 	PROJECT		Standby SRU & Additional Tanks	
	CLIENT		IOCL Paradip Refinery	
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Design Basis for Civil, Structural, Architectural and U/G network

C	16-06-2020	Issued for Design	SUR	KRK	JP / KC	JMC
B	07-02-2020	Issued for Review	SUR	KRK	JP / KC	JMC
REV.	DATE	DESCRIPTION	PREPARED	CHECKED	APPROVED	AUTHORIZED

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			IOCL Paradip Refinery		
		CLIENT	INDIAN OIL CORPORATION LIMITED		
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1. INTRODUCTION

INDIAN OIL CORPORATION LIMITED (IOCL) has awarded Fax of Acceptance (FOA) dated 29th August 2019 to M/s. Technip India Limited (TPIL) for Consultancy services (PMC/EPCM services) for overall project management, FEED Review / FEED, Detailed Engineering, Procurement & expediting services, Tendering & award, Construction Management & Supervision, Assistance in start-up, Commissioning & performance test runs for installation of a Standby SRU of 525 TPD capacity and execution of Additional tanks for Paradip Refinery, Odisha, India.

2. DEFINITIONS & ABBREVIATIONS

Abbreviation	Definition /Expanded form
IOCL/ CLIENT	Indian Oil Corporation Limited
PMC/ CONSULTANT	Technip India Limited
LICENSOR	Party selected by IOCL for process technology ownership for any UNIT
CONTRACTOR	Party whose services are obtained for performing the works specified as part of LSTK / packages.
EPCM	Engineering, Procurement & Construction Management Services.
LSTK	Lump Sum Turn Key portion of the work to be executed by CONTRACTOR
FEED	Front End Engineering Design
AUTHORISED REPRESENTATIVE	IOCL's/ CONSULTANT's representative authorized to act for and on behalf of them.
VENDOR	Any third party supplying the equipment/materials for setting up the Plant
PROJECT	Indicates Standby SRU and Additional tanks Project, Paradip Refinery
SITE	Indicates Paradip Refinery in Odisha, India
UNIT	Indicates any particular portion of the project to be built which can be Process related or Utilities/Offsites related
SRU	Sulphur Recovery Unit
BIS	Bureau of Indian Standards

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3. CONFLICTS AND DEVIATIONS

If conflicting statements exist within this document or between this document and other applicable specifications, Standard Drawings, Industry standards, codes, etc., it shall be brought to Owner's / PMC notice for clarification and proper approval shall be obtained before implementation. Decision of Owner / PMC shall be final.

In case of contradiction between licensor specification, design basis, JSS and STC, it has to be brought to the notice of Owner/PMC and Decision of Owner/PMC shall be binding on Contractor/Vendor.

In general, order of priority of the documents shall be as follows,

- ◆ Local regulatory and statutory requirement.
- ◆ Licensor Requirements (as applicable)


Project specification and datasheets, wherever applicable.

4. BASIC GUIDELINES

- 1) All Civil / Structural designs shall be carried out in accordance with latest IS Codes (with all amendments issued there to) on the notified date of tender
- 2) Internal / External materials of construction for buildings shall conform to Specifications.
- 3) Construction material such as sand, cement, aggregate, water, reinforcement, weld-mesh and structural steel & structural steel sections, etc., shall conform to relevant BIS Codes & specifications.
- 4) IS Codes shall be followed for workmanship and testing of materials.
- 5) All other material shall be in accordance with specifications.
- 6) Apart from the IS codes particularly mentioned in various clauses of this document, all other relevant codes related to specific job under consideration and/or referred to in the above-mentioned codes, shall be followed wherever applicable. Reference to some of the codes in various clauses of this document does not limit or restrict the scope of applicability of other relevant Codes.

5. UNIT

The International System of Units (SI) shall be used.

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6. REFERENCED STANDARDS & PUBLICATIONS

(All codes & Standards shall be latest revision with all amendments issued thereto and refers to all parts)

Si No.	Description	Code
1.	Paving Bitumen – Specification	IS:73
2.	Specification for Coarse and Fine aggregates for natural sources for Concrete	IS:383
3.	Classification of Commercial Timbers & their zonal distribution	IS:399
4.	Specification for expanded metal steel sheets for general purposes	IS:412
5.	Specification for mild steel and medium tensile steel bars and hard-drawn steel wire for concrete reinforcement.	IS:432
6.	Specification for Portland slag cement	IS:455
7.	Code of practice for plain & reinforced concrete	IS:456
8.	Precast Concrete Pipes (With and Without Reinforcement)	IS:458
9.	Specification for test sieves: Part-1 Wire cloth test sieves	IS:460
10.	Methods of test for strength of concrete	IS:516
11.	Code of practice for general construction in steel	IS:800
12.	Code of practice for use of cold formed light gauge steel structural members in general building construction	IS:801
13.	Code of practice for use of structural steel in overhead transmission line towers	IS:802
14.	Code of practice for design, fabrication and erection of vertical mild steel cylindrical welded storage tanks	IS:803
15.	Code of practice for use of steel tubes in general building construction	IS:806
16.	Cold formed light gauge structural steel section	IS:811
17.	Covered electrodes for manual metal arc welding of carbon and carbon manganese steel	IS:814
18.	Code of practice for use of metal arc welding for general construction	IS:816
19.	Code of practice for design loads	IS:875
20.	Code of practice for Design of structural timber in building	IS:883

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Si No.	Description	Code
21.	Common burnt clay building bricks specifications	IS:1077
22.	Code of practice for design and construction of shoulder foundations in soils (other than raft, ring and shell)	IS:1080
23.	Method of identification of natural building stone	IS:1123
24.	Method of test for Determination of water absorption, apparent specific gravity and porosity of natural building stone.	IS:1124
25.	Recommendations for dimensions and workmanship of natural building stone for masonry work	IS:1127
26.	Recommendations for dressing of natural building stones	IS:1129
27.	Steel tubes for structural purposes- specification	IS:1161
28.	Code of basic requirements for Water supply, drainage & sanitation	IS:1172
29.	Bitumen-Mastic for flooring- specification	IS:1195
30.	Methods of sampling and analysis of concrete	IS:1199
31.	Steel tubes, tubulars & other wrought steel fittings	IS:1239
32.	Methods of sampling and test for anaerobic adhesives and sealants.	IS:1305
33.	Specification for bitumen felts for water proofing and damp proofing	IS:1322
34.	Code of Practice for Pre-stressed Concrete	IS:1343
35.	Hexagon Head bolts, screws and nuts of product grade 'C' - Part-1: Hexagon Head Bolts	IS:1363
36.	Technical supply conditions for threaded steel fasteners	IS:1367
37.	Specification for portland pozzolana cement	IS:1489
38.	Specification for hard-drawn Steel Wire Fabric for Concrete reinforcement	IS:1566
39.	Code of practice for construction of stone masonry	IS:1597
40.	Code of Practice for Building Drainage	IS:1742

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Si No.	Description	Code
41.	Specification for high strength deformed steel bars and wires for concrete reinforcement	IS:1786
42.	Specification for hot applied Sealing Compounds for Joints in concrete	IS:1834
43.	Fillers for expansion joints	IS:1838
44.	Criteria for earthquake resistant design of structures	IS:1893
45.	Design & Construction of Foundations in solids	IS:1904
46.	Code of practice for structural use of unreinforced masonry	IS:1905
47.	Specification for plain washers	IS:2016
48.	Hot rolled low, Medium and high tensile structural steel	IS:2062
49.	Code of practice for water supply in buildings	IS: 2065
50.	Specification for sand for masonry mortars	IS:2116
51.	Specification for concrete masonry units	IS:2185
52.	Code of practice for brick works	IS:2212
53.	Code of practice for preparation and use of masonry mortars	IS:2250
54.	Steel wire ropes for General Engineering purposes- Specification	IS:2266
55.	Specifications for thimbles for wire ropes	IS:2315
56.	Bulldog grips- specification	IS:2361
57.	Methods of test for aggregates for concrete (Part-II)	IS:2386
58.	Methods for sampling of aggregates for concrete	IS:2430
59.	Code of practice for installation of septic tanks	IS: 2470
60.	Drop forged sockets for wire ropes for General Engineering purposes	IS:2485

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Si No.	Description	Code
61.	Code of Practice for Bending and Fixing of Bars for Concrete Reinforcement	IS:2502
62.	Recommended practice for hot dipped galvanizing on iron and steel	IS:2629
63.	Methods for testing uniformity of coating of zinc coated articles	IS:2633
64.	Integral waterproofing compounds for cement mortar and concrete-specification	IS:2645
65.	Methods of Test for Soils	IS: 2720
66.	Code of practice for design and construction of pile foundation	IS:2911
67.	Code of practice for design & construction of raft foundations	IS:2950
68.	Code of practice for design & construction of machine foundations	IS:2974
69.	Methods of sampling & test (physical & chemical) for water and wastewater	IS:3025
70.	Specification for bitumen mastic for use in water proofing of roofs	IS:3037
71.	Specification for ballies for general purposes	IS:3337
72.	Code of practice for concrete structures for storage of Liquids	IS:3370
73.	Specification for bitumen primer for use in water proofing and damp proofing	IS:3384
74.	Design & Installation of Joints in Buildings	IS:3414
75.	Specification for masonry cement	IS:3466
76.	Methods of test of burnt clay building bricks	IS:3495
77.	Steel chequered plates: specifications	IS:3502
78.	Specification for structural timber in building	IS:3629
79.	Specification for high strength structural bolts	IS:3757
80.	Roof Extractor Units	IS:3963

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Si No.	Description	Code
81.	High strength bolts in steel structures- code of practice	IS:4000
82.	Methods of physical tests for hydraulic cement	IS:4031
83.	Recommendations on stacking and storage of construction materials and components at site	IS:4082
84.	Code of practice for design and construction of foundation for transmission line towers and poles	IS:4091
85.	Code of practice for ancillary structures in sewerage system	IS: 4111
86.	Code of practice for earthquake resistant design and construction of buildings	IS:4326
87.	Chemical Resistant Mortar-Silicate type	IS: 4441
88.	Chemical Resistant Mortar-Sulphur type	IS: 4442
89.	Chemical Resistant Mortar-Resin type	IS: 4443
90.	Testing of Mortar	IS: 4456
91.	Chemical Resistant Mortar (Parts I to III)	IS: 4832
92.	Hollow steel sections for structural use	IS:4923
93.	Ready-Mixed Concrete - Code of Practice	IS:4926
94.	Recommendations for Buildings and facilities for the Physically Handicapped	IS:4963
95.	Specification for high density polyethylene pipes for potable water	IS: 4984
96.	Unplasticized PVC pipes for potable water supplies specifications	IS:4985
97.	Plywood for concrete shuttering works - specifications	IS:4990
98.	Criteria for blast resistant design of structures for explosions above ground	IS:4991
99.	Criteria for blast resistant design of structures for explosions above	IS:4994
100.	Criteria for design of reinforced concrete bins.	IS:4995

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Si No.	Description	Code
101.	Criteria for design of RCC chimneys	IS:4998
102.	Determination of dynamic properties of soil	IS:5249
103.	Cement paint	IS:5410
104.	Methods of sampling of clay building bricks	IS:5454
105.	Specification of bitumen mastic for tanking and damp proofing	IS:5871
106.	Code of practice for anti-termite measures in buildings	IS:6313
107.	Code of practice for determination of bearing capacity of shallow foundation	IS:6403
108.	Specification for High Alumina Cement for structural use	IS:6452
109.	Code of practice for water-proofing of underground water reservoirs and swimming pools	IS:6494
110.	Code of practice for installation of joints in concrete Pavements	IS:6509
111.	Code of practice for design & construction of steel chimney	IS:6533
112.	Method for determination of mass of zinc coating	IS:6745
113.	Specification for glass fibre base bitumen felts	IS:7193
114.	Code of practice for damp-proofing using bitumen mastic	IS:7198
115.	Code of practice for calculation of settlements of foundation	IS:8009
116.	Specification for 43 grade ordinary portland cement	IS:8112
117.	Specification for bitumen mastic, Anti-static and electrically conducting grade	IS:8374
118.	Guidelines for design of surface drains	IS: 8835
119.	Chlorpyrifos emulsifiable concentrates	IS:8944
120.	Concrete admixtures- Specifications	IS:9103

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Si No.	Description	Code
121.	Criteria for design of steel bins for storage of bulk Materials	IS:9178
122.	Unplasticized Polyvinyl Chloride (UPVC) Single Wall Corrugated Pipes for Drainage	IS: 9271
123.	Recommendations for metal arc welding of carbon and carbon manganese steel	IS:9595
124.	Specification for precast concrete septic tanks	IS: 9872
125.	Recommended guidelines for concrete mix design	IS:10262
126.	Code of practice for design and construction of ring Foundation	IS:11089
127.	Specification for one part polysulphide base joints sealant	IS:11433
128.	Code of practice for design & construction of shallow foundations on rock	IS:12070
129.	Two parts polysulphide based sealants	IS:12118
130.	Pro vision of water-stops at Transverse contraction joints in masonry & concrete dam- code of practice	IS:12200
131.	Specification of 53 grade Ordinary Portland Cement	IS:12269
132.	Specification for sulphate resisting Portland cement	IS:12330
133.	Hot -dip Zinc Coating on Structural Steel Bars for Concrete Reinforcement – Specification	IS:12594
134.	Hot rolled parallel flanged steel sections for beams, columns and bearing piles- Dimensions and section properties	IS:12778
135.	Pulverised fuel ash Lime bricks- specifications	IS:12894
136.	Guidelines for selection of ground improvement technique for foundation in weak soils	IS:13094
137.	Guidelines for vibration isolation for machine foundations	IS:13301
138.	Specification for UPVC pipes for soil and waste discharge systems inside buildings including ventilation and rainwater system	IS: 13592
139.	Fusion bonded epoxy coated Reinforcing bars	IS:13620

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Si No.	Description	Code
140.	Code of practice for ductile detailing of reinforced concrete structures subjected to seismic forces	IS:13920
141.	Specification for PVC Geo-membranes for lining	IS: 15909
142.	Design and Construction for Ground improvement - Guidelines	IS:15284
143.	Unplasticized Non-Pressure Polyvinyl Chloride (PVC - U) Pipes for use in Underground Drainage and Sewerage Systems - Specification	IS: 15328
144.	Codes for Roads	IRC
145.	Process Design & Operating Philosophies on Blow down and Sewer system	OISD-STD-109
146.	Layout of Oil & Gas Installations	OISD-STD-118
147.	Control Room Safety (a publication of Oil Industry Safety Directorate)	OISD-STD-163
148.	Fire Proofing in Oil and Gas Industry (a publication of Oil Industry Safety Directorate)	OISD-STD-164
149.	Fire Protection System for Electrical Installations (a publication of Oil Industry Safety Directorate)	OISD-STD-173
150.	Design aids for reinforced concrete to IS: 456	SP 16
151.	Explanatory Handbook on Codes for Earthquake Engineering.	SP 22
152.	Explanatory Handbook on Indian Standard Code for plain and	SP 24
153.	National Building Code	
154.	Building Bye Laws	
155.	Factory Rules	

Note:


Licensors standard/ standard specification shall be followed wherever applicable /available.

The above list is suggestive not exhaustive. Apart from these basic codes any other codes should also be followed wherever required.

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PART-A STRUCTURAL



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1. General

This specification defines the design criteria and loads that should be taken in to account for the design of all industrial plant and non-plant structures and buildings.

2. Material and Material of Construction

2.1 General

Unless otherwise specified in the drawings, material specifications should conform to the following.

2.1.1 Cement:

Generally, for all concrete works both above and below ground, the use of one of the following type of cements shall be considered:

- ◆ 43 Grade or 53 Grade Ordinary Portland Cement (OPC) conforming to IS: 8112/IS: 12269.
- ◆ Portland Pozzolana Cement (PCC, fly ash based) conforming to IS: 1489 Part 1.
- ◆ Portland Pozzolana Cement (PCC, calcined based) conforming to IS: 1489 Part 2.
- ◆ Portland Slag Cement (PSC) conforming to IS: 455.
- ◆ Sulphate Resistant Portland Cement (SRC) conforming to IS: 12330 shall be used (if required as per soil recommendation for respective site).

2.1.2 Aggregate:

Aggregates used in concrete works shall be conforming to IS: 383. For most works, graded 20 mm down aggregate shall be used. Where there is no restriction to the flow of concrete into sections, 40 mm down aggregate shall be used in special cases. The grading of fine aggregates, when determined as described in IS: 2386 (Part-I) shall be within the limits as given in IS: 383.

Blast furnace slag and manufactured sand shall not be used as aggregates.

2.1.3 Reinforcement:


Reinforcement shall be High Strength deformed TMT bars of grade Fe 500D conforming to IS: 1786.

Reinforcement steel of minimum grade Fe500D to be used. Unless specifically stated otherwise use of mild steel is not permitted in R.C.C. works. If used, it shall be of Grade I conforming to IS: 432 Part I.

Corrosion resistant steel (CRS-rebars) to be used for liquid retaining structures like sump, reservoir, Cooling tower cell etc.,

2.1.4 Binding Wire:

18-gauge black soft annealed SWG wire shall be used for binding of reinforcement bars.

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2.1.5 Admixtures:

Admixtures shall conform to IS: 9103 and are to be mixed with concrete strictly as per manufacturer's recommendations.

2.1.6 Grouting:

Refer Document No. 080557C-000-JSS-1700-004 – Specification for Grouting and also clause 5.15 of this document.

2.1.7 Bolts

Unless otherwise specified in the item, Bolts shall be Snug Tight High Strength Bolts of Grade 8.8 or 10.9 conforming to IS: 3757 & IS: 4000.

