 to 4
2. Carbon steel	IS 1030:1998
3. Stainless steel	IS 3038:2006
4. Copper and copper alloy	IS 3288:1986 Part 1 to 8

19.3 Forgings

All major stress-bearing forgings shall be made to a standard specification which shall be submitted to the Engineer for approval before work is commenced. They shall be subject to internal examination and non-destructive tests for the detection of flaws and shall be heat treated for the relief of residual stresses. The name of the manufacturer and particulars of the heat treatment proposed for each such forging shall be submitted to the Engineer.

19.4 Non-metallic Materials

Fabrics, cork, paper and similar materials which are not subsequently to be protected by impregnation, shall be treated with an approved fungicide. Sleeving and fabrics treated with linseed oil varnish will not be permitted.

The use of organic materials shall be avoided as far as possible but where these have to be used they shall be treated to make them fire resistant.

The use of wood shall be avoided unless specifically approved by the Engineer. If used, woodwork shall be thoroughly seasoned teak or other approved hardwood which is resistant to fungal decay and free from blemishes. All woodwork shall be treated to protect it against damage by fire, moisture, fungus, vermin, insect, bacteria or chemical attack. All joints in woodwork shall be dovetailed or tongued and pinned. Metal fittings on wood shall be of non-ferrous material. Adhesives shall be specially selected to ensure the use of types that are impervious to moisture and fungal growth. Synthetic resin cement shall be used for joining wood.

19.5 Nuts, Bolts and Washers

Nuts, bolts, studs and washers for incorporation in the Works shall conform to IS 10238: 2001, IS 1363: 2002, IS 1364: 2002, IS 1367, IS 2016: 1967, IS 3757: 1985 and IS 3138: 1966.

Nuts and bolts for pressure fittings shall be of the best quality steel machined on the shank and under the head and nut. Fitted bolts shall be a light driving fit in the reamed holes they occupy, shall have the screwed portion of such a diameter that it will not be damaged in driving and shall be marked in a conspicuous position to ensure correct assembly at site.

Washers, locking devices and anti-vibration fittings shall be provided where necessary to ensure that no bending stress is caused in the bolt. Two washers shall be supplied and fitted with each bolt.

The bolts should be of sufficient length that between two and four threads shall show past the nut when tightened (including allowance for the washer).

Before tightening, graphite grease or PTFE tape shall be applied on the bolts.

When there is a risk of corrosion, bolts and studs shall be designed so that the maximum stress in the bolt does not exceed half the yield stress of the material under all conditions.

Installation of high strength friction grip bolts in joints shall comply with IS 4000:1992. The diameter of the bolt holes must not be more than 1.5 mm larger than the nominal diameter of the bolt. All contact surfaces in a connection including those associated with the nut heads, nut in washers, shall be free of scale, burrs, dirt and other foreign matter tending to inhibit uniform sealing of the joint components/ nuts and washers need not be removed.

When nut or bolts heads bear on tapered/angled surfaces, corresponding levelled or tapered or angled washers/shims shall be provided.

19.6 Fixings

The Contractor shall supply all anchor bolts, holding down bolts, fixing bolts, washers, nuts, straps, supports, brackets, spacers and fixtures, which are necessary for the satisfactory installation and erection of the Works.

The Contractor shall make all holes required for fixings before final plastering and decorating is carried out.

19.7 Fixing in Concrete

Where items of Plant are required to be fixed in concrete, the Contractor shall be responsible for its positioning. This shall entail shimming, temporary fixing and final checking as necessary to satisfy himself of its correctness.

19.8 Threads

All threads shall be of preferred metric sizes with the standard coarse form of medium fit to IS 4218:2001 Part 1 to 4, IS 14962:2001 Part 1 to 5, BS 3643:2007 except for special applications for which the metric fine thread may be utilised, or other thread forms subject to the approval of the Engineer.

19.9 Welding

19.9.1 General

All structural, shop fabricated and on site welding of steel shall be metal arc unless otherwise specified and shall comply with the requirements of IS 816:1969. All welds shall be continuous. When tack welds and temporary attachments are used they shall be incorporated in accordance with the procedures specified in IS 816:1969.

All welding electrodes for use with carbon or carbon manganese steel shall comply with the requirements of IS 15769:2008, including the requirements for storage prior to use.

The welding of metals other than mild steel by oxyacetylene or other approved methods shall be carried out in accordance with the appropriate Indian Standard.

Welding of pipework shall be in accordance with IS 10234:1982 or IS 11790:1986 to suit the pressure rating of the pipes.

19.9.2 Standards

Site welding shall not be commenced without the prior approval of the Engineer. The Contractor in requesting approval shall provide full details including safety precautions suitable for the location of the welding.

Welding shall be in accordance to the following Indian standards as applicable.

Standard	Description
IS 816	Code of practice for metal arc welding for general construction in mild steel
IS 822	Code of practice for Inspection of welds
IS 1024	Code of practice for welding in bridges and structures subject to dynamical loading
IS 819	Code of practice for resistance spot welding for light assemblies in mild steel
IS 1261	Code of practice for seam welding in mild steel
IS 1323	Code of practice for oxyacetylene welding for Structural Work in mild steel

For welding any particular type of joint, welders shall submit evidence acceptable to the Engineer of having satisfactorily completed appropriate tests as described in the following relevant Indian standards.

Standard	Description
IS 7307	Approval tests for welding procedures Part 1 fusion welding of steel
IS 7310	Approval tests for welders working to approved Welding procedures

Special standards are required for welding aluminium and stainless steel.

19.9.3 Welding Consumables

Covered electrodes shall conform to IS 814:2004 or IS 1395:1982 as appropriate.

Filler rods and wires for gas welding shall conform to IS 1278:1972.

The bare wire electrodes for submerged arc welding shall conform to IS 7280:1974. The combination of arc and flash shall satisfy the requirements of I.S. 3613:1974.

The filler rods and bare electrodes for gas shielded metal arc welding shall conform to IS 6419:1971 and IS 6560:1996 as appropriate.

19.9.4 Size of Electrode Runs

The maximum gauge of the electrodes for welding any work and the size of run shall be based on the following table.

Average thickness of plate or section	Maximum gauge or diameter of electrodes to be used
Less than 3/16"	10 SWG
3/16" and above but less than 5/16"	8 SWG
5/16" and above but less than 3/8"	6 SWG
3/8" and above but less than 5/8"	4 SWG
5/8" and above but less than 1"	5/16"dia
1" and above thick section	3/8" dia

Note: On any straight weld the first run shall not ordinarily be deposited with a larger gauge electrode than No. 8 SWG For subsequent runs the electrode shall not be increased by more than two electrode sizes between consecutive runs.

19.9.5 Welding Contractors

The contractor shall ensure that each welding operator employed on fabrication or erection is an efficient and dependable welder, who has passed qualifying tests for the types of welds to be used. Sample test shall have to be given by the contractor to the entire satisfaction of the Engineer.

Welding shall be carried out only under the direction of a competent supervisor.

19.9.6 Welding Procedure

Welding procedure specifications shall be prepared according to IS 2825:1969 and submitted to the Engineer. They shall detail steel grades, joints design and material thickness, welding processes, consumables, principal welding positions, working/preheating temperature and post-weld heat treatment. No alterations shall be made to any previously approved procedures without the approval of the Engineer.

All welding procedures shall be arranged to suit the details of joints as designed and the position in which the welding is carried out shall be such as to ensure that the weld is fully and satisfactorily deposited throughout the length of all joints.

Members to be welded shall be securely held in their relative positions during welding, either by jigs or tack welds or any other means and distortion of finished parts shall be minimized.

Welding should be done with the structural steel in a flat position in a down hand manner wherever possible. Adequate steps shall be taken to maintain the correct arc length, rate of travel, current and polarity for the type of electrode and nature of work. Welding plant capacity shall be adequate to carry out the welding procedure laid down. Adequate means of measuring the current shall be available either as a part of the welding plant or by the provision of a portable ammeter. In checking the welding current, a tolerance of 10% or 30 amperes from the specified value whichever is less shall be permitted.

The welding procedure shall ensure that the weld metal can be fully and satisfactorily deposited through the length and thickness of all joints so that distortion and shrinkage stresses are reduced to the minimum and thickness of welds meet the requirements of quality specified.

19.9.7 Preparation of Fusion Faces

Profiles of fusion faces may be prepared by shearing, chipping or gas cutting. In all cases, the faces should be dressed by chipping, filing or grinding and made regular.

Each lead of metal shall have slag removed by light hammering and wire brushing before the next lead is deposited. The weld must show a good, clean contour and on a cut specimen, good fusion with the parent metal. Before applying paint, the weld shall be carefully chipped and wire-brushed.

Fusion faces shall be cut by steering machine or gas cutting and later dressed by filling or grinding so that they shall be free from irregularities such as would interfere with the deposition of the specified size of weld to cause the defects.

Fusion faces and the surrounding surfaces for a distance of not less than 20 mm shall be free from heavy slag, oil paint or any substance which might affect the quality of the weld or impede the progress of welding. The welding face shall be free of rust and shall have metal shine surfaces.

The parts to be welded shall be brought into as close contact as possible and the gap due to faulty workmanship or incorrect fit up shall not exceed 1.6 mm. If a separation of 1.6 mm or more occurs locally, the size of the fillet weld shall be increased at such position by an amount of equal to the width of the gap.

The parts to be welded shall be maintained to their correct position during welding. They shall be securely held in position by means of tack welds, service bolts, clamps or rings before commencing welding to prevent relative movement due to distortion, wind or any other cause.