Nuts & bolts shall conform to IS: 1363 or IS: 1364 as applicable and as shown in the drawing. Unless otherwise specified nuts and bolts heads shall be hexagonal. Class of nuts and bolts shall be compatible. Wherever shown in the drawing, high strength friction grip bolts and nuts conforming to IS: 3757 and IS: 6623 respectively shall be used.

Washers: Plain washers shall be made of MS conforming to IS:5369 unless otherwise specified. Helical spring washers conforming to IS: 6755 shall be provided for bolts carrying dynamic or foundation loads and direct loads. Tapered washers conforming to IS: 5372 and IS: 5374 shall be used for channels and beams respectively. Washers for high strength friction bolts shall conform to IS: 6649.

All Bolts, Nuts and Washers shall be Hot Dip Galvanized shall confirm to IS: 4759.

2.1.8 Anchor Bolts

Anchor bolts shall be of mild steel conforming to Grade E250 and quality A/BO/BR of IS: 2062 and fabricated as per Document "Construction Standards for Concrete Works". Minimum two nuts shall be used for all anchor bolts except for ladder, stair and handrail.

2.1.9 Structural Steel

Steel sheets shall conform to IS: 1079.


Crane rails shall conform to IS: 3443-1980.

Refer Document No. 080557C-000-DW-1802-001 – General Notes for Structural Steel works and 080557C-000-JSS-1800-001 – Specification for Structural Steel and clause 11.2 of this document.

2.1.10 Insert Plates

Insert plates should be of structural steel grade E250 (FE 410W) Quality B0/ Quality BR conforming to IS: 2062 and should be provided with mild steel lugs and /or TMT bar lugs as per drawings/ standards.

Mild steel bars should conform to IS: 432. **Minimum thickness of Insert plate shall be 10mm.**

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2.1.11 Gratings

Electro-forged hot dip galvanized MS Gratings shall be minimum 25mm deep. The maximum size of voids in the grating shall be limited to 30mm x 100mm. The minimum thickness of galvanizing shall be as per IS 2629. Steel chequered plates shall conform to IS: 3502.

2.1.12 Design Strength of Concrete

Unless otherwise specified, the minimum concrete grade should be as follows,

Piles	M30
Liquid Retaining Structures	M30
Structural Concrete	M30
Cable Trench	M30
Storm water Drainage	M25
Grade Slab *	M30
Leveling Concrete	M20
Filling / Mass / Plum Concrete	M15
Dense Fire proofing	M20

* For Paving Refer to clause 6 in Part-D General Civil.



Minimum cement content, maximum water cement ratio and minimum grade of concrete for different exposures shall be as per IS: 456 (Latest edition).

Unless otherwise stated, the mix design is to be carried out by the Contractor for approval of PMC/ IOCL.

2.1.13 Plain Cement Concrete (PCC):

- 1) 75 mm thick lean concrete of grade 1:4:8 should be provided under all RCC foundations except under base slab of liquid retaining structures where 100mm thick concrete of grade 1:3:6 shall be used.
- 2) The lean concrete shall extend 75mm beyond the foundation for normal foundations and 100mm under liquid retaining structures.
- 3) PCC of grade M20 of minimum 150mm thickness shall be provided under all masonry wall foundations.
- 4) Acrylic based waterproofing compound (2% by weight of cement) shall be mixed in concrete used as damp proof course at plinth level of all masonry walls.
- 5) Minimum grade of concrete for General Civil work should be as specified in Detail specification for General Civil works.

2.2 Technological structures (supporting process equipment) shall be in Structural Steel. All operating floors should be in Electro-forged Gratings. Fireproofing requirement shall be as per OISD-STD-164.

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- 2.3** Unless otherwise specifically stated, all shed type structures such as Pump House, Compressor house etc. should be in structural steel. Roofing & side cladding shall be as per Architectural Design basis/specification.
- 2.4** Encasing of steel structures for reciprocating compressors pipe supports etc. if required should be as per analog study. (For pulsating flow lines detailed thermal and vibration analysis by analog study shall be done to decide on location of anchor supports and guides etc. Pulsating flow lines shall be as identified by licensor/owner).
- 2.5** All Pipe racks shall be in Structural Steel.
- 2.6** Fire-proofing material for steel structures wherever required as per OISD, shall be as follows:

- i) Concrete for structures, supporting transfer line & two phase flow line above 6" diameter.
- ii) Vermiculite for all other structures, however fire-proofing up to minimum 1.8 m from HPP shall be in concrete and above 1.8m by Vermiculite.

2.7 Buildings

All buildings should be of RCC Frame type construction with brick masonry /Burnt clay fly ash building bricks infill walls as per Architectural Design Basis. However, blast resistant buildings shall have RCC walls.

In acid and caustic handling units / dosing areas and sulfur handling units, steel structure to be avoided. If unavoidable, suitable protective coatings shall be provided as per site specific exposure conditions / painting specifications.

Unless otherwise stated, bricks for masonry works shall be class 7.5 conforming to I S: 1077 and /or Burnt clay fly ash building bricks confirming to IS: 13757.

3. Loads and Forces

3.1 General

This specification covers the Definitions and Combinations of Design Loads which shall be considered in the Design and Engineering for Concrete, Structural Steel and General Civil facilities. Design shall be done with due considerations of functional requirements, the conditions at site so that the requirements of this specification are met and economical, effective methods and materials be used.

3.2 Design Loads

All foundations and structures, irrespective of the material employed for their construction, shall be designed for the worst possible load combination in accordance with the corresponding tables given in this document. However, in case of special loadings for which load combination is unavailable in this Design Basis, relevant provisions in IS/International Codes & Publications may be referred to.

The various types of loads for design are:

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DL : Dead Load
 IL : Imposed / Live Load
 E(E) : Equipment Loads for Erection / Empty
 E(O) : Equipment Loads for Operation
 E(T) : Equipment Loads for Testing
 BP : Bundle Pull
 VL : Impact / Vibratory Load
 WL : Wind Load
 SL : Seismic / Earthquake Load
 PL : Piping Load
 P(E) : Piping Loads for Erection / Empty
 P(O) : Piping Loads for Operation
 P(T) : Piping Loads for Testing
 TL : Thermal Load/ Friction Load
 TA : Thermal Anchor Load
 CRL : Crane Load
 H : Earth Pressure Load
 Hd : Handling Device Load
 BP : Blast Force / Load



3.3 Dead Load (DL)

Dead load shall be the weights of all permanent construction, including foundations, walls, floors, roofs, and partitions, stairways, equipment excluding their contents. During the estimation of loads for the weight of process equipment, only empty weight including all the associated piping, fixtures and excluding the contents will be considered.

The weight of all permanent construction including self-weight of structural members, walls, fire proofing, refractory, burner, duct, floors, roofs, partitions, stair ways & fixed services & other (Electrical /Instrument cable trays including cables) shall be considered.

If piping weight is not indicated separately or included in the weight of the equipment, the same shall be taken as 10% of the operating weight of the equipment. Component of soil backfill weight over foundation slab shall be considered as foundation dead load.

The unit weight of materials in general, shall be in accordance with IS: 875 part-1 (Latest edition).

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Also, the following unit weights shall be considered for the purpose of Design.


Reinforced Concrete	25 kN/m ³
Plain Concrete	24 kN /m ³
Brickwork	19 kN/m ³
Structural Steel	78.5 kN /m ³
Backfill Soil	18 kN /m ³
Operating floor with grating	1.0 kN/m ²
Steel Staircase	1.4 kN /m ²
6 mm thk. Chequered plate	0.55 kN /m ²
25 mm thk Grating	0.50 kN /m²
Handrail	0.16 kN /m
Ladder	0.40 kN /m
Heavy duty tar felting	0.30 kN /m ²
Electrical Panel Load	As per Actual panel loads
Instrumentation Panel Load	As per Actual panel loads
Battery backup Load	As per Actual panel loads

3.4 Imposed Load (IL)

Imposed loads shall mean the total weight of moving or movable external loads on structures, buildings and / or foundations, produced by people, tools, furnishings of buildings etc., which are not permanently fixed there to.

However, weight for small equipments and miscellaneous facilities like following, which may be permanently fixed there to, shall be included in imposed loads.


- Local lighting facilities
- Local instrumentation & electrical facilities & cables except for substation and control room.

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3.4.1 Imposed Loads on locations other than roofs

Imposed loads should, in general, be as per IS:875 Part-II. However, the following minimum live loads should be considered in the design of structures to account for maintenance and erection as well:



	Location	Design Imposed Loads
1.	Process Building or Technological Structure (Open / Enclosed Type)	
	Operating Area	5.0 kN /m ² or as per actual Working condition whichever is more
	Maintenance Area	7.5 kN /m ² or as per actual working condition whichever is more
	Ground Floor	10 kN/m ²
2.	Compressor House/TG house	
	Operating Area	7.5 kN /m ² or as per actual working condition whichever is more
	Maintenance Area	7.5 kN /m ² or as specified by Machine vendor whichever is more
	Ground Floor	10 kN/m ²
3.	Substation/Control Room	
	Panel floor	10.0 kN /m ² (Minimum) or subjected to actual panel load whichever is more.
	Other areas	5.0 kN /m ²
	Partitions	1.0 kN /m ²
4.	Office Building	
	Office area	3.0 kN /m ²
	Lobby	5.0 kN /m ²
	Exit way	5.0 kN /m ²
	Partitions / Misc. Portions	1.0 kN /m ²
5.	Laboratory	
	Upper Floors	4.0 kN /m ²
	Ground Floor	5.0 kN /m ²
6.	Cooling Tower	
	Operating platform/	3.0 kN /m ²

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	Location	Design Imposed Loads
	Hot water basin cover slab	
7.	Staircase	
	Process Building / Technological Structures	5.0 kN /m ²
	Office	5.0 kN /m ²
	Substation / Control Room	5.0 kN /m ²
	Laboratory	3.0 kN /m ²
	Service Platform	2.5 kN /m ²
8.	Platforms & Walkway	
	Walkway of Gantry Girder	3.0 kN /m ²
	Access-way	3.0 kN /m ²
	Service platform around Vessel /Tower	3.0 kN /m ²
	Isolated Platform (For valve operation)	3.0 kN /m ²
	Pipe Rack (Walkway)	2.5 kN /m ²
	Cross over	2.5 kN /m ²
	Pipe Rack (Blind Floor below Air Fin Cooler / Valve Operation) <i>* Wherever a lower floor load is expected, suitable reduction over specified load shall be adopted.</i>	5.0 kN /m ²
9.	Operating platform in GT Buildings/ DM Plant/ ETP	3.0 kN /m ²
	Ware House & Work Shop	
	Light	5.0 kN/m ²
	Medium	7.5 kN/m ²
	Heavy	10.0 kN/m ²
10.	Storage Areas	
	Light Storage Areas	5.0 kN/m ²
	Medium Storage Areas	7.5 kN/m ²
	Heavy Storage Areas	12.0 kN/m ²

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	Location	Design Imposed Loads
11.	Miscellaneous	
	False Ceiling	0.75 kN /m ²
	Archive Area / Documentation	6.0 kN/m ²

Loads on account of equipment and incidental loads shall be taken over and above the loads indicated in the table.

1 kN/m² allowance shall be made for services supported from bottom of the floor.

Apart from specified live loads, any other equipment load or possible overloading during construction/hydrotest/ maintenance/erection shall also be considered in design.

3.4.2 Imposed Loads on roofs

Flat Roof, Sloping Roof with slope $\leq 10^\circ$

With Access	1.5 kN /m ²
Without Access except for maintenance	1.0 kN /m ²

Sloping Roof with slope $> 10^\circ$

For roof membrane sheet or purlins	0.75 kN /m ² less 0.02 kN /m ² for every degree increase in slope over 10 degrees subject to minimum of 0.4 kN /m ²
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For all other buildings not covered in the above table the live loads /imposed loads shall be taken as per IS:875 (Part-II).

3.5 Equipment Loads

The empty / operating / test weight of process equipment including all fixtures, platforms, ladders and attached piping but excluding contents, shall be considered.



Equipment Loads shall be defined as per the following 3 cases, according to the governing conditions of erection, operation and testing.

3.5.1 Equipment Loads for Erection / Empty (E(E)):

This shall mean the weight of equipment during erection/empty and exclude the weight of internals, fluids and solids within the equipment, platforms, insulation and piping attached to the equipment.

3.5.2 Equipment Loads for Operation (E(O)):

This shall mean, the load of equipment during normal operating conditions, including the weight of internals, fluids and solids within the equipment and all materials permanently attached to the equipment,

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such as platforms, insulation and piping. For silos, the contents shall be considered as operating load.

Vibration caused by operation of equipment shall be considered separately as vibration loads.

3.5.3 Equipment Loads for Testing (E(T)):

This shall mean, the load of equipment during hydrostatic testing after erection / installation, including the weight of water within the equipment, piping and all materials permanently attached to the equipment, such as platforms, insulation and piping. Hydrotest shall be considered for one equipment at a time. Further, under hydro-test condition the wind force shall be taken as 25% of normal wind loading. Seismic forces shall not be considered while hydro-testing.

3.6 Wind Load (WL)

Wind loads will be calculated in accordance with IS 875 Part 3 and the following:

Basic wind speed, V_b = 65 m/sec.

Risk Coefficient (k_1) = As per IS 875 (Part-3) (Mean probable-design life 50 years)

However, Temporary sheds, structures such as those used during construction operations (e.g. formwork and false work), structures during construction stages and boundary walls shall be designed for mean probable design life span of 5 years.

Terrain and height Factor (k_2) = As per IS 875 (Part-3) (Category 2 to be considered)

Topography Factor (k_3) = As per IS 875 (Part-3)

Importance factor for cyclonic region, (k_4) = 1.15 (As per IS 875 Part-3)

Design Wind Speed (V_z) = $V_b * k_1 * k_2 * k_3 * k_4$ m/s

Wind Pressure (p_z) = $0.6 * V_z^2$ N/m²

Design wind pressure, p_d = $K_d K_a K_c p_z$

Value of p_d shall not be less than 0.7 p_z

Wind directionality factor, K_d - As per IS 875 (Part-3)

Area averaging factor, K_a - As per IS 875 (Part-3)

Combination factor, K_c - As per IS 875 (Part-3)

To account for surface area of piping, platforms and other attachments fixed to the equipment, the surface area of the equipment (vessel/column) exposed to wind shall be increased by 20% or as specified in the mechanical data sheets of the equipment.

In calculation of wind force frictional drag shall be considered wherever applicable.

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Flexible slender structures and structural elements shall be investigated to ascertain the importance of wind induced oscillations or excitations along and across the direction of wind. Guidelines given in IS:875 (Part-3) shall be used to examine the problems of wind induced oscillations.

For switch yard structures & transmission towers, IS:802 shall be applicable.

3.7 Seismic Loads (SL)

The Analysis and Design of structures and foundations shall be based on IS1893(Part 4 & 2) - (Latest edition) and for general guidance IS:1893 (Part 1)- (Latest Edition) shall be referred and Project specific recommendations & Site Specific Response Spectra, whichever is stringent. Guidance on site specific seismic design parameters is given in Appendix of 080557C-000-JSS-1700-008. For Process columns, vessels, tanks, exchangers, compressors etc., seismic loads shall be taken from Mechanical Group.

3.7.1 Design Consideration

Design Site Data Considerations

Reference : IS: 1893 Part-I & Part-IV

Sr.No.	Parameter	Reference and Details
1.	Plant Location	Paradip, Odisha
2.	Seismic Zone	III
3.	Zone Factor, (Z)	0.16
4.	Important Factor-I	For non-plant buildings, as per IS-1893 Part-I; For Industrial Structures including Stack-like Structures as per IS:1893 Part-IV
5.	Soil Type	As per Geotechnical data
6.	Response Reduction Factor (R)	As per IS 1893 (Part – I & Part – IV)
7.	Spectral Acceleration	IS 1893 (Part – I & Part – IV) / Site Specific Response Spectra
8.	Damping Factor	Table-8, IS- 1893- Part-IV

3.7.2 Ductile Detailing

Appropriate ductility details, for reinforced concrete members, should be provided as per the provisions of IS: 13920 to avoid premature failure during earthquake.

In steel structures, members and their connections should be so proportioned that high ductility is obtained to ensure that premature failure due to elastic or inelastic buckling does not occur. Ductile detailing of

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steel structures shall be carried out as per the provisions of IS: 4326 and IS: 1893 and chapter 12 of IS 800.

3.8 Impact Load / Vibratory Load (VL)

Structures subjected to impact or vibratory loads should be designed as per the provisions of IS:875 (Part 2) & IS:2974 part 1, 3 & 4.

Requirement of monorails and overhead cranes shall be as per IS: 800, IS:875 or manufacturer's data, whichever is more stringent.


Vibration loads should mean the vibration forces caused by heavy vibrating equipment or machinery and dynamic forces caused by fluids in the normal operation. Frames, structures and foundations for machinery or equipment causing vibration should be designed to limit vibrations to an acceptable level.

It should be designed such that whether they are independent or part of the building, it should not only safely carry the loads for such items but also prevent resonance.

Dynamic analysis shall be carried out for foundations of critical equipment like compressors & pumps. While carrying out dynamic analysis of foundation/structures supporting dynamically loaded equipment's, the loads indicated by vendor in his documents shall be used.

However, in the absence of such vendor data, the following load shall be assumed as the equivalent static loads when the dynamic analysis is not carried out.