19.9.8 Step Back Method

The Step Back Method should be used to avoid distortion. The minimum leg length of a fillet weld as deposited should not be less than the specified size and the throat thickness as deposited should be not less than that tabulated below:

Angle between fusion faces	60º-90º	91º -100º	101º -106º	107º -113º	114º -120º
Throat thickness (mm)	7	6.5	6	5.5	5

In no case should a concave weld be deposited without the specific approval of the Engineer unless the leg length is increased above the specified length so that the resultant throat thickness is as great as would have been obtained by the deposition of a flat.

All welds shall be deposited in a pre-arranged order and sequence taking due account of the effects of distortion and shrinkage stresses.

After making each run of welding, all slag shall be removed and final run shall be protected by clean boiled linseed oil until approved.

The weld metal, as deposited, shall be free from cracks, slag, excessive porosity, cavities and other faults. The weld metal shall be properly fused with the parent metal without overlapping or serious undercutting at the toes of the weld.

The surfaces of the weld shall have a uniform and consistent contour and regular appearance.

In welds containing cracks, porosity or cavities in which the weld metal tends to overlap on the parent metal without proper fusion, the defective portions of the welds shall be out cut and re-welded. Where serious under cutting occurs, additional weld metal shall be deposited to make good reduction.

19.9.9 Welded Joints for Steel Pipelines

Welding of joints in steel pipes shall be carried out manually by the metal arc welding process complying with AWWA Standard C206 and in accordance with IS 816:1969 arc welding, or BS 2633 to suit the pressure rating of the pipework. Before starting the welding of any pipe joints in the Works, the Contractor shall submit for the Engineer approval details of the plant, methods and materials he proposes to use, including make and size of electrodes, number of runs, current strength and arrangements for air testing of individual joints.

Pipework shall be radio-graphed as required in accordance with IS 1182:1983 or BS EN 1435, the technique number to be subject to the approval of the Engineer.

All parts to be welded shall have loose scale, slag, rust, paint and other foreign matter removed by means of a wire brush and shall be left clean and dry. All scale and slag shall be removed from each weld run when it is completed. Pipes manufactured with longitudinal or spiral welds shall be lined up before jointing so that these welds are at least 15° apart around the joint circumference.

Sealing of cable entries shall only take place after the satisfactory testing of joints for which the cable entry is required. Cable entries shall be closed with the screwed plug provided and the plug welded in place. Lining and coating shall be applied to the area of the entry to the same standard as the pipe.

19.9.10 Butt Welded Joints

Unless otherwise agreed by the Engineer, welded joints shall be of the butt welded type. The Contractor must submit his proposals and his welding procedures for butt welding to the Engineer for approval and shall not commence any butt welding jointing work until he receives the Engineers approval.

Butt welded joints shall be single groove or double groove welded and shall be full penetration butt welds. Unless otherwise approved by the Engineer, welds shall be single run welds.

Pipe ends for butt welding shall be plain end pipe in accordance with API Spec 5L (Addendum). They shall be bevelled to an angle of 30° measured from a line drawn perpendicular to the axis of the pipe and with a root face of 1.6 mm ± 0.8 mm. The root face shall be located to suit whether the pipes will be welded from the inside or from the outside.

Any internal backing rings used shall be removed after the welding operation.

19.9.11 Lap Welded Sleeve Joint

Lap welded sleeve type joints shall be welded inside and outside. The internal weld shall be a full depth structural weld, whilst the exterior weld shall be a small fillet weld to seal the joint and to allow gas testing of the joint.

For pipes larger than 900 mm diameter, a triple run convex fillet weld shall be used. For pipes of 900 mm diameter or less, a double run convex fillet weld shall be used.

The minimum length of the fillet, as deposited, is to be equal to the full thickness of the pipe wall. The actual throat depth shall not be greater than 9/10 and not less than 7/10 of the minimum leg lengths as deposited. The depositing of the weld metal shall be carried out in such a manner as to ensure that all the welds have adequate root fusion and are of good clean metal free from cracks, gas holes, slag inclusions and all other impurities. The surface of the weld shall have an even contour with regular finish and shall indicate proper fusion with the parent metal. All slag shall be thoroughly removed after depositing each run of welding by light hammering with a chipping hammer followed by wire brushing. Any welds showing cracks or other cavities or in which the weld metal tends to overlap onto the parent metal without proper fusion or containing any other defects whatsoever shall be cut out and re-welded to the satisfaction of the Engineer.

19.9.12 Lap Welded Collar Joint

Where the Engineer permits two plain-ended pipes to be jointed by a welded collar joint, the gap between the two ends shall not exceed 75 mm. An external steel sleeve collar, of a thickness not less than that of the pipe itself and approximately 300 mm in length, shall be placed centrally over the two ends to be jointed. The end of each pipe shall then be fillet welded to the sleeve collar, inside and outside, in accordance with the above procedure for a lap welded sleeve joint.