S. N	Equipment Type & Direction		Equivalent Static Load
1.	Rotating (Centrifugal) Type		
	Vertical		0.5 times the weight of equipment / machinery.
	Horizontal	Along direction of rotation (perpendicular to centerline of shaft)	0.25 times the weight of equipment / machinery.
		Along direction of shaft axis	0.10 times the weight of equipment / machinery.
2.	Reciprocating Type		
	Vertical		0.5 times the weight of equipment / machinery.
	Horizontal	Along direction of reciprocating motion	0.25 times the weight of equipment / machinery.

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S. N	Equipment Type & Direction	Equivalent Static Load
	Along direction perpendicular to reciprocating motion	0.10 times the weight of equipment / machinery.

3.9 Blast Forces

Structures subjected to blast forces generated due to accidental blasts shall be designed to withstand maximum of the following:

- ◆ Actual Blast Pressure.
- ◆ Minimum equivalent pressure of 3psi (20.7 kN/sqm) as per OISD-STD-163.
- ◆ As recommended in Rapid Risk Analysis (RRA) report.

3.10 Bundle Pull

Structures and foundations supporting heat exchangers with removable tube bundle shall be designed to withstand a longitudinal horizontal force applied at the center of it due to the removal operation.

The fixed saddle only shall support such force, that shall be equal to 100% of the tube bundle weight or 10 kN, whichever is greater. Above figure can be reduced if special extraction devices are provided as per Vendor's recommendations and adjusted accordingly. Bundle pulling force is not applicable when bundles are pulled by means of a mechanical device which acts on the principle of equilibrium of forces (no forces on the support structure).

In case of stacked equipment's, it shall be assumed that the bundle pulling of equipment is not simultaneous.

3.11 Thermal Expansion

Horizontal force due to thermal expansion of horizontal vessels / exchangers shall be relieved by using slotted holes and slide plates and remaining force derived from the product of the sliding saddle gravity load and the coefficient of friction taking shall be applied to each support.



When the thermal expansion or contraction results in friction between the equipment & its support at the sliding end, the friction force shall be calculated in accordance with the following coefficient of static friction & sliding ends in opposite directions:

Concrete to soil.....0.40

Steel on Steel..... 0.30

Steel on concrete..... 0.45

PTFE to PTFE..... 0.10*

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* Compressive stress on PTFE (Poly-tetra-fluoro-ethylene / Teflon) shall be minimum 3.5 N/mm².

3.12 Non-Static Loading

Foundations and structures supporting vessels subject to surge loading, such as Deaerators shall be designed with sufficient stiffness and rigidity to resist a notional horizontal force of 10% of those derived from the Vessel's operating weight or the given surge load whichever is the greater.



The forces shall be applied at the vessel's center of gravity and act longitudinally or transversely. Consideration shall be given to bracing these structures.

The design of foundations and structures supporting agitated vessels, centrifuges, reactors and other variable load equipment shall take full account of all the loading data provided by the equipment vendors. Where no loads are available, consideration shall be given to applying force at 10% of operating weight. In addition, for dynamic effect loads will be increased by 50% of steam agitated equipment and 25% for mechanical agitated vessels.

Where two or more similar items of such equipment are supported on a common foundation or structure, the design must be based on the assumption that these items will resonate in phase.

Rotating Equipment

Comprehensive loading data of mechanical equipment, such as, fans, blowers, pumps, compressors, D.G. Sets, turbines, motors engines etc., as furnished by the equipment vendor shall be considered.

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3.13 Earth Pressure/Liquid Pressure

Earth pressure shall mean pressure of the soil acting on the underground structure and/or foundation of retaining walls /dykes.

Earth pressure at rest, acting on basement, trenches and pit shall be calculated from the following equations:

- a) Above ground water level

$$P_v = \gamma H \pm q \text{ (T/m}^2\text{)}$$

$$P_h = K_0 P_v \text{ (T/m}^2\text{)}$$

- b) Below ground water level

$$P_v = \gamma H + q + \gamma' (h_0 - H) + \gamma_w (h_0 - H) \text{ (T/m}^2\text{)}$$

$$P_h = K_0 (\gamma H + q + \gamma' (h_0 - H) + \gamma_w (h_0 - H)) \text{ (T/m}^2\text{)}$$

Where,

P_v = Vertical soil pressure (T/m²)

P_h = Horizontal soil pressure (T/m²)

γ = Unit weight of soil (T/m³)

h_0 = Soil depth from grade surface (m)

q = Distributed load on ground surface (T/m²) $(\gamma' + \gamma_w) \times (h_0 - H)$

H = Underground water level from grade surface (m)

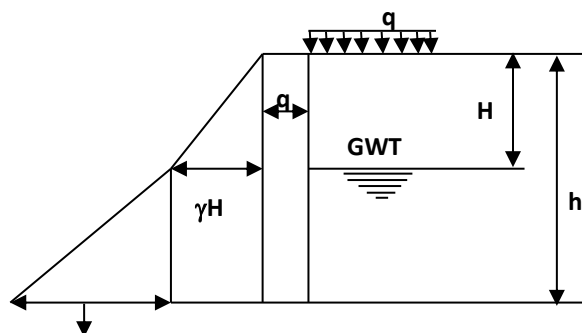
γ' = Submerged weight of soil in water (T/m³)

γ_w = Unit weight of water (T/m³)

K_0 = Ratio of horizontal to vertical pressure = $\tan^2 (45^\circ - \phi/2)$

ϕ = Internal friction angle of soil (As per geotechnical report)

Active and passive earth pressure acting on retaining wall shall be calculated from Coulomb's or Rankine's earth pressure equation.



Liquid Pressure

Liquid Pressure shall mean the pressure of liquid acting on the Pit / Basin / Dyke wall.

Liquid pressure shall be calculated by using the following equation:

$$P_1 = \gamma \times h_1 \text{ (T/m}^2\text{)}$$

Where,

P_1 = Liquid pressure (T/m²)

h_1 = Depth of liquid content (m)

γ = Unit weight of liquid (T/m³)

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3.14 Traffic Loads

Minimum wheel load of 5 MT for 10 MT hydras on precast covers and minimum surcharge load of 1.0 T/m² on cable trench wall shall be applied for design. Similar loads are also being considered for U/G drainage pipes wherever applicable.

Culverts shall be designed for a minimum class-A loading and Crane movement shall be designed for appropriate loading as per IRC 6.

3.15 Handling Facilities

Permanent handling facilities shall be designed for the following loads:

- Trolley beams and their supports shall be designed to IS 800/ IS 807/ IS 3177 with an allowance of 25 % of the total load for vertical impact. Where the hoist is to be operated with a grade mounted winch, a line pull of not less than 25 % of the lifted load shall be included.

i.e. Design Load = 1.25 (W + 0.25 W + weight of trolley).

This line pull allowance assumes the pulley system has a mechanical advantage of 4.

- Crane beams and supports for travelling cranes shall be designed in accordance with IS 800/ IS 807/ IS 3177.
- Davits shall be designed for the heaviest item to be lifted plus 25 % for impact but not less than a total of 450 kg. Lateral forces shall be assumed as 20 % of the lifted load. A line pull of 100 % of the lifted load shall be included to provide for the possibility of the load being handled by a line over a single pulley.

3.16 Process Vibration

Structures supporting process equipment subject to vibration due to normal process surging, e.g. fluid crackers, fluid hydroformers and fluid cokers, shall be designed for the following dynamic loads which will be periodic in the range of 60 to 100 cycles per minute (1 to 1.67 Hz):


Fluid coker 0.150 C

Fluid cracker and Hydroformer 0.075 C

where C = weight of fluid in vessel and adjacent piping.

3.17 Piping Load & Pipe Rack design requirements:

Insulation density shall be taken as 2600 N/m³ minimum. In case of gas/steam carrying pipes, the material content shall be taken as 1/3rd volume of pipe filled with water. The total actual weight thus calculated shall then be divided by the actual extent of the span covered by the pipes to get the uniform distributed load per unit length of the span. To obtain the design uniformly distributed load over the entire span, the UDL obtained as above shall be increased by 20% to account for fittings and accessories and shall be

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assumed to be spread over the entire span. However, minimum loading for any pipe rack shall not be less than 1.25 kN/m². In case, the calculated loading is higher than 1.25 kN/m², this shall be rounded off to the nearest multiple of 0.25 (i.e. 1.50, 1.75, 2.0 kN/m²).

Structures supporting piping shall be designed for the rigidity assumed in pipe stress analysis.

Vertical loads of flare pipe shall be taken as one third full of water for piping within units & one sixth full for outside unit battery line. All flare line independent support shall be of four legged braced open tower type construction.

In addition to piping loads, gravity loads due to encasement, if any, shall be considered.

Piping Loads shall be defined as per the following 3 cases, according to the governing conditions of erection/empty, operation and testing.

3.17.1 Piping Loads for Erection / Empty (P(E)):

This shall mean the weight of piping during erection or non-operating conditions (empty), exclude the weight of internals fluid but including insulation. These loading shall be as per piping loading data. 60% of the estimated piping operating load shall be considered if piping empty load data not available.

3.17.2 Piping Loads for Operation (P(O)):

This shall mean, the load of piping during normal operating conditions, including the weight of internals fluids & insulation. Piping Loads shall be calculated considering the pipe diameters and piping arrangement. These loading shall be as per piping loading data subject to minimum of 1.25 kN/m² over entire span.

3.17.3 Piping Loads for Testing (P(T)):

This shall mean, the load of piping during hydrostatic testing after erection / installation, including the weight of water within the piping & insulation.

Only one biggest pipe of diameter $\geq 12''$ on tier shall be considered at a time, along with all other pipes in empty condition. Otherwise, simultaneous hydro testing of pipes of diameter $\leq 6''$ shall be considered.

For lines of diameter between 6" & 12", two lines can be tested simultaneously.

3.17.4 Frictional Force:

Where the pipes are of similar diameter and service condition, the friction force at each tier on every portal, both in longitudinal and transverse directions shall be 10% of the design vertical loading of the pipes for four or more pipes supported on a tier, and 30% of the design vertical loading of the pipes for single to three pipes supported on a tier. Longitudinal friction force shall be considered as uniformly distributed over the entire span of the beam at each tier and transverse friction force shall be considered as a concentrated load at each tier level. Friction force on T supports and trestles shall be taken as 30% of the vertical loading. Both longitudinal and transverse friction forces shall be considered to be acting

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simultaneously.

3.17.5 Anchor and Guide Force (Thermal load) (TA):

Piping Anchor and guide forces shall be considered as per piping input resulting from Piping stress analysis. These anchor forces shall be transferred to the appropriate resisting frames / bracings and foundations.

3.17.6 Cable Tray/Ducts and Walkway Loads:

The estimated actual load from electrical trays and instrumentation ducts shall be considered at the specified locations, together with walkways, if provided.

3.17.7 Loading on Longitudinal & Transverse Beams:

Longitudinal beams connecting portal columns shall be sufficiently strong to sustain 25% of the load on the transverse beams. This total load shall be assumed as two equal concentrated loads acting at 1/3 span. Other longitudinal axial forces coming on it from the design of the supporting system shall also be simultaneously taken into account in the design of the longitudinal beam. Friction & Anchor forces, if specifically given by the Piping Specialist shall also be catered for in the design. Loads from monorails, when supported from these beams shall also be considered to be acting simultaneously along with all other loads mentioned above.

Intermediate beam at tier level shall be designed for 25% of load on main portal beams in transverse direction. A reduction of 10% in vertical loading shall be considered for main portal beams if intermediate beams are provided.

3.17.8 Wind Force:


Transverse wind loading shall be calculated depending on the width of the Pipe Rack as follows:

- Basic wind pressure shall be considered as per IS: 875.
- This force shall be considered irrespective of height between two tiers as per following table.

Width of Pipe Rack	Wind force at each tier level
Up to 4.0 m	1.25 x p x s
Above 4.0m but up to 6.0m	1.50 x p x s
Above 6.0m but up to 10.0m	2.00 x p x s
Above 10.0 m	H x p x s

p = design wind pressure as per IS: 875 (Part 3) in N/m².

s = spacing of portals (in m).

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H = Projected height (m)

Pipe racks should be adequately braced in all possible directions, consistent with functional requirements.

Limiting permissible horizontal deflection for pipe rack shall be as per IS 800 (Latest code).

3.18 Buoyancy

If the structure or footing extends below the design water level, the effect due to uplift and subsoil water table shall be considered.

3.19 Elevator Loads:

All Elevator loads shall be increased by 100% for impact and the Structural Supports shall be designed within the limits of deflection prescribed by the elevators' vendor.

Dynamic analysis (required if any) shall be carried out due to adjacent vibrating machine/equipment (if any).

3.20 Contingency Load

RCC Structures

All floor slabs and beams shall be designed for a concentrated load of 10 kN acting simultaneously with the uniform live load, but not with actual concentrated loads from equipment, piping etc.

This load shall be placed to result in maximum moment and / or maximum shear. It shall not be considered for the design of columns, foundations and in overall frame analysis. For floor slabs, the load shall be considered to be distributed over an area of 0.75 m x 0.75 m

Structural Steel

For process plants, the following contingency additional loading shall be applied to individual beam elements, these shall be applied as point loads to produce worst shear and bending stresses;

Platform Walkways 3 kN

Secondary Floor Trimmers 5 kN



Primary beams 10 kN

3.21 Other Loads:

Apart from the specified live loads, any other equipment load or possible overloading during construction/hydro-test maintenance/erection shall also be considered in the design.

All handrails, parapets, parapet walls, balustrades shall be designed for horizontal load mentioned in Table 3 of IS:875 (Part 2).

Operational load shall be defined as the dead load of Piping plus weight of any liquids or solids, normally

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present within piping during operation. Design of all structures should also consider any other relevant and consequential load/stress imparted to the structure.

All liquid retaining/storage structures should be designed assuming liquid upto the full height of wall irrespective of provision of any over flow arrangement. Pressure relief valves or similar pressure relieving devices should not be made in underground water retaining/storage RCC structures. Hot water basin in Cooling tower should be designed for the weight of water up to top of parapet wall.

All buildings/ structures shall be designed to resist the worst combination of the above loads (in accordance with IS:875 Part-5, other than seismic loads). However, wind/ seismic loads shall not be considered in combination together or with loads during maintenance.

Consideration shall be given to loads of a special nature such as piping counterweights, spring hangers, thrusts from expansion joints, expansion loads from horizontal vessels and exchangers, purpose made handling equipment such as counterbalanced crane hooks, and thermal expansion of the structure.

4. **Load Combinations**

It should be recognized in load combinations that the simultaneous occurrence of maximum values of wind, earthquake, imposed and snow load is not likely.

Selection of Load combinations to be considered in analysis and design shall be decided based on the type of structure under consideration.

Design shall be done to resist the worst combination of the above loads.


The overall stability of the structure and foundations may need to be reviewed against a more critical load combination than combinations defined below depending upon configuration of structure.

Earthquake Load shall be considered in all the three directions, as per IS 1893. Various load combination shall be taken as follow:

4.1 **Load Combination for Foundations for Stacks, Towers and Vertical vessels**

Load Combinations for check of soil bearing pressure / pile capacity and stability of foundation.

Load condition	Load combination
Erection	DL + E(E)
	DL + E(E) ± WL
Operating	DL + E(O)
	DL + E(O) ± WL

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Load condition	Load combination
	DL + E(O) ± SL
Test	DL + E(T)
	DL + E(T) ± 0.25 WL

Load combinations for RC Member Design viz. for footing, pedestal etc.

Load condition	Load combination
Erection	1.5 [DL + E(E)]
	1.5 [DL + E(E) ± WL]
	0.9 [DL + E(E)] ± 1.5 WL
Operating	1.5 [DL + E(O)]
	1.5 [DL + E(O) ± WL]
	1.5 [DL + E(O) ± SL]
	0.9 [DL + E(O)] ± 1.5 WL
	0.9 [DL + E(O)] ± 1.5 SL
Test	1.5 [DL + E(T)]
	1.5 [DL + E(T)] ± 1.5 [0.25 WL]
	0.9 [DL + E(T)] ± 1.5 [0.25 WL]

4.2 Load Combination for Foundations for Horizontal Vessels / Exchangers

Load Combinations for check of soil bearing pressure / pile capacity and stability of foundation.

Load condition	Load combination
Erection	DL + E(E)
	DL + E(E) ± WL
Operating	DL + E(O) ± TL

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Load condition	Load combination
	DL + E(O) ± TL ± WL
	DL + E(O) ± TL ± SL
Test	DL + E(T)
	DL + E(T) ± 0.25 WL
Maintenance (For Exchanger only)	DL + E(E) + BP

Load combinations for RC Member Design viz. for footing, pedestal etc.

Load condition	Load combination
Erection	1.5 [DL + E(E)]
	1.5 [DL + E(E) ± WL]
	0.9 [DL + E(E)] ± 1.5 WL
Operating	1.5 [DL + E(O) ± TL]
	1.5 [DL + E(O) ± TL ± WL]
	1.5 [DL + E(O) ± TL ± SL]
	0.9 [DL + E(O) ± TL] ± 1.5 WL
	0.9 [DL + E(O) ± TL] ± 1.5 SL
Test	1.5 [DL + E(T)]
	1.5 [DL + E(T)] ± 1.5 [0.25 WL]
	0.9 [DL + E(T)] ± 1.5 [0.25 WL]
Maintenance (For Exchanger only)	1.5 [DL + E(E)] + 1.5 [BP]


4.3 Load Combinations for Pipe Rack / Structures

Load Combinations for check for stability of foundation and soil bearing pressure for foundations / Pile Capacity

Load Condition	Load Combination
ERECTION	DL + E(E) + P(E)
	DL + E(E) + P(E) + IL
	DL + E(E) + P(E) ± WL

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Load Condition	Load Combination
	DL + IL + E(E) + P(E) ± WL
TEST	DL + E(T) + P(T)
	DL + E(T) + P(T) + IL
	DL + E(T) + P(T) ± 0.25WL
	DL + E(T) + P(T) + 0.5IL ± 0.25WL
	DL + 0.5IL + ET + 0.25WL + PL + Hd
OPERATING	DL + E(O) + P(O) + TA ± TL
	DL + IL + E(O) + P(O) + TA ± TL
	DL + E(O) + BP + VL + P(O) + TA ± TL
	DL + IL + E(O) + VL + P(O) + TA ± TL
	DL + IL + E(O) + PL + Hd ± TL
	DL + E(O) + P(O) + TA ± TL ± WL
	DL + IL + E(O) + P(O) + TA ± TL ± WL
	DL + 0.5IL + E(O) + BP + P(O) + TA ± WL
	DL + 0.5IL + E(O) + PL + Hd ± TL ± WL
	DL + EO + PO + TA ± TL ± SL
	DL + 0.5IL + EO + PO + TA ± TL ± SL
	DL + 0.5IL + EO + BP + PO + TA ± SL
	DL + 0.5IL + EO + PL + Hd ± TL ± SL
MAINTENANCE (for exchangers only)	DL + 0.5IL + E(E) + P(E) + BP
	DL + IL + EO + BP + H

Load Combinations for Foundation Reinforcement design for Pipe rack / Structures

Load Condition	Load Combination
ERECTION	1.5 [DL + E(E) + P(E) + IL]
	1.2 [DL + IL + E(E) + P(E)] ± 1.2 WL
	1.5 [DL + E(E) + P(E)] ± 1.5 WL
TEST	1.5 [DL + IL + E(T) + P(T)]
	1.2 [DL + 0.5IL + E(T) + P(T)] ± 1.2 [0.25WL]
	1.5 [DL + E(T) + P(T)] ± 1.5 [0.25 WL]
OPERATING	1.5 [DL + IL + E(O) + P(O) + TA ± TL]
	1.5[DL + P(O)] + 1.2[E(O) + BP + VL + TA] ± 1.2TL

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Load Condition	Load Combination
	$1.5IL + 1.2 [DL + E(O) + VL + P(O) + TA] \pm 1.2TL$
	$1.2 (DL + E(O) + BP + H) + 1.5IL$
	$1.5 [DL + E(O) + P(O) + TA \pm TL] \pm 1.5WL$
	$1.2 [DL + IL + E(O) + P(O) + TA] \pm 1.2TL \pm 1.2WL$
	$0.9 [DL + E(O) + P(O) + TA \pm TL] \pm 1.5WL$
	$0.5IL + 1.2 [DL + E(O) + BP + P(O) + TA] \pm 1.5WL$
	$1.5 [DL + E(O) + P(O) + TA \pm TL] \pm 1.5SL$
	$1.2 [DL + 0.5IL + E(O) + P(O) + TA] \pm 1.2TL \pm 1.2SL$
	$0.9 [DL + E(O) + P(O) + TA \pm TL] \pm 1.5SL$
	$0.5IL + 1.2 [DL + EO + BP + PO + TA] \pm 1.5SL$

Load Combinations for Serviceability check for Pipe rack / Open Technological Structures

Load Condition	Load Combination
ERECTION	$DL + E(E) + P(E)$
	$DL + E(E) + P(E) + IL$
	$DL + E(E) + P(E) \pm WL$
	$DL + IL + E(E) + P(E) \pm WL$
TEST	$DL + E(T) + P(T)$
	$DL + E(T) + P(T) + IL$
	$DL + E(T) + P(T) \pm 0.25WL$
	$DL + E(T) + P(T) + 0.5IL \pm 0.25WL$
	$DL + 0.5IL + ET \pm 0.25WL + PL + Hd$
OPERATING	$DL + E(O) + P(O) + TA \pm TL$
	$DL + IL + E(O) + P(O) + TA \pm TL$
	$DL + E(O) + BP + VL + P(O) + TA \pm TL$
	$DL + IL + E(O) + VL + P(O) + TA \pm TL$
	$DL + IL + E(O) + PL + Hd \pm TL$
	$DL + E(O) + P(O) + TA \pm TL \pm WL$

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Load Condition	Load Combination
	DL + IL + E(O) + P(O) + TA ± TL ± WL
	DL + 0.5IL + E(O) + BP + P(O) + TA ± WL
	DL + 0.5IL + E(O) + PL + Hd ± TL ± WL
	DL + EO + PO + TA ± TL ± SL
	DL + 0.5IL + EO + PO + TA ± TL ± SL
	DL + 0.5IL + EO + BP + PO + TA ± SL
	DL + 0.5IL + EO + PL + Hd ± TL ± SL
MAINTENANCE (for exchangers only)	DL + 0.5IL + E(E) + P(E) + BP
	DL + IL + EO + BP + H

Load Combinations for RC / Steel Member Design.

Load Condition	Load Combination
ERECTION	1.5 [DL + IL + E(E) + P(E)]
	1.2 (DL + IL + E(E) + P(E)) ± 1.2 WL
	1.5 (DL + E(E) + P(E)) ± 1.5 WL
TEST	1.5 [DL + IL + E(T) + P(T)]
	1.2 [DL + 0.5IL + E(T) + P(T)] ± 1.2 [0.25WL]
	1.5 [DL + E(T) + P(T)] ± 1.5 [0.25 WL]
	1.5 [DL + IL + ET + PL + Hd] ± 1.5 WL
OPERATING	1.5 [DL + IL + E(O) + P(O) + TA ± TL]
	1.5 [DL + P(O)] + 1.2[E(O) + BP + VL + TA] ± 1.2 TL
	1.5IL + 1.2 [DL + EO + VL + PO + TA] ± 1.2 TL
	1.5 [DL + IL + E(O) + PL + Hd] ± 1.5 TL
	1.5 [DL + E(O) + P(O) + TA ± TL] ± 1.5 WL

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Load Condition	Load Combination
	$1.2 [DL + IL + EO + PO + TA \pm TL] \pm 1.2 WL$
	$0.9 [DL + E(O) + P(O) + TA] \pm 0.9 TL \pm 1.5 WL$
	$1.2 [DL + IL + E(O) + P(O) + TA] \pm 1.2 TL \pm 1.2 WL$
	$1.5 [DL + E(O) + P(O) + TA \pm TL] \pm 1.5 SL$
	$1.2 [DL + 0.5 IL + E(O) + P(O) + TA] \pm 1.2 TL \pm 1.2 SL$
	$0.9 [DL + E(O) + P(O) + TA] \pm 1.5 TL \pm 1.5 SL$
	$1.2 [DL + IL + E(O) + PL + Hd] \pm 1.2 TL \pm 1.2 SL$



Also load combinations specified in all relevant codes to be considered for RC / steel structure member design.

4.4 Shed Type building with Crane loads

Load Combinations for check for stability of foundation and soil bearing pressure for foundations / Pile Capacity and deflection Check.

Load Condition	Load Combination
NORMAL	$DL + IL + CRL$
WIND**	$DL + 0.5 IL \pm 0.5 WL + CRL$
	$DL + 0.5 IL \pm WL + 0.5 CRL$
SEISMIC	$DL + IL + CRL \pm 0.5 SL$
	$DL + 0.5 IL + 0.5 CRL \pm SL$

Load Combinations for RC Structure Member Design.

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Load Condition	Load Combination
NORMAL	1.5 DL + 1.5 IL + 1.5 CRL
WIND**	1.2 DL + 1.2 IL \pm 0.6 WL + 1.2 CRL
	1.5 DL + 0.75 IL \pm 1.5WL + 0.75 CRL
SEISMIC	1.2 DL + 1.2 IL \pm 0.5 SL + 1.2 CRL
	1.5 DL + 0.75 IL \pm 1.5 SL + 0.75 CRL

(**) Wind Load check with Parallel and Perpendicular to Ridge.


4.5 For General Buildings & Buildings (with or without Equipment) and their Foundations

Load Combinations for Foundation sizing.

Load Condition	Load Combination
NORMAL	DL + IL
	DL + IL + Hd
	DL + IL + EE
	DL + ET
	DL + IL + EO
	DL + Bp
WIND	DL \pm WL
	DL + IL \pm WL + Hd
	DL + EE \pm 0.8WL
	DL + EO \pm 0.8WL

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Load Condition	Load Combination
SEISMIC	DL + IL + EE \pm 0.8WL
	DL + 0.8IL + ET \pm 0.8WL
	DL + 0.8IL + EO \pm 0.8WL
	DL \pm SL
	DL + 0.5IL \pm SL + Hd
	DL + EE \pm 0.8SL
	DL + EO \pm 0.8SL
	DL + IL + EE \pm 0.8SL
	DL + 0.8IL + ET \pm 0.8SL
	DL + 0.8IL + EO \pm 0.8SL

Load Combinations for Deflection Check.



Load Condition	Load Combination
NORMAL	DL + IL
WIND	DL \pm WL
	DL + 0.8 IL \pm 0.8 WL
SEISMIC	DL \pm SL
	DL + 0.4 IL \pm 0.8 SL

Load Combinations for Reinforcement design for Buildings.

Load Condition	Load Combination
NORMAL	1.5 DL
	1.5 [DL + IL]
	1.5 [DL + IL + Hd] + Bp
	1.5 [DL + IL + EE]
	1.5 [DL + ET]
	1.5 [DL + IL + EO]
WIND	0.9 DL \pm 1.5 WL
	1.2 [DL + IL] \pm 1.2WL
	1.2 [DL + IL + Hd] \pm 1.2 WL

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Load Condition	Load Combination
	1.5 DL \pm 1.5 WL
	1.5 [DL + EE] \pm 1.5 WL
	0.9 [DL + EE] \pm 1.5 WL
	1.5 [DL + EO] \pm 1.5 WL
	1.2 [DL + IL + EE] \pm 1.2 WL
	1.2 [DL + IL + ET] \pm 1.2 WL
	1.2 [DL + IL + EO] \pm 1.2 WL
SEISMIC	0.9 DL \pm 1.5 SL
	1.2 DL + 0.6 IL \pm 1.2 SL
	1.2 [DL + IL + Hd] \pm 1.2 SL
	1.5 DL \pm 1.5 SL
	1.5 [DL + EE] \pm 1.5 SL
	0.9 [DL + EE] \pm 1.5 SL
	1.5 [DL + EO] \pm 1.5 SL
	1.2 [DL + IL + EE] \pm 1.2 SL
	1.2 [DL + IL + ET] \pm 1.2 SL
	1.2 [DL + IL + EO] \pm 1.2 SL

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5. Design of Foundations / Footings

5.1 General Requirements:

- 1) Foundation design should be as per Geo-Technical Data. Minimum depth of foundation for all structures should be as per Geo-Technical Data.
- 2) The design ground water level should be as per the Geo-Technical Data and the hydrostatic pressure should be adequately accounted for in design.
- 3) Pile capacities (compression, shear and uplift/tension) shall be per Geotechnical Recommendations.
- 4) For transient loadings, e.g. wind/seismic, SBC (safe bearing capacity) shall be considered based on shear criteria instead of settlement criteria.
- 5) Permissible increase in SBC/ Pile capacities (for compression, shear and uplift/tension) shall be as per the Geotechnical Recommendations.
- 6) Under blast (due to hydrocarbon explosion) load combinations the SBC of soil shall not exceed 2.0 times allowable static bearing pressure of soil.
- 7) Under blast (due to hydrocarbon explosion) load combinations Pile capacity shall not exceed 1.5 times the permissible capacity under compression, tension and shear modes.
- 8) Foundation for vibrating equipment shall be kept independent of building floors/ foundations and other adjacent foundations.
- 9) Foundation for tanks shall be of RCC ring wall type, as required from anchorage or counterweight considerations.
- 10) For load combinations including earthquake, the Safe Bearing Pressure of Soil and the Safe Bearing Load of piles shall be increased as permitted in IS:1893.
- 11) In reinforced and plain concrete footings, the thickness at the edge shall be not less than 150 mm for footings on soils, nor less than 300 mm above the tops of piles for footings on piles.



5.2 Stability against Overturning & Sliding

Foundations should be checked for stability against overturning & sliding, while checking against sliding/overturning, the following should be considered.

Minimum Stability Ratio i.e. Factor of safety required against overturning (MR/MO) both being calculated at the leading edge of the foundation considering all forces and moments.

MR = Resistant moment and

MO = Over turning moment should be restricted to the followings for the worst load case combination.



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The resistance to sliding should be calculated from the following, where applicable: -

- ◆ Foundation / soil friction
- ◆ Passive soil resistance to the side of the foundation
- ◆ Passive soil resistance of soil bearing against keys

FOUNDATION DESIGN - FACTORS OF SAFETY

Type Of Structure	Minimum Factor of Safety Against Overturning				Minimum Factor Of Safety Against Sliding	
	Erection Condition		Operating Condition			
	With Wind Or Seismic	Without Wind Or Seismic	With Wind Or Seismic	Without Wind Or Seismic	With Wind or Seismic	Without Wind or Seismic
All Buildings/ Structures /Equipments in Units	1.5	1.5	1.5	2.0	1.5	1.75
Over Head Water Tank	1.5 (empty) 2.0 (full)	-	1.5 (empty) 2.0 (full)	-	1.5	-
Flood Light Mast	1.5	-	1.5	-	1.5	-
Retaining Wall / Dyke wall	-	-	1.5	2.0	1.5	1.75
Flare Supporting Structure	1.5	-	1.5	-	1.5	-
Blast Resistant Structures	-	-	1.5	2.0 Or 1.2#	1.5	1.5
Transmission Tower / Switch Yard Structure	1.5	2.0	1.5	2.0	1.5	1.75
Pipe Rack (Offsite)	1.5	2.0	1.5	2.0	1.5	1.75

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With blast pressure.

Percentage weight of overburden shall be taken as 100% & to be considered on projected plan area of footing. In case area is paved, overburden should be based on NGL (for area under filling) or 600mm below HPP whichever is lower. In case of unpaved area, it should be w.r.t. FGL.

Grade of concrete to be used in foundation should in general be as per the philosophy adopted for the entire structure. However, minimum cement content, type of cement & any remedial actions required for foundation due to aggressiveness of sub soil water should be as per the Geo-Technical Data.

5.3 Stability against Uplift

In case area is paved, overburden shall be based on NGL (for area under filling) or 600mm below HPP whichever is lower. In case of unpaved area, it shall be w.r.t FGL.


Minimum factor of safety against Uplift shall be 1.2 for all structures. (Note: In case of sumps, lining weight should not be included).

In the design of foundations, the upward pressure of water, where applicable, should be taken as the full hydrostatic pressure applied over the whole area. The hydrostatic head shall be measured from the underside of construction. The beneficial load of backfill can be included only in circumstances where it will never be removed.

5.4 Allowable loss of contact area

Allowable loss of contact area between underside of foundation and soil (due to resultant overturning moment) under different loading conditions should be as given below.

Sr.No.	Load Combination	Allowable % Loss of Contact Area
1	For Foundations on soils	
a	Operating with or without LL, for worst cases	0 to 10%
b	Operating with Wind or Earthquake (with or without LL, for worst cases)	Up to 25%
2	For Foundations on Rocks	
a	Operating with or without LL, for worst cases	0 to 20%
b	Operating with Wind or Earthquake (with or without LL, for worst cases)	Up to 30%

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5.5 Allowable Net SBC based on the settlement criteria:

Allowable Net Safe Bearing Capacity (SBC) of soil for isolated/ raft/pile/ tank foundations shall be based on the settlement criteria for dead plus imposed load conditions, as follows:

- For foundations in Unit areas, Utility areas and foundations of Plant buildings, settlement shall be considered as 25mm.
- Allowable total settlement of foundation for Machine foundations and critical equipment with interconnected piping– 25 mm.
- For foundations of Non-plant buildings, settlement shall be considered as 40mm.
- For Raft foundations, settlement shall be considered as 40mm.
- For Mounded Bullets, differential Settlement of 25 mm & overall settlement of 60mm shall be considered for design.

Beneficial load of backfill can be included only in circumstances where it will never be removed.

5.6 Settlement Criteria for Tanks:

Design/details given in this document are minimum requirements and contractor can make only upward revision, if necessary. Contractor shall offer performance guarantee for the satisfactory performance of the tanks. Total settlement at edge and differential settlement along the periphery (between any two consecutive settlement observation points) should not exceed the following criteria unless otherwise stated in geotechnical report

Type of Roof	Total Settlement at Edge	Differential settlement along periphery (local slope between any two consecutive settlement observation points)
Fixed / Cone Roof Tanks	As given in geo technical report	1 in 300
Floating Roof Tanks	As given in geo technical report	1 in 500

5.7 Soil and hydrostatic pressure on walls below grade:

In the design of walls below grade, provision should be made for the lateral pressure of adjacent soil. Due allowance should be made for possible surcharge from fixed or moving loads. When a portion or whole of the adjacent soil is below a free water surface, computations should be based on the weight of the soil diminished by buoyancy, plus full hydrostatic lateral pressure.

The lateral pressure from surcharge loads should be taken in addition to the lateral earth pressure loads.

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5.8 Foundations for Rotating and Reciprocating Equipment


a) General:

- 1) Foundation for rotating and reciprocating equipment such as turbines, engines, compressors and generators should be designed to secure the dynamic stability of the foundation system, as well as the static stability.
- 2) Dynamic stability for foundation supporting heavy vibrating equipment like the following should be secured by dynamic analysis in general:
 - ◆ Heavy vibrating equipment,
 - ◆ Equipment sensitive to vibration,
 - ◆ Equipment causing large dynamic force

b) General Requirements for Design:



Following minimum requirements should be taken into account for foundation design in principle.