19.9.13 Welder Performance Test

The Contractor shall submit for the Engineer's approval, the names of the proposed welders together with evidence that they have passed appropriate qualifying tests and possess certificates from an independent testing authority. Weld specimens from each of the welders shall be submitted for the approval of the Engineer, who may also require satisfactory test welds to be carried out under Site conditions and on materials similar to those for use in the Works. The Contractor shall maintain an up-to-date list of welders that have been approved by the Engineer.

The Contractor shall remove from the approved list any welder whose workmanship is, in the opinion of the Engineer, below a reasonable standard of quality or consistency.

19.9.14 Inspection and Testing

Testing of welded joints shall be done as per relevant Indian standards IS 3600:1985 Part 1 to 2, IS 3600:2009 Part 3, IS 3600: 1984 Part 4, IS 3600:1983 Part 5 to 6, IS 3600:1985 Part 7 to 9, IS 3613:1974, IS 7307:1974 Part 1, IS 2595:2008, IS 4260:1986 or British standards BS Codes BS EN 1321:1997, BS EN 895:1995, BS EN 10208:2009 Part 1 to 2, BS EN 10208-2:2009, BS EN ISO 15614-1:2004+A1:2008, BS 4871:1985 Part 2, BS 4872:1985 Part 1.

All inspection and testing shall be carried out by certified inspectors appointed by the Contractor. Reports on inspections and tests shall be submitted to the Engineer promptly.

All welds shall be visually inspected.

The first 10 joints made by each welder shall be 100% tested; thereafter 10% of the joints made by the welder shall be tested. If a weld is found to be defective, the welder concerned will have his previous and subsequent weld 100% tested, if a further defect is found the next three welds will be 100% tested.

Non-destructive testing methods:

Weld Type	**Testing Method**
Butt welds	radiographic testing
Part penetration and fillet welds	magnetic particle testing

Radiographic inspection of welds shall be made by the Contractor, in the presence of the Engineer, in accordance with IS 4853:1982, IS 1182:1983 or IS 2595:2008 to a maximum of 10% of the total run of weld. Each joint to be radiographed shall be cleaned and any weld spatter removed. Any defective weld shall be repaired by approved means or cut out if necessary. If, in the opinion of the Engineer, excessive repair work is necessary, the radiographic inspection may be increased beyond 10% of the total run.

Spherical and other forms of sleeve welded joints shall be gas tested.

Gas Testing

The Contractor shall carry out nitrogen tests on a number of completed welded sleeve/collar type joints, at the discretion of the Engineer.

A tapped hole (approximately 6 mm diameter) made in the socket end of the pipe to be tested shall be fitted with a suitable non-return valve. Moisture free nitrogen gas, at a pressure of 1 bar shall then be pumped into the annular space between the spigot and socket and the pump disconnected.

If no drop in pressure occurs over the ensuing test period the test shall be deemed to be successful. The duration of this test period shall be 30 minutes unless otherwise approved by the Engineer. If the test pressure cannot be maintained for 30 minutes, all defects in the weld shall be cut back and re-welded and the test reapplied until successful. Once the joint has successfully passed a gas test, the tapped hole shall be sealed with a threaded steel plug, which is tack welded in place.

The Contractor shall provide all items necessary for the nitrogen gas tests including compressor, gas bottles, valves, gauges, tubing and so forth.

19.10 Surface Protection

19.10.1 Consideration for Electroplating/Galvanising

Piping systems: Corrosion protection of pipelines by methods other than those described in BS EN ISO 1456:2009, BS EN ISO 12540:2000, BS EN ISO 12944-5:2007 may be suitable. Consideration of such systems will be given provided that the Contractor can demonstrate a level of performance and durability equivalent to coating systems complying with BS EN ISO 12944-5:2007.

Other components: Electroplating or hot dip galvanising may be acceptable as an alternative to some components made of stainless steel subject to the Engineer approval.

Should electroplating/galvanising be accepted – it shall be carried out in accordance with IS 2629: 1985 with a deposition rate of at least 610 g/m^2. After galvanising, all parts shall be passivated to minimise discoloration.

Where galvanized coatings are damaged, repairs shall be undertaken using one of the methods given in IS 2629: 1985.

Zinc or cadmium electroplated components shall be in accordance with IS 3655:1985, IS 3656:1968. Cadmium coating shall not be used where the component might come into contact with food or water supplies.

Chrome electroplating shall be in accordance with BS EN ISO 6158:2011 and the minimum coating thickness shall be 85 microns.

If the chosen method of repair uses a zinc rich primer, the primer shall comply with the requirements of IS 13238:1991. Repairs to galvanized coatings shall not be made using materials that are applied from an aerosol can.