- 1) Foundation for heavy vibrating equipment should be kept independent of building floors/foundations and other adjacent foundations.
- 2) The weight of foundation slab should not be less than the combined weight of the structure and the machine.
- 3) Foundation should be of uniform rectangular/ square shape. Beams and columns of foundations should be of uniform rectangular/ square shape.
- 4) The horizontal eccentricity, in any direction, between the center of gravity of the machine - foundation system and the center of base contact area or centroid of the pile group, should be within 5% for block foundations and 3% for frame foundations. However, in highly compressible soils no eccentricity should be permitted.
- 5) The geometric layout of the foundation and structure should be basically symmetric with respect to the vertical plane passing through the rotational axis of the equipment.
- 6) Mechanical equipment foundations should satisfy the requirements of IS: 2974 and any other parameters as per machine vendors.
- 7) Foundation block extensions supporting auxiliary equipment requiring rigid positioning with respect to the main equipment should be detailed to act integrally with the block.
- 8) Generally, foundations and structures supporting rotating machinery should be so proportioned that their natural frequency should not fall within the range of 0.8 to 1.2 of normal operating speed of the equipment.
- 9) Design should be carried out such that amplitude of vibration during normal operation or other critical conditions should not exceed the allowable amplitude specified by the equipment manufacturer or IS: 2974, whichever is more stringent. The above design criterion may be

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omitted for centrifugal pumps and fans and other minor rotating equipment weighing less than 1 ton or if the mass of the rotating parts are less than 1/100th of the mass of foundation installed directly on concrete foundation provided that the weight of foundation is not less than 3 times of the equipment weight. In such cases, dynamic analysis is not necessary.

- 10) Where deviations (resulting from inaccuracies in soil parameter measurements, approximations in design method, etc.) from calculated natural frequencies, leading to amplitudes in excess of specified limits, are foreseen, provisions for increasing foundation mass without removal of the machine and without affecting surrounding space availability or connected piping should be made, if possible.
- 11) Machine foundations should satisfy the following requirements:
Minimum reinforcement as per requirements of IS: 2974 should be provided unless required otherwise by design. All units of the foundation system, except foundation raft should be provided with symmetric reinforcement on opposite faces, even if not required by design considerations.
- 12) No common raft should be designed for set of machines.
- 13) The soil stress below foundations under dead loads should not exceed 80% of the allowable soil bearing capacity, or safe load on pile, for static loading.
- 14) It should be ensured that there is no transfer of vibrations from machine foundations to any part of the adjoining structures. Such foundations should be isolated from other foundations and floor /paving slab by providing adequate gap between the foundation faces and surrounding soil mass; the gap should be filled with bitumen impregnated fiber board unless otherwise stated in the item.
- 15) The foundations and its superstructure should be separated from adjacent floors and platforms. Clear air gap should be provided in superstructure to avoid transmission of vibration to adjacent structures. Special note should be given on the drawing in this respect, and suitable details should be shown as required.
- 16) Block foundations for machine should be cast in a single concreting operation.
- 17) Foundations consisting of various blocks of the same machine seated on a common foundation raft may be provided with a single, properly designed construction joint at the top of base raft. However, a special note should always be given on the drawing regarding the recommended procedure of construction.
- 18) All faces of the foundation block should be provided with surface reinforcement. Minimum reinforcement diameter in horizontal and vertical directions should be 12Ø, and maximum spacing of bars should not exceed 200 mm.
- 19) For frame foundations, base raft should be cast in a single concreting operation. A properly designed construction joint should be provided between the base slab and columns. The entire superstructure of columns and upper deck should be cast in a continuous concreting operation.

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If height of the frame columns above raft level exceeds 8.0m, an additional construction joint at the junction of columns / top-deck may be provided.

- 20) The location of beams and columns, and their reinforcement should be arranged, as far as possible, symmetrically with respect to the vertical plane passing through the longitudinal axis of the machine.
- 21) The minimum beam depth should be one-fifth of the span and the beam width is normally equal to the width of the column, consistent with anchor bolt requirements, embedded depth, and edge distances etc.
- 22) Weight of base raft of the frame foundation should not be less than the combined weight of the machine and foundation superstructure above the base raft, i.e. columns, top-deck slab/beams etc.
- 23) For frame type of foundations, all the elements of foundations should be provided with top and bottom, two way reinforcements. Reinforcement should be provided on all the faces of beams and columns even if not required by design calculations. The diameter of main bars in column / beam should be so selected to limit the maximum spacing of bars to 150 mm.
- 24) For tie beams below ground, consideration shall be given for designing, additionally, for superimposed load and/or traffic loading, where applicable.

c) Dynamic Analysis:

General

Dynamic analysis should be performed by suitable and approved method so that dynamic feature can be evaluated correctly.



Following effects should be taken into account:

- ♦ Dynamic features of subsoil
- ♦ Dynamic features of supporting foundation system
- ♦ Dynamic effect of the foundation system
- ♦ Dynamic forces of equipment

All machine foundations shall satisfy two fundamental criteria that resonance does not occur between the frequencies of the pulsating loads and natural frequency of foundation/soil system and also the amplitude of vibration does not exceed safe limits.

Data of dynamic load to be used for the dynamic analysis should be supplied by Equipment Supplier and should state unbalanced force due to:

- ♦ Eccentricity of dynamic mass of rotating equipment.
- ♦ Different crank arrangement of reciprocating equipment.

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Evaluation of Dynamic Analysis:

Foundations should be so designed that natural frequency of the foundation system should not resonate with the following:

- ♦ Operating speed of the motor.
- ♦ Operating speed of the machine.
- ♦ 2 times operating speed of the machine
(This condition should be complied only when the manufacturer has furnished the unbalanced forces related to 2 times the operating speed of the machine)
- ♦ Critical speed of the machine (for centrifugal machines)
- ♦ Natural frequency of the foundation should be $\pm 20\%$ away from the above mentioned frequencies. However, amplitudes of vibration of the foundation block should always be checked to be within permissible limits.

Allowable amplitude due to dynamic load:

Amplitude of the foundation systems for vibrating equipment should be calculated through dynamic analysis by using dynamic load supplied by supplier and the allowable amplitude should conform to supplier's requirement.


If supplier's requirement on amplitude is not specified, Permissible Amplitudes mentioned in IS: 2974, Part-1 shall be adopted.

Unless otherwise specified foundation design shall follow general criteria indicated below.

CRITERIA		APPLICATION
Dynamic Analysis	* Allowable amplitude, Natural frequency of foundation	Rotating : $P \geq 400$ KW Reciprocating : $P \geq 100$ KW
	Natural frequency of foundation	Rotating : $P \geq 100$ KW Reciprocating : $P \geq 40$ KW
Foundation weight control	More than 3 x equip. weight	Rotating : $P < 100$ KW
	More than 5 x equip. weight	Reciprocating : $P < 40$ KW

P = Rated Power output of equipment (unit KW).

*If the supplier's requirement is available, it shall be considered.


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5.9 Pile Foundations:

- 1) Piles should be designed as per IS: 2911(part 1 to 4) such that the Safe Working Load on the piles should not be exceeded based on pile capacity value arrived from soil parameter available in referred soil report.
- 2) Safe working load on piles should be confirmed by the Piling CONTRACTOR as per specification or by conducting confirmatory pile test /soil test.
- 3) The increase in Safe Working Load permitted due to wind /earthquake should apply equally to uplift and shear conditions, subject to confirmations by the piling contractor in respect to the particular piling system.
- 4) Design capacity should be established by conducting sufficient number of initial load tests. Routine pile load tests should be carried out as per relevant IS code. When any major machinery is to be supported on piles, behavior of the piles under dynamic loading conditions as established by necessary field tests should be considered.
- 5) The capacity of pile groups should be obtained by applying appropriate group efficiency factors.
- 6) Where piles pass through filled ground the available pile safe working load should be suitably reduced to account for negative skin friction caused by settlement of fill. Where suitable consideration should be given to reducing draw down effects by slip coating the piles.
- 7) While computing horizontal capacity, piles should be treated as fixed head or free head depending on the degree of fixity at the top. **Top of pile cap should be minimum 1.5m below the ground level.**
- 8) Driven cast in-situ piles should have safe distance (as per IS Code requirement) from the existing structure to avoid any damage due to vibration.
- 9) Minimum embedment of piles in pile caps should be 100 mm.

5.10 Blast Resistant Construction:

- 1) Minimum thickness of Reinforced Concrete Blast walls should be 250mm.
- 2) R.C.C. blast walls should be taken up to 1.5m below FGL or up to top of footing whichever is lower, maintaining the wall thickness and reinforcement same as in superstructure.
- 3) Members should be designed for reversal of stresses.
- 4) Minimum reinforcement in wall in each face should be 1% (as total in both directions) of gross cross-sectional area or as calculated from structural design considerations. Maximum reinforcement in each face should not exceed 2%.
- 5) Roof slab shall be doubly reinforced. Minimum reinforcement in roof slab in each face should be 1% (as total in both directions) of gross cross-sectional area or as calculated from structural design considerations.
- 6) Minimum bar diameter in walls and slab should be 12mm.

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- 7) Maximum spacing of bars in walls and roof slab should not exceed 150mm c/c.
- 8) The structure shall be designed on shear wall concept with roof acting as a diaphragm that transfers the transverse loads to the side shear wall & columns in proportion to their stiffness. Internal partitions & division walls shall not be designed as shear wall.
- 9) Design bearing pressure of soil shall not exceed twice the allowable static bearing pressure of soil for blast load combination only.
- 10) Allowable Pile capacity in Compression, Uplift & Shear may be increased by 50% under blast load combination.

5.11 Anti Termite Treatment:

All buildings coming in units, offsite and utility areas shall be provided with Post Constructional anti-termite treatment shall be done as per IS: 6313 and IS: 8944.

5.12 Foundation Bolts:

Minimum Cover to Foundation Bolts: Minimum distance from the centerline of foundation/anchor bolt to edge of pedestal should be the maximum of the following:

- 1) Clear distance from the edge of the base plate/base frame to the outer edge of the pedestal should be minimum 50mm.
- 2) Clear distance from the face of pocket to the outer edge of the pedestal should be 100mm.
- 3) Clear distance from the edge of the sleeve or anchor plate to the edge of pedestal should be 100mm.

The tension capacities of anchor bolts shall be worked out based on the bolt to bolt spacing and the distance between anchor bolt to the edge of concrete. If required, additional reinforcement around anchor bolts shall be provided in the concrete pedestal.

In case of no tension loads in the anchor bolts of equipment such as small towers, tanks, heat exchangers, pumps, blowers, compressors, etc. anchor bolts shall generally be set in anchor boxes unless embedment is required.

Anchor bolts for heavy towers, which are subject to pull out force, shall be embedded into the foundation at the time of placing concrete using templates.

Minimum size of bolts shall be 16mm (10mm & 12mm can be used for miscellaneous structures). Minimum center-to-center distance of bolts shall be 2.5 times nominal diameter.

All anchor bolts shall also be provided with a nut and lock nut.

Sleeve type anchor bolts shall be used preferably.

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5.13 Expansion Joint:

Expansion joints in concrete structures shall be provided at 30-35 m intervals. The expansion joint shall be provided preferably by way of twin columns on a common foundation. Sliding joints shall be avoided as far as possible. Design and installation of Joints shall be as per IS: 3414.

5.14 Height of Pedestals:



Minimum height of pedestals from finished paving / floor/ ground:

Sr. No.	Description	Pedestal Height
1	Building plinth	600 mm above finished ground level.
2	Pedestals for structural columns	300 mm (min.) above the finished floor level / HPP
3	Covered area (building etc.)	150 mm (min.) OR as indicated in drawing
4	Storage tank foundation	As per equipment layout
5	All equipment supporting foundations /pedestals	
a	Open area	As required but not less than 500 mm
b	Covered area	As required but not less than 150 mm
6	Stair Pedestals	150 mm (min.) OR as indicated in equipment layout drawing
7	Ladder pedestals	150 mm

5.15 Grouting & Minimum Grout Thickness:

- 1) Unless otherwise specified by equipment manufacturers, top of foundations except for local foundations should be provided with an allowance for grouting as specified below:

Process Columns (equipment), unless otherwise required in equipment datasheet	Min. 50 mm
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Foundation for large heavy duty compressors, generator, etc	50 mm
Foundation for big towers (>20 m)	50 mm
Other foundation bases for columns, trusses, etc	30 mm



- 2) All anchor bolt sleeves/ pockets and spaces under column bases, shoe plates etc. shall be grouted with free flow, non shrink (premix type) grout with 28 day minimum cube crushing strength of 40 N/sq mm.
- 3) Nominal thickness of grouting between the top of concrete foundation levels and the underside of base plates should be 30 mm, for up to a plate dimension of 500 mm and 50 mm for plate sizes in excess of 500 mm - grout edges & sides shall be splayed at 45 degrees.
- 4) The thickness of grout should not be less than 30 mm and should not be more than 50mm (Unless otherwise required in equipment datasheet).
- 5) Neat cement should not be used for grouting under any condition.
- 6) Grouting requirement for machines and equipments are not covered here. The same should be governed by vendor's requirement.
- 7) Grout shall be finished at a slope of 1:1 from the Bottom of Base Plates to the finished concrete level.
- 8) Non-Shrink Cement Base Grout, as per specifications shall be applied for major Steel Structures and Stationary Equipment's unless Epoxy Grout is used.
- 9) Ordinary cement sand (1:2) grout should only be used under the base plates of cross-overs, short pipe supports (not exceeding 1.5 m height) and small operating platforms (not exceeding 2 m height) not supporting any equipment.
- 10) For rotating equipment bases, (above 300 kW rating) grout shall be as per requirements of equipment vendor; or in absence of any stated requirements, grout type shall be Non-Shrink Epoxy Grout.

6. **Plinth Protection:**

Each building shall be provided with 1.0 m wide (100mm high from top of Approach Road Level) concrete M15, 75 mm thick laid on 75 mm thick M7.5 concrete with brick bats all round as plinth protection, with building drain around the building. Paving shall be sloped for a rapid run off of rain water away from the building.

7. **Ramps:**

Ramps for building entrance shall be cast in situ R.C.C designed as a grade slab and the slope of ramps shall not be less than 1 in 10. Minimum thickness of the slab shall be 150mm.

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Ramps for physically challenged persons shall be designed in accordance with IS: 4963 and National Building Code.

8. Covering of Pits / Basins:

- 1) Open pits and basins without roofing or covering should have safety railings. Stepladders should also be provided for the pits and basins having a depth of more than 1 m.
- 2) The minimum 600 mm diameter cover for access should be provided for pits and basins with roofing.

9. Flooring Details for Buildings & Sheds:

The specifications given hereunder should be adopted for the non- suspended ground floor slabs for buildings & sheds as categorized in following table:

Sr. No.	Description		Flooring Type		
			I	II	III
1.1	Sub Grade	Earth fill base compacted to 95% dry density	To be provided	To be provided	To be provided
1.2		Compacted layer of sand/ boulder packing over thoroughly compacted Earth fill (in mm)	200mm thick	200mm thick	150mm thick
2	Structural Grade Slab	Lean concrete 1:5:10 over sand layer (in mm)	50mm thick	50mm thick	50mm thick
		Structural Non suspended slab in M20 Grade concrete (Reinforced with 8mm dia bars @ 200mm c/c both ways) over lean concrete	150 mm thick slab with reinforcement placed centrally	150 mm thick slab with reinforcement placed in 2 layers (at top & bottom)	100 mm thick slab without reinforcement
3	Finish	Floor Finish	As per Architectural Details		


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- a) Flooring details as given above shall be adopted for the non-suspended ground floor slabs for buildings & sheds only as categorized for various flooring types.
- b) Flooring Type I shall be considered for Control Rooms, Satellite Rack Rooms, Sub-Station, Pump houses, Utility Compressor Houses, Parking Areas, Stores, Porches.
- c) Flooring Type II shall be considered for Ware Houses, Workshops, Cement Godowns, Fire Stations, Process Compressor Houses.
- d) Flooring Type III shall be considered for Administration, Laboratory, Canteen, Time Office, Gate House, Training Centre, Guest House, Residential buildings.
- e) Floor finish for all the above three types of flooring shall be as per Engineering Design Basis - Architecture.
- f) Reinforcement steel shall be as per other relevant clause of this document.
- g) Expansion gap if provided in the building shall be provided in flooring also.
- h) Outdoor pavements shall be as per Engineering Design Basis – General Civil. However 20 mm gap to be provided between floor slab and equipment foundation/ column and shall be sealed using joint sealing compound.

10. Special Considerations for RCC Structures:

10.1 General/design methods:

- a) All buildings, structures, foundations, machine/equipment foundations, liquid retaining/storage structures, trenches, pits etc. should be of RCC and designed based on the following IS Codes (latest revision with all amendments issued there to) in general and other relevant IS Codes applicable: IS:456, 875, 1893, 1904, 2911, 2950, 2974, 3370, 4091, 4326, 4991, 4995, 4998, 5249, 6403, 8009, 13920.
- b) Only limit state method as per IS:456 should be followed in the design unless otherwise specified elsewhere in this document for special structures.
- c) All structures shall be of frame type construction, with ductile detailing as per IS: 13920.
- d) Bi-polar concrete penetrating corrosion inhibiting admixture shall be used in concrete works exposed to moderate to Extreme environment based on the environmental exposure condition given in IS: 456.
- e) Where the specified design depth of groundwater table so warrants, all underground pits, tunnels, basements etc. (excluding appurtenances of storm water/effluent collection system, cable trench, pipe trench) should be of leak-proof RCC construction using approved make of waterproofing compounds.
- f) All liquid retaining/storage RCC structures should be leak-proof and designed as un-cracked section (or with limited crack width in limit state design) as per IS:3370. However, the parts of such structures


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not coming in direct contact with the liquid should be designed according to IS:456 except ribs of beams of suspended floor slabs, counter forts of walls (located on the side remote from the liquid) and roof which should be designed as un-cracked section. No increase in permissible stresses in concrete and reinforcement should be made under wind or seismic conditions for such structures.

- g) All liquid retaining/storage RCC structures/Sludge pits etc. shall be lined with HDPE/LDPE lining or any other suitable impermeable media such that no leaching takes place at any point of time. Adequate safety measures shall also be implemented to protect the structures/pits from getting breached. Also the lining shall meet the process requirement.
- h) The walls and base slabs of liquid retaining/storage structures should be provided with reinforcement on both faces for thickness greater than or equal to 150mm. In all liquid retaining structures, PVC water bars (minimum size 230mm wide x 5mm thick) should be provided at each construction joint (horizontal and vertical).
- i) The coating requirement for underground RCC structures which are in contact with soil, shall be in line with that required by Codes of practices and other recommendation of confirmatory soil investigation.
- j) Coating requirement of Liquid retaining structures like Ct cell, reservoir etc shall be as per IS:6494.
- k) Hot/cold water basin and other primary framing members of Cooling towers or similar liquid retaining structures which remain constantly in contact with water (stored/sprayed) should be designed as un-cracked sections.
- l) Following conditions shall be also considered for design of liquid retaining structures, basement, trenches and other underground structure:
 - i. Only water pressure from inside and no earth pressure, groundwater pressure or surcharge from outside wherever such a condition is likely to exist either in operation or during installation / testing.
 - ii. Earth pressure, surcharge pressure or ground water pressure from outside and no water pressure from inside.
 - iii. Base slab shall also be designed for the empty condition during construction and maintenance stages with maximum ground water table.
 - iv. Intermediate dividing walls of pump sumps shall be designed considering water in one pump sump only and the other sump being empty for maintenance.

10.2 Concrete:

- a) The minimum grade of reinforced cement concrete to be used for superstructure & substructure (in case otherwise specified in Geotechnical Recommendations, higher grade shall be followed for substructure) shall be M30 (design mix) as per IS:456 based on Severe exposure condition.
- b) Minimum cement content for concrete in foundation shall be as per Geotechnical Recommendations document.

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- c) Plain Cement Concrete (PCC) mud mat of grade M20 (nominal mix) of minimum 150 mm thickness shall be provided under all masonry wall foundations.
- d) Plain cement concrete of grade M20 (nominal mix) of minimum 40 mm thickness shall be provided as damp proof course at plinth level of all masonry walls. Integral waterproofing compound conforming to IS:2645 shall be mixed with concrete (as per manufacturer's specifications) and coated with bitumen emulsion.
- e) Crystalline water-proofing compound of approved make shall be mixed with concrete for all liquid retaining/ leak-proof structures.
- f) Minimum grade of concrete for General Civil work shall be as specified in Engineering Design Basis – General Civil.
- g) From durability considerations, the minimum cement content and maximum free water-cement ratio shall be as per table given under relevant other clause of this document.
- h) However, the maximum cement content shall not exceed 450 kg/cum.



10.3 Minimum Cover to Main Reinforcement:

Unless specified otherwise, actual concrete cover should not deviate from required nominal cover by +10 mm.

Nominal cover to meet durability requirement and specified period of fire resistance shall be as per IS: 456.

Nominal cover should be as per IS: 456, however the following minimum clear cover should be provided for RCC works.

Sr.No.	Description	Minimum clear cover
1	Slab (roof & floors, canopy, cantilever, waist slab)	25 mm
2	Beam (roof, floor, tie & lintel)	45 mm or dia. of bar whichever is greater
3	Column	50 mm above FGL 75 mm below FGL
4	Retaining wall, Basement and Pit Wall	
a	Face in contact with earth	50 mm
b	Free face	45 mm or dia. of bar whichever is greater

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5	Liquid retaining structure	
a	Face in contact with liquid	50 mm or dia. of bar whichever is greater
b	Face away from liquid but in contact with earth	50 mm
c	Free face	45 mm or dia. of bar whichever is greater
6	Foundation slab, base slab, pedestal, plinth beam	75 mm
7	Pile Cap	
a	Bottom face	125 mm
b	Top & Sides	75 mm

The above requirements shall not be applied to concrete construction of trench, local foundation, minor platform foundation, sump pit/ manhole, paving and other miscellaneous concrete construction, for which minimum clear cover shall be 25 mm.

Designer shall ensure that the reinforcement cover, mentioned above shall in no case be lower than that required by Codes of practices as per exposure condition of site and other recommendation of confirmatory soil investigation report.

10.4 Minimum Thickness of Structural Concrete Elements:

The following minimum thickness should be followed:

Sr.No.	Description	Minimum Thickness
1	Footings (all types with or without beams) (Note: Tapered footings should not have thickness less than 150mm at the edges. Minimum average thickness should not be less than 300mm)	300 mm
2	Pile Cap	500mm
3	Liquid Retaining / Leak-proof structure / Basement / Underground Pit:	

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a	Walls	150 mm
b	Base slab with beams	200 mm
c	Base slab without beams	300 mm
4	Slab thickness in Raft foundations with beam & slab construction	225 mm
5	Floor/Roof Slab, Walkway, Canopy Slab	150 mm
6	Cable/Pipe Trench/Laundry Walls & Base Slab	125 mm
7	Parapet	125 mm
8	Louvre / Fin	125 mm
9	Precast Trench Cover/Precast Floor Slab	125 mm
10	Louvre (in contact with liquid)	125 mm

10.5 Minimum Bar Diameter:

Minimum bar diameter shall be as follows:

Piles – Main Bars	12 mm
Piles – Ties	8 mm
Major Foundation	12 mm
Block Foundation - Main Bars & Tie Bars	12 mm
Minor Foundation (Local foundation etc.)	12 mm
Column, Pedestal - Main Bars	12 mm
Column, Pedestal – Ties	8 mm
Beam - Main Bars	12 mm
Beam - Anchor Bars	10 mm
Beam – Stirrups	8 mm
Slab & Wall - Main Bars	10 mm
Slab & Wall - Distribution Bars	8 mm

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Minor Elements such as Chajjas, Lintel, Parapet etc.	8 mm
Slab and Wall for Blast Resistant building	12 mm

10.6 Deflections:

Deflections in concrete structures shall in generally be limited by adherence to the limits on span by depth ratio for beams and slabs and length to lateral dimension ratios for columns as prescribed in IS: 456. Where special functional / serviceability requirements or large spans demand actual deflections and / or crack widths shall be calculated and the following limits adhered to:

Total vertical deflection due to all loads including the effects of temperature creep and shrinkage	Span/250
Crack width (for non-liquid retaining structural)	0.3 mm
Total horizontal deflection between two floors	Storey height / 200 (for wind) Storey height / 250 (for earthquake)

10.7 Bar Spacing:

Minimum and maximum bar spacing for Foundations, Slabs, Stirrups for Beams, Ties for Columns, Pedestals, Walls etc. should be 100 mm and 300 mm respectively. Bar spacing should be provided in multiples of 5 mm.



10.8 Cathodic Protection of Reinforcement:

Where reinforcement is to be cathodically protected, reference should be made to IS 8062/ BS 7361 for guidance on design and detailing requirements.



11. Special Considerations For Steel Structures:

11.1 General/design methods:

- Design, fabrication and erection of the Steel Structures should be carried out in accordance with the following IS Codes as applicable to the specific structures, viz. IS:800, 801, 802, 806, 814, 816, 875, 1893, 6533, 9178, 9595 etc. Basic consideration of structural frame work should primarily be stability, ease of fabrication/erection and overall economy satisfying relevant Indian Standard Codes of Practice. Simple and fully rigid design as per IS:800 should be used. Where fully rigid joints are adopted they should generally be confined to the major axis of the column member. The minimum grade of reinforced cement concrete to be used for superstructure & substructure (in case otherwise specified in Geotechnical Recommendations, higher grade shall be followed for substructure) shall be M30 (design mix) as per IS:456 based on Severe exposure condition.

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- b) Structural elements continuously exposed to temperatures above 215°C should be designed for reduced stress as per Table 4 of IS:6533 (Part 2) / clause 16.4 (Fig. 24) of IS: 800. The expected temperature of steel components should not be allowed to exceed 400°C.
- c) Fireproofing shall be carried out on all exposed structural steel members, wherever required, in process and Tankage areas as per OISD-164 norms.
- d) Crane gantry girders should generally be of welded construction and of single span length. Chequered plate should be used for gantry girder walkway flooring.
- e) Steel staircases for main approaches to operating platforms should have channels provided as stringers with minimum clear width of 900mm and slope of app. 41 degree. The vertical height between successive landings should not be less than 2.6m nor exceed 4.0 meters. Treads should be minimum 250mm wide made of electro-forged galvanized grating (with suitable nosing) spaced equally so as to restrict the rise as per construction standard. However, for non-important structures like crossovers etc. the minimum width of stair shall be 600 mm.
- f) Hand rails, 1000mm high (from top of grating / top of chequered plate / FFL), should be provided to all walkways, platforms, staircases. Toe plate (100mmx5mm) should be provided for all horizontal hand railing (except for hand railing in inclined portion of staircases). Spacing of uprights should be 1500mm (maximum).
- g) Two types of hand railing should be provided:
 - i. For Tech. structures, walkways, platforms (except platform around/on circular/horizontal vessels), staircases: Top rail, mid-rail and upright should be 32mm dia (NB) galvanized medium grade MS tubes.
 - ii. For platforms around circular vessels: Top rail should be 32mm dia (NB) galvanized medium grade MS tubes but mid rail shall be 50X6 MS flat and vertical post shall be of angle section L50X50X6.
- h) Welded connections should be adopted as far as practicable except for the removable members where bolted connections are required viz. removable members, Galvanized electrical switchyard structures and transmission towers. Field / Site connections shall be bolted. Structural connections should have minimum two bolts of 16mm dia. unless otherwise limited by the size of members.
- i) Dedicated monorail for every pump with driver rating of 75 kw and above shall be provided. The monorail shall be placed longitudinally along the centerline of the pump and its drive.
Monorail and trolley shall also be arranged for pumps with driver rating of 30 to 75 kw. But in such cases, different clusters can be formed with the like pumps and a monorail can be placed across every cluster of pumps over the line joining the CGs of the motors in that cluster.
- j) Minimum capacity of monorail shall be 3 MT or 1.5 times weight of concerned equipment, whichever is higher.
- k) Minimum two nuts should be used for all anchor bolts except for ladder, stair and handrail.

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- l) Lock nuts shall be provided for anchor bolts of tall structures, tall process columns, vibrating equipment etc.
- m) Framing and bracing shall be planned so that the stiffness of the structure can be well balanced with the loads and the structural stability can be secured.
- n) Vertical & Horizontal bracings shall be arranged properly, considering the following requirements:

Plant Layout

Equipment / Piping arrangement

Structural layout

Construction, operation & maintenance requirement.

The Vertical bracings provided for lateral stability of structure may be diagonal or V type and shall satisfy clearance, rigidity requirements and codal requirement.

- o) Expansion joints for the structure shall be as per IS: 800.
- p) Removable stoppers, fixed with bolts shall be provided on both sides of Hoist Beams.

11.2 Grade of Steel:

Structural Steel shall conform to IS: 2062 with minimum yield Strength of 250 N/mm² & shapes shall be as per SP 6 of IS: 800 / IS: 12778 (wide flange/narrow flange sections) or Universal beams and Columns as per BS.

Structural Steel shall comply with requirements as follows:

For ISMB, ISMC, ISA (Angles) : IS 2062 Grade E250B0/BR

For Flats : IS 2062 Grade E250B0/BR

For Plates : IS 2062 Grade E250BR / E350BR



For Universal Columns/Beams : BSEN 10025 S275JR / S275J0 / S355J0

Tubular / Hollow steel should conform to Yst 310 of IS:1161.

Properties of steel section shall be as follows:

- a) Rolled section as per IS: 808
- b) Parallel flanged sections as per IS: 12778.
- c) Circular Hollow sections (CHS) as per IS: 1161.
- d) Square Hollow sections (SHS) / Rectangular Hollow Sections (RHS) as per IS: 4923.

Connection Bolts shall be High Strength Structural Steel Bolts of Property Class 8.8 (minimum) conforming to IS:3757 & IS:4000. Hexagonal Nuts shall conform to IS:6649. Washers shall conform to IS:6649.

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11.3 Fireproofing of steel structures:

Fire-proofing of steel structures should be with vermiculite, wherever required as per OISD-STD-164, and should be done for 2 hours fire rating as per Specifications.

Fire resistance of a material is defined by fire rating, evaluated through a fire test based on applied thickness and time taken to reach the defined critical steel temperature. Fire rating adopted is based on UL-1709 rapid rise fire tests of protection materials for structural steel, conducted by Underwriters Laboratory, USA. In this test, fire resistance of a material is evaluated on a W10x49 steel column as per UL-1709 fire curve and fire rating is published in a UL design number under XR category for thickness and time. In addition to the fire rating, under this test, material for exterior use is also evaluated for accelerated ageing, high humidity, salt spray, wet-freeze-dry cycling, acid spray, solvent spray etc.

Thickness of fireproof coating to be applied shall be based on the following:


- Type-I : In-situ cement concrete for application up to 1.8m from grade level for steel structures shall be applied with minimum 65mm thickness.
- Type-II : Structural steel members such as column, beam etc. which shall be protected for 2 hours from reaching critical temperature 538°C, shall be applied with vermiculite based lightweight cementitious fireproof of thickness corresponding to 2 hours fire rating as per respective UL design number under UL-1709 (XR category) subject to a minimum of 30mm.
- Type-III : For equipment skirts/ saddles/ supports (which shall be protected for 2 hours from reaching critical temperature 427°C), 2 hours fire rating as per UL design is not adequate as the UL-1709 test is based on 538°C critical temperature. Therefore for the required fire protection from reaching 427°C, higher thickness shall be necessary. For this, fireproof thickness corresponding to 3 hours fire rating as per respective UL design number under UL-1709 (XR category) shall be adopted subject to a minimum of 30mm.

11.4 Limiting permissible Stresses:

- Permissible stresses in structural members should be as specified in:

IS:800	Hot rolled sections (excluding transmission towers and switchyard structures).
IS:801	Cold formed light gauge sections
IS:806	Tubular structures
IS: 802	Transmission Towers & Switchyard structures.

- Permissible stresses in bolts should be as specified in:

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IS:800	Hot rolled sections (excluding transmission towers and switchyard structures).
IS:801	Cold formed light gauge sections
IS: 802	Transmission Towers & Switchyard structures.

3) Permissible stresses in welds should be as specified in:

IS:816	Metal Arc Welding
IS:801	Cold formed light gauge sections



11.5 Limiting Deflection:

The limiting permissible vertical deflection for structural steel members such as gantry girder for electric overhead crane, manually operated crane, purlin supporting any type of roofing material under dead + live load or dead + wind load conditions shall be as specified in IS: 800.

1) Pipe Rack and Equipment Supporting Structure

Allowable deflection of beams and columns, to support Pipe and / or Equipment directly during normal operation, shall be as stated below for unfactored load.

Pipe Rack Beams	Span / 325, but not more than 30mm
Equipment Supporting Structure:	
Static Equipment supporting Beams	Span / 325, but not more than 30mm
Vibrating Equipment / Hoist Supporting Beams	Span / 450, but not more than 30mm
Other Beams	Span / 325, but not more than 30mm
Stack	Height / 200
Cantilevers	Span / 250, but not more than 20mm at free end
Duct (Refractory lined)	Span / 360
Duct (Others)	Span / 240

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Horizontal Sway at top of Column of each Story for:	
Open framed Structures	Height / 200
Cladded Structures	Height / 325
Pipe Rack	Height / 325

2) Crane Girders

Allowable Vertical and Horizontal deflection of girders for traveling cranes during normal operation, depending on types, shall be as stated below:

Manually Operated Crane	Span / 500
Electrical Overhead travelling Crane up to 50T	Span / 750
Electrical Overhead travelling Crane over 50T	Span / 1000
Other Moving Loads E.g. Charging Cars, etc.	Span / 600



3) Miscellaneous

Allowable deflection of miscellaneous members shall be as stated below:

Monorails and Hoist Beams	Span / 500
Joists	Span / 325
Purlins, Cladding Runners	Span / 200
Grating / Chequered plates	Span / 200 or 6mm whichever is minimum

The limiting permissible horizontal deflection for structural steel members shall be as specified below, where 'H' represents the height:

S.No.	Type of Structure	Deflection Value	Unit
1	Multi storeyed steel structure/ building	As per IS: 800	Same as 'H'

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2	Flare stack supporting structures	H / 200	Same as 'H'
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11.6 Minimum Thickness:

The minimum thickness of various structural components (Hot rolled sections) should be as given:

1.0	Trusses, purlins, side girts & bracings	6 mm
2.0	Columns, beams	7 mm
3.0	Gussets in trusses & girders	
3.1	Up to and including 12m span	8 mm
3.2	above 12m span	10 mm
4.0	Stiffeners	8 mm
5.0	Base Plates	12 mm
6.0	Chequered plate	6mm (on plain)
7.0	Grating	3 mm

The ends of all tubes shall be sealed by using 6 mm thick plates welded all round.

Structural members exposed to marked corrosive action should be increased in thickness or otherwise suitably protected against corrosion.

The minimum thickness of structural components (except gratings & chequered plates) which are directly exposed to weather and inaccessible for repainting should be 8mm. Chequered plates shall be avoided on structures exposed to atmosphere.

For Transmission Towers & Switchyard Structures, the minimum thickness of various structural components should be as per IS:802.



The minimum thickness for rolled beams and channels should be mean flange thickness regardless of the web thickness.

The minimum thickness of tubes should be as specified in IS: 806.

11.7 Connections:

Unless otherwise specified, the following shall be followed:

- 1) Shop connections shall be welded and all welds shall be continuous fillet / butt structural welds. Where galvanizing is specified, seal welding is required at all shop connections prior to hot-dip galvanizing. Welding subsequent to galvanizing shall not be permitted generally. But from construction point of view, if openings in gratings are provided after erection, galvanizing spray shall be used on cut & welded surfaces.

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- 2) Field connection for Ladder, Handrails, post, stair stringers, removable members, platform framing members shall be made with Black Bolts.
- 3) Bolted connection for structural members shall be made, with at least two bolts except for lacing bolt, where it may be with single bolt.
- 4) High Tensile Friction Grip bolts shall be used for connections subjected to repetitive cycles of loadings and moments.
- 5) Ordinary black bolts & nuts (property class 4.6) shall conform to IS: 1367, part 3 shall be used for purlins, side runners, platforms, ladders. Etc. High strength bolts (property class 8.8) shall conform to IS: 1367, part 3 shall be used for main structure members, such as beams, columns, etc.
- 6) Minimum two nuts shall be used for all Anchor Bolts.
- 7) Crane gantry girders shall generally be of welded construction and of single span length.
- 8) Permissible stresses in bolts shall be as specified in IS: 800.

11.8 Platforms and Walkways:



- 1) Platform and walkways shall be as per piping design basis and shall be made of grating flooring unless otherwise specified. Platforms below the air fin coolers shall be provided with RCC platform.
- 2) The minimum clear headroom over platforms and walkways shall be 2250 mm to the lowest point of overhead structural framing or equipment.
- 3) Chequered plates shall be minimum 6 mm thick.

11.9 Ladders:

- 1) Ladders shall be 450 mm wide and shall be made of stringers with 20 mm diameter M.S. rungs at 300 mm (max.) intervals.
- 2) The flight of Ladder without the intermediate platform shall not exceed 6000 mm. However, wherever feasible, staircase shall be provided.
- 3) Ladders over 3500 mm in height or originated from a point which is 3500 mm or more above grade, shall be provided with safety cages, originating 2500 mm from the bottom.
- 4) Ladder access openings shall be provided with the safety chain/safety bars.
- 5) Ladders shall preferably be vertical. In no case, will the angle with the vertical exceed 5 degrees.

11.10 Electrical switchyard structure and Transmission Tower:

All electrical switchyard structure and Transmission Tower should be bolted connection structural steel, and designed on the basis of IS:802.

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Structural Steel members including bolts, Nuts and washers should be hot dip galvanized in accordance with relevant IS Codes. The zinc coating on tower members shall not be less than 900 gm/ sqm of the surface area.

11.11 Slenderness Ratio:

Maximum slenderness ratio of a member shall be in accordance with IS: 800.

11.12 Painting:

Painting including shop primer to Structural Steel should be as per the painting specification to be adopted for the concerned project.

All underground structures including top surface of foundations shall be painted with two coats of hot bitumen paint of grade 20/30 with quantity of bitumen at least 1.2 kg/m² per coat.

12. Special Considerations for Masonry Works:

- All masonry works should be designed in accordance with IS:1905, IS:1597, IS:2185, IS:4326, IS:12894, IS: 1077, IS: 4860 and other relevant IS Codes as applicable. All external brick masonry walls should be of minimum 230mm thickness except for fire walls. For General Civil work, refer General Civil Design Basis.
- All masonry walls from ground floor shall be placed on R.C.C grade beams. However, light internal partitions may be placed on ground floor slab.
- All masonry work should be constructed in cement sand mortar 1:4 for load bearing walls and 1:6 cement sand mortar for non-load bearing walls except half brick partition walls which should be constructed in 1:4 cement sand mortar with two numbers of 6mm diameter MS bars provided at every fourth course properly anchored with cross walls or pillars. However construction of load bearing wall shall be avoided.
- Thickness of masonry firewalls around transformers shall be 345mm or as per OISD-STD-173, whichever is more.

13. Platform Below Air Coolers:



Blind floors should be provided below air coolers located on Pipe Rack / Technological Structure, if pump handling hydrocarbon or other equipment is located below air cooler else 2m center platform with 3m wide local extension below motors should be provided.

14. RCC and STEEL Chimneys:

RCC and Steel chimneys should be designed as per the requirements of IS:4998 and IS:6533.

15. Barricading:

Foundation and superstructure shall be designed as per plant operation & safety department/ General Civil requirements of location & height, keeping in view the mean probable design life of structure.

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16. Tank Foundations:

The design of tank foundations shall be based on the recommendation and design parameters given in the Geotechnical Reports and as per API-650. Stone columns for ground improvement / Pile foundation shall be considered as per Geotechnical Reports. Stone Column design shall be submitted for PMC approval. Minimum requirement of tank pad shall be as per 080557C-000-DW-1724-001.

In general, RCC Ring wall shall be considered.



All anticipated settlement and deformations of the foundation shall be reported to the tank and piping design engineers in order for them to assess if the anticipated movement of the tank is acceptable for the design of the tank and the tank piping attachments.

Anticorrosive layer of 50mm thick bitumen sand mix shall be provided below storage tanks directly resting on grade for tanks content having temperature upto 80oC and thermal isolation shall be provided if the temperature of tank content is more than 80°C.

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PART-B

SEISMIC

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1. General

1.1 Scope:

This establishes the basic inputs required for seismic design of the plant and provides certain guidelines for the methods used for seismic analysis of structures/equipment. However, detailed mathematical formulations of seismic analysis are outside its scope.

Calculations of Seismic forces shall be made as per the provisions of latest revision of IS: 1893 as well as this document and design shall be done based on greater of the two forces obtained.

1.2 Codes and Standards:

Latest editions of codes and standard as referred in the above section shall be followed:

1.3 Categorization of Structures / Equipment:

Structures / equipment shall be classified into the following four categories.

1.3.1 Category-I :

Structures / Equipment whose failure can cause conditions that can lead directly or indirectly to extensive loss of life/ property to population at large in the areas adjacent to the plant complex.

1.3.2 Category-II :

Structures / Equipment whose failure can cause conditions that can lead directly or indirectly to serious fire hazard / extensive damage within the plant complex.

Structures / Equipment which are required to handle emergencies immediately after an earthquake, also are included.

1.3.3 Category-III :

Structures / Equipment whose failure, although expensive, does not lead to serious hazard within the plant complex.

1.3.4 Category-IV :

All other structures / Equipment.



Typical categorization of structures shall be as per Table-6 given in the IS: 1893 Part-4.

Category of structures not covered in Table-6 of IS: 1893 Part-4, shall be determined based on the above definition of different categories,

The term failure used in the definition of categories implies loss of function and not complete collapse.

Pressurized equipment where cracking can lead to rupture may be categorized by the consequences of rupture.

Structures which are ductile detailed as per IS 13920 or IS 800 and equipment which are made of ductile

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materials can withstand earthquakes many fold higher than the design spectra without collapse; and damage in such cases is restricted to cracking only.

Generally, such equipment / structures where cracking will not lead to hazards are to be placed in category-III and where it may lead to hazards within the complex are to be placed in category - II.

Category - I earthquake is an extreme event with little possibility of its occurrence. Nevertheless, in the remote case when it occurs, structures / equipment whose failure can lead to loss of life at large, are to be designed so as to avoid failure.

2.0 **Design Consideration:**

2.1 **Design Site data consideration:**

Reference Seismic Zone	III (As per IS : 1893 Part-1)
Zone Factor	0.16 (As per IS : 1893 Part-1)
Importance Factor	For non-plant buildings, as per IS-1893 Part-I; For Industrial Structures including Stack-like Structures as per IS:1893 Part-IV
Soil Type	As per Geotechnical investigation report.
Response Reduction Factor (R)	As per IS: 1893 Part-I & Part-IV.
Spectral acceleration Coefficient (Sa/g)	As per IS: 1893 Part-I & Part-IV.

2.2 **Design Acceleration Due to Earthquake:**

The Horizontal seismic coefficient A_h and Vertical acceleration shall be obtained as per the IS: 1893 Part-1 & 4.



3.0 **Permissible Stresses:**

3.1 **Material Stresses:**

Whenever seismic forces are considered along with other normal design forces, the permissible stresses in material shall be governed by the respective codes as per which the structure/equipment is being designed. In the absence of such code/standard, provision of IS:1893 shall be used.

3.2 **For permissible Increase in allowable bearing pressure of Soil and Pile capacity Provisions of IS: 1893 (Part-1) shall be used.**

Earthquake shall not be considered to act simultaneously with wind.

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4.0 **Method of Seismic Design:**

4.1 **General:**

This document provides certain guidelines for the methods to be used for seismic analysis of structures/equipment. However, detailed mathematical formulations of seismic analysis are outside its scope. IS:1893 essentially defines the acceleration spectra to be used in different zones and gives the method of design of various kinds of structures and refer JSS 080557C-000-JSS-1700-008 for site specific spectra. Apart from the modification factors of acceleration values for different damping, other provisions given in IS:1893 in respect of the applicability of the methods remain unaltered. Stringent of IS 1893 and site specific spectra shall govern the Seismic analysis / Design.

If Site-Specific Spectrum gives design MCE acceleration spectrum A_h value less than that by the MCE Spectrum value specified (as per IS 1893 Part-IV), the latter shall govern.

If Site-Specific Spectrum gives design DBE acceleration spectrum A_h value less than that by the DBE Spectrum value specified (as per IS 1893 Part-IV), the latter shall govern.

All category-I Industrial structures shall be analyzed using site specific spectra. However, if site specific studies are not carried out, the code specified spectra may be used with modifications as per the provisions given in IS: 1893 (Part-IV). For all other structures the spectra and seismic zone shall be as per IS: 1893 (Part-I & IV).

Site specific earthquake hazard assessment may not be required for Category-2, 3 & 4 Industrial structures.

4.2 **Fundamental Natural Period of Structure/Equipment:**

This shall be determined by any of the standard methods described in IS: 1893 Part-4.

4.3 **Method of Analysis:**

Detailed analysis shall be carried out for structures of Category 1, in all seismic zones.

Detailed analysis shall be carried out for all structures of Category 2 and 3 in seismic zones III, IV and V.



Simplified analysis may be used for structures of Category 2 and 3 in seismic zone II.

Simplified analysis may be used for structures of Category 4 in all seismic zones. However, those structures of Category 4, which could be identified as buildings, may be analysed as per provisions of IS 1893 (Part 1).

This shall be determined by any of the standard methods described in IS: 1893 Part-4.

4.4 **Effect of Masonry Infill Walls:**

In RC buildings with moment resisting frames and unreinforced masonry (URM) infill walls, variation of storey stiffness and storey strength shall be examined along the height of the building considering in-plane

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stiffness and strength of URM infill walls. If storey stiffness and strength variations along the height of the building render it to be irregular as per IS: 1893 (Part 1), the irregularity shall be corrected especially in Seismic Zones III, IV and V.

The estimation of in-plane stiffness and strength of URM infill walls shall be based on provisions given in IS: 1893 (Part 1).

4.5 Lateral Force:

Buildings shall be designed for the design lateral force VB given by:

$$VB = A_h \times W$$

where,

A_h is Design horizontal seismic coefficient,

W is Seismic Weight of floors.

Buildings and portions thereof shall be designed and constructed to resist at least the effects of lateral force specified above. But, regardless of design earthquake forces arrived at, buildings shall have lateral load resisting systems capable of resisting a horizontal force not less than as specified below:

Sl. No.	Seismic Zone	Percent
1	II	0.7
2	III	1.1
3	IV	1.6
4	V	2.4

4.6 Structures / Equipment not covered in IS: 1893

If fundamental time period is less than or equal to 0.04 sec. equipment / structure may be treated as a rigid body and A_h corresponding to zero period may be used in conjunction with the use of pseudo static method (a method of design whereby seismic force on any structures / equipment is assumed to be static and acting at C.G and its magnitude is given by the weight of body multiplied by A_h). It has been observed that generally horizontal heat exchangers and horizontal storage vessels mounted directly on the foundations having nominal support height fall in this category.

If fundamental time period is greater than 0.04 second, one may use pseudo static method or response spectrum method depending on the height of structure / equipment. The height above which one should use response spectrum method shall be as per the discretion of the designer.

In the pseudo static method, value of A_h corresponding to the fundamental period of structure is taken from the site dependent spectra. Small vessels supported on lugs and storage vessels which can be approximated as single degree of freedom system are examples where pseudo static method may be used.

Steps involved in response spectra method are given briefly:

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- Calculate all natural periods above 0.04 second and their mode shapes.
- Pick up A_h corresponding to each period from the site dependent spectra curve.
- Calculate response of structure for each mode. (i.e. Displacement, bending moment, shear force etc.).
- Combine response of each mode by SRSS (square root of sum of squares).

For seismic analysis of piping, seismic coefficient method is not valid and one has to resort to the use of response spectrum method. Thermal loading calls for a flexible system while seismic loading calls for a rigid system and the designer has to make an optimum choice. Generally, it is seen that pipes are provided with supports in the vertical direction with little or no support in the horizontal plane. Such supporting arrangement gives large seismic forces and moments on the equipment / vessel nozzles. As far as possible supports which restrain the motion of pipe in horizontal plane, should be provided without exceeding the seismic forces and moments on the equipment/vessel nozzles.

4.7 Combination of Responses Due to Multi-Component Seismic Accelerations

All types of structures / equipment shall be designed for multicomponent earthquakes as per the provisions given in IS: 1893 Part-4.



4.8 Damping

The variety of damping displayed in different types of structures has made the choice of a suitable damping co-efficient for a given structure largely a matter of judgement. In general, damping increases with increase in stress amplitude or displacement amplitude or both. Moreover, damping exhibited in lower-frequency modes of vibration is generally lower than that exhibited in higher-frequency modes. For detail design, Bidder shall follow values in IS: 1893 Part-1.

4.9 Base isolation and energy absorbing devices

Base isolation and energy absorbing devices may be used for earthquake resistant design. Only standard devices having detailed experimental data on the performance should be used. The designer must demonstrate by detailed analyses that these devices provide sufficient protection to the buildings and equipment as envisaged in IS:1893. Performance of all assembled isolation and energy absorbing devices should be evaluated experimentally, and duly approved by the competent authority identified by the client / owner of the structure, before such devices are used in practice. Design of buildings and equipment using such device should be reviewed by a competent authority. In general, base isolation systems are found useful for short period structures, say those with fundamental periods, including soil-structure interaction less than 0.7s.

To control the serious loss of life and economic loss, the technique of base isolation can be an alternate damage control strategy, which should be promoted or encouraged in Seismic Zones III, IV and V. The commonly used seismic isolators are:

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- (i) laminated natural rubber bearings,
- (ii) high damping rubber bearings,
- (iii) laminated lead rubber bearings, and
- (iv) sliding bearings.

A combination of different types of isolators can be adopted to achieve satisfactory stiffness of the isolation system. Supplementary dampers (viscous or metallic yielding dampers) can be used along with base isolation systems, to reduce relative displacement demand on the isolated superstructure.



5.0 Ductile Detailing

Appropriate ductility details of reinforced concrete members should be provided as per the provisions of IS:13920 to avoid premature failure during earthquake. In steel structures, members and their connections should be so proportioned that high ductility is obtained to ensure that premature failure due to elastic or inelastic buckling does not occur. Ductile detailing of steel structures should be carried out as per the provisions of IS: 4326 and IS: 1893.

6.0 Special Provision for Storage Tanks


Seismic design of storage tanks shall be carried out as per the provisions of API 650 Appendix-E / API 620 Appendix-L (as applicable). For double-walled tanks inner and outer tanks have to be checked separately and the outer tank has also to be checked for possible inner tank failure.

The value of Z and I (refer API 650 Appendix-E/ API 620 Appendix-L) shall be taken as unity unless otherwise specified. The spectral acceleration values for periods greater than 3.0 seconds may be considered same as that for 3.0 seconds.

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PART-C

ARCHITECTURAL WORKS

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Referenced Publications

- 1) National Building Code of India
- 2) State Govt. Factory Acts
- 3) Local Municipality or any other Authority's Bye- Laws as applicable.
- 4) OISD Standards.
- 5) BPE (Bureau of Public Enterprise) Norms.
- 6) Bye-laws of Town & Country Planning Organization.
- 7) BIS (Bureau of Indian Standards) Codes.
- 8) (IER) Indian Electricity Rules.
- 9) CEA (Central Electricity Authority).
- 10) Guidelines of IGBC/ GRIHA/ LEED for Green Building concept.
- 11) Pollution Control Board norms.
- 12) Any other applicable Law, Rules, Standard as referred in respective clause.
- 13) Process Control Room Safety

1. Standard Specifications Codes & Practices

Engineering design incorporates Codes and Standards as referred in the design philosophy of respective engineering disciplines as well as applicable standards and specifications. All codes & Standards shall be latest revision with all amendments issued thereto. However, effort shall be made for effective utilization of space and facilities for cost effective design.

2. Design Philosophy / Criteria – General

2.1 Architectural Design

Architectural Design of Buildings / Sheds shall be in accordance with this Design Basis and References as stated above to meet the functional requirements. In plant area, no underground / basement shall be provided in the building.

2.2 Building Requirements

2.2.1 Spatial Requirements

Spatial requirements inside a Building / Shed shall be decided based on equipment / panel layout, activities to be performed in the building and consequent occupancy pattern, Equipment Layout, etc. Sizes of various type of spaces shall be decided based on occupancy/ equipment/Panel layout, clearances, maintenance &

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safety requirements. The objective of spatial arrangement shall be to satisfy functional requirements, physical comfort and safety regulations as well as aesthetics.

Requirement of services/utilities such as air conditioning, LAN etc. shall be finalized as per Owner's specific requirement. Special care shall be taken to design buildings to meet the criteria of Green Buildings as per the standards of IGBC/ GRIHA or any other Green Building rating system decided by Owner, for desired rating.

Spaces can be generally classified as follows, which shall be provided in all the Buildings / Sheds.

1) Functional Spaces

Functional areas of any building / shed are constituted by main activity areas for which building is required. Various spaces / rooms shall be judiciously sized and shall be integrated logically to generate the total building plan taking into account the following parameters.

- a) Activities, group of activities and consequent work-flow pattern.
- b) Site conditions i.e., dimensions, contours, etc.
- c) Climatic conditions vis-à-vis orientation.
- d) Site Planning (solar geometry, approaches, adjoining facilities, safety standards etc.)
- e) General arrangement of equipment
- f) Health, Safety & environmental standards & regulations.
- g) Lighting and Ventilation
- h) Acoustics
- i) Building utilities, amenities & Services
- j) Security
- k) Economy
- l) Aesthetics
- m) Statutory requirements (viz. local building authority bye-laws, fire authority approval, airport authority approval, environmental clearance, forest authority approval, power utility & requirement approval, consent to establish / operate etc.)
- n) Any Specific requirements pertaining to particular buildings
- o) All other established Architectural Design Parameters.

The objective of spatial arrangement shall be to satisfy functional requirements and physical comfort and safety regulations as well as aesthetics which has significant role in creating working and living conditions.

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2) Circulation Spaces

Following spaces are classified as circulation spaces. These spaces shall be provided for integrating various types of spaces and as means of access / exit / escape.

- Corridors & passages
- Staircases
- Elevators
- Entrance lobby / Foyer including reception & waiting
- Gangways / Walkways
- Equipment loading / unloading platforms
- Emergency exits
- Ramps for physically challenged and equipment entry/exit as applicable.

3) Amenity Spaces

Following spaces are classified as amenity spaces.


- Toilet
- Drinking Water Facility
- Locker & Change room
- Rest room / Lunch room
- Wash rooms & space for drying clothes
- Canteen / Pantry room
- First-aid room

Out of the above-mentioned areas, a) Toilet, b) Drinking Water and first aid room enclosure shall be mandatory requirement for human occupied buildings / sheds. Other requirements shall be provided as required.

4) Utility Spaces

Utility spaces are space requirements which materialize due to provision of services like air- conditioning, pressurization, firefighting, electrical, telephone etc. These spaces shall be provided as per required building services. Following are examples.

- Air-conditioning plant room.
- Air handling rooms.
- Pressurization blower plant room

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- d) Electrical distribution panels rooms
- e) Service ducts
- f) Firefighting equipment room
- g) Telephone exchange equipment room
- h) UPS room
- i) Battery room

NBC shall be followed for Minimum width/ dimension of the spaces of the building.

However, following are the minimum sizes/ dimensions for various purposes, which are to be adhered to.

Minimum size of any habitable room	9.5 sq.m. with minimum dimension not less than 2.5 m.
Minimum height of any habitable room	For Residential Buildings, 3.0m which may be reduced to 2.75 m for air-conditioned areas. Headroom below beams: min. 2.4m. For Educational & Industrial Buildings, the minimum height shall be 3.6 m & 3 m for air conditioned spaces.
Maximum height of habitable room	3.6 m or as stipulated by local byelaws.
Scale of accommodation for Industrial workspaces	@ 14cu.m.per occupant. Minimum clear height of such workspaces shall be 3.6m. Heights above 4.25m shall not be taken into account.
Minimum height of Fire Station Building / Control Room	5.0 m

All height dimensions are to underside of ceiling or beams, whichever is lower.

The height shall be determined considering the clearance from equipment, bus duct and lighting fixtures etc.

2.2.2 Day Lighting

Established level of illumination shall be maintained for all parts of the buildings by means of windows, skylights, ventilators etc. Following references shall be adhered to in this regard.

- a) National Building Codes of India
- b) BIS (Bureau of Indian Standards) Codes
- c) State Factory Act

The objective of day lighting shall be as follows:

- ◆ Direct solar illumination shall not be considered and only sky radiation shall be taken as contributing to illumination of the building.

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- ◆ Openings shall be provided with shading devices to avoid glare. For the purpose of illumination, day lighting shall also be supplemented by artificial illumination particularly at fire exit.

2.2.3 Ventilation

1) Natural Ventilation

Established level of Ventilation in terms of air changes per hour shall be maintained for all spaces. Following references shall be adhered to for the purpose:

- a) National Building Code of India
- b) BIS (Bureau of Indian Standards) Codes
- c) State Factory Act

Natural Ventilation shall also be supplemented by mechanical or electrical means of ventilation in all human occupied areas. Sufficient no. of Glazed/Louvered windows/Ventilators shall be provided and supplemented by exhaust fans.

2) Mechanical Ventilation

In addition to natural ventilation, if required Mechanical or electrical ventilation is provided depending on the type of building and its use. Refer Design Basis of Packaged Equipment for its requirement and applications.

2.2.4 Acoustics and Sound Insulation

Specified acceptable noise level and reverberation time shall be maintained inside a building / shed. Following references shall be referred to for the purpose:



- 1) National Building Code of India
- 2) State Factory Act
- 3) Limitations on decibel level stated elsewhere, if any, in the bid document

Required noise level in any space shall be maintained by means of

- 1) Segregating noise sources by buffer zones
- 2) Dampening of noise levels by damping devices
- 3) Providing Acoustic treatment with acoustic material (on walls, ceilings, floors, as required).

2.2.5 Safety Requirements

Safety from fire and like emergencies shall be taken into account in building / shed design. Every building / shed meant for human occupancy shall be provided with exits sufficient to permit safe escape of occupants in case of emergency. The exits shall be in terms of doorway, corridors, passage ways to internal / external staircase or to areas having access to the outside. Control room building shall be provided with emergency exit on the other side of the entrance.

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Following references shall be adhered to in this regard.

- 1) National Building Code of India
- 2) State Factory Act
- 3) OISD

2.2.6 Site planning & landscaping

Site planning of building shall take into account aspects like interrelationship of the buildings with the whole system, movement pattern, traffic and road net-work, safety regulations, service network, fire safety, climatic and environmental aspects, site conditions like site dimension, contour, drainage, noise level, view, future expansion, visual aspects, Natural Light and Ventilation etc.

Main and service/ maintenance entrances of buildings shall be provided with vehicular access. All exit points shall also be provided with footpath/ vehicular access. Truck movement space in accordance with traffic pattern shall be provided for the building as per the location of hoisting bay/loading, unloading platform. Road network and open space around the buildings shall be designed considering movement and functioning of Fire tenders and cranes etc. Parking space in accordance with traffic load shall be provided to all buildings.

Climatic factors like wind direction, solar geometry shall be taken into account in orienting the buildings depending on type of climate. Orientation of building shall also consider noise and smell propagation, views, and visual effect from various directions.

Sufficient open space shall be provided for planned expansion of buildings. Sufficient open space shall also be provided around the buildings for lighting and ventilation in accordance with Factory Acts & National Building Code. Open spaces in a plot and around buildings proportional to the height of the structure shall satisfy the requirements of the local byelaws.

Suitable Landscaping treatment shall also be done around the important buildings. Such treatment shall generally consist of lawns, road side plantation and beautification of building entrance areas. Standard landscape elements such as earth contours, paving, flower beds, hedges, shrubs, ground cover and ornamental trees shall be incorporated in landscape treatment. Necessary water supply/sprinklers shall also be provided.


2.3 Building Services

Following services shall be provided for all buildings / sheds as essential services.

2.3.1 Water Supply, Distribution and Drainage, Sanitary Services

This service is essential for all human occupied buildings / sheds. All buildings with human occupancy shall have toilet and drinking water facility and accordingly water supply, distribution and drainage, sanitary services as per the following references:

- 1) National Building Code of India

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2) State Factory Act

Drinking water provisions, including sufficient number of water cooler (Minimum one per area) shall be provided within an enclosure separated from the toilets.

All service pipes showing on the external wall shall be suitably concreted or shall be provided within a shaft.

2.3.2 Electrical services

This service shall be provided as essential service for all the buildings. Electrical services for building shall consist of electrical supply, and distributions, electrical lighting installations, telephone network, fans, exhaust fans, lighting protection system etc., including all accessories, cabling etc. including Emergency power supply, all as defined under Engineering Design Basis of Electrical.

2.3.3 Air Conditioning and Heating

Control Room Building, Satellite Rack Rooms, Administration Building, Amenity Building, Training Center etc. shall be centrally air-conditioned. Accordingly, A.C. Plant/ AHU etc. of the require capacity (depending on the requirement) shall be provided and suitably housed. Some designated rooms (as per Electrical requirement) in the Sub Station Buildings or in other buildings like canteen; scale room etc. may be required to be air-conditioned. For this suitable window/ split/ package type units may be provided as per requirement w.r.t. the Design Basis of Packaged Equipment.



2.4 Aesthetics

Apart from the fulfilment of functional & safety requirement, aesthetic requirement of the building shall be taken care of in the design. As specific guidelines for achieving required aesthetics are difficult to establish, preliminary drawings indicating Architectural treatment (with minimum three different alternative proposals) shall be submitted for Owner's approval.

Architectural scheme shall be based on general principles of Aesthetics. Building facades shall reflect such principles like symmetry, balance, proportion, rhythm, light and shade etc.

Following elements shall be considered as contributory elements to aesthetics and their design etc. shall be subjected to the Owner's approval. Any change/modifications sought for aesthetics improvements with regards to these elements shall be carried out. Any incidental elements like brickwork, RCC work etc. required for such changes/modifications shall also be added.

- ♦ Building/shed shape and features
- ♦ Canopies, overhangs & shading devices
- ♦ Gutters, roof projections
- ♦ Entrance/exit steps, door
- ♦ Window/Ventilator composition

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- ◆ External wall location with respect to columns
- ◆ Colour scheme, grooves in plaster
- ◆ Spatial arrangement

Local Climatic conditions shall be considered while designing the buildings.

Architectural scheme including design of above mentioned elements shall be subjected to Owner/ PMC approval.

2.5 Structural and Construction Elements

Blast resistance control room buildings, if provided, shall be fully R.C.C. structure to withstand the specified blast pressure. Other buildings (Non-blast proof Control Room Buildings, Sub Stations etc.) shall be R.C.C. framed structure (columns, beams and R.C.C. roof slab) with brick masonry / Burnt clay fly ash building bricks / AAC block infill walls. Structural & Construction elements shall be designed as per the details given in Engineering Design Basis-Structural.

2.6 Building Elements



1) Plinth protection

All the buildings & sheds shall be provided with minimum 1000 mm wide (top of plinth protection shall be 100mm high from top of Approach Road Level) plinth Protection with building drain around the building /shed.

2) Finished Floor Level (FFL)

In general, FFL of the buildings, sheds shall be determined with respect to top of Approach road or pavement. Following schedule shall be adhered to for FFL of various buildings & sheds.

Control Room Building/Satellite Rack Room Building (Building having false flooring)	Top Road level of Approach road + 450 mm + Height of false flooring
Sub Station Buildings	Top of approach Road level + 300 mm (Cable Cellar floor)
	Top of approach Road level + 150 mm (Transformer bays) with pebbles
	F.G.L. (+) approx. 1000 mm high from top of road (in case of single storey Substation Building with trenches as per electrical requirement)
Plant Buildings (Unit area)	(HPP) shall be maintained as per site grading w.r.t. Design Basis of General Civil

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Other Buildings/Sheds	Top of approach Road level + 450 mm(min.) and or as per functional requirement
Vehicle Scooter, Cycle Shed including Fire Tender Bays, Repair Shop	Top of approach Road level + 150 mm
Loading, Unloading platforms	Top of approach Road level + 1100 mm


Notes:

- ◆ In case of approaches with different top levels, the highest top level of approach road/pavement shall be considered.
- ◆ FFL shall be same throughout in a building/shed. Split levels may be considered in exceptional cases due to ground terrain etc.
- ◆ FFL of external loading/unloading bays/platforms, toilet, pantry, kitchen shall be 10-15 mm lower than that of the building/shed's FFL to check ingress of rainwater.
- ◆ In case of discrepancy, philosophy of levels shall be followed.
- ◆ FFL of Loading/ Unloading bays of Warehouses, Godowns, stores shall be maintained as Loading platform level of trucks with outward slope to avoid ingress of rain water splash.

3) Steps / Ramps / Stairs

Steps/ramps shall be provided for access to the buildings/sheds for Pedestrian/Vehicular equipment entry as per relevant code. Minimum 1000 mm wide platform shall be provided in between entrance door and steps/ramps. Following dimensions of the steps/ramps shall be adhered to:

Stairs width	1500 mm minimum
	1250 mm minimum for one side open staircase (Emergency Exit)
Tread	300 mm minimum
Riser	150 mm maximum
Slope of ramp	Not steeper than 1:12 or as per requirement
Ratio of Tread & Riser	$2\text{Riser} + \text{Tread} = 600 \text{ to } 650 \text{ mm}$
No. of Risers per flight	15 nos. maximum

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Landing width	1500 mm minimum
Width of step / ramp	1500 mm minimum

Handrail shall be provided as per the provisions of National Building Code and IS: 4963. (Recommendations for Buildings and facilities for the physically challenged).

Edge of treads shall be provided with friction grip strips or similar anti-skid arrangement.

Ramps for physically challenged persons shall be designed in accordance with IS: 4963.

4) Wall

Following schedule shall be adhered to for wall material and thickness.

External walls	230 mm thk. Brick / fly-ash building brick wall
Internal partition wall	230mm / 115 mm thk. Brick / fly ash building brick / AAC block wall depending on the overall length and height of the wall (refer note below)
Transformer walls	200 thk. RCC or 345 thick (excluding plastering) fire brick walls as per Electrical requirements (OISD /IER)
Concrete wall (Blast resistant)	As per structural design basis

Notes:

- ◆ 115 mm thick. Brick partition walls (with nominal steel requirement as per structure design) shall be provided with 230 mm thick. brick pillars for stability depending upon the length and height of wall.
- ◆ Wherever conduits or pipes are required to be concealed within partition wall, the wall thickness shall be increased suitably
- ◆ Wherever, bricks are not commonly available, suitable alternative material shall be used for obtaining OWNER's/PMC approval

5) Doors

Doors shall be provided for access, security and safety to all entry & exits of rooms, functional areas in a building. Air tight door shall be provided in pressurized area and in gaseous protection area. Fire

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check doors shall be with minimum two hours rating as per statutory requirement. Emergency door shall be opened outwards. Sizes of the doors shall be determined on the basis of the following schedule:

- Equipment, Panel area: Maximum size of equipment including packing.
- Other areas: Volume of movement through door.
- Minimum door size at entrance: 1500 mm x 2100 mm (wall opening size)
- W.C. bath Cubicle door: 800 mm x 2100 mm (wall opening size)
- Minimum size of other doors: 1000 mm x 2100 mm (wall opening size)

Notes:

- ◆ Entrance doors shall be provided covering full width of the entrance lobby. In that case the door shall be of composite type consisting of openable shutters & fixed panels. Entrance lobby shall be provided with elaborate canopy.
- ◆ Rolling shutters shall be provided wherever size of opening exceeds 2500 mm width x 2700 mm height.
- ◆ Mechanically operated rolling shutters shall be provided for opening sizes exceeding 8 Sq.m
- ◆ Blast resistant Control room entry door shall be provided with blast Resistant baffle wall in front of entry door and shall have 45 degree / 90 degree overlap on both sides.



6) Windows / Ventilators

Windows / ventilators shall be provided in all areas for natural lighting, ventilation and visibility at working level.

For the purposes of ventilation, total openable area of the windows/ventilators shall be as required for necessary air changes as per Factory Act subjected to a minimum of 15% of the floor area to be ventilated. However, the % shall finally depend on the Climate Zones (complying with NBC) and shall count only the openable area of the windows.

Windows/ ventilators are also elements of building aesthetics and shall be provided in accordance with approved Architectural control scheme. Windows shall be provided at working levels. For the purpose of natural lighting total glass area shall be minimum 15% of the floor area. However, in case of offices, work places etc. windows shall be provided for the full length of walls as per approved Architectural scheme.

Areas accommodating panels / equipment shall be normally provided with ventilators at high level for unobstructed distributed lighting. Ventilators shall be provided below roof beam. Ventilators shall be with Aluminium louvers in case of buildings. In case of Sheds, Aluminium louvers or cladding sheet louvers as approved shall be provided.

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Rooms, spaces, sheds having height more than 4 metre shall have windows and ventilators at multiple levels to ensure required natural lighting and ventilation at all levels. Such windows & ventilators must be provided at all intermediate working levels of such high rooms, spaces, sheds.

Fly mesh shutters shall be provided for windows/ventilators in Kitchen, Pantry, Dining hall etc.

Ventilator shall be able to serve as smoke vents in the event of fire.

Wherever due to limitation of external wall area or any other reasons, stipulated area of window/ventilation cannot be provided, suitable mechanical devices shall be provided. For Workshop/Warehouse sheds etc. with pre-coated/GI roof sheeting etc. suitable monitor may added in provide additional ventilation.

Transparent roof light sheeting / Light Pipe / Light Tube shall be provided in roofing of shed type structures for day lighting.

Blast resistant Control room windows openings through wall may be provided as per OISD-STD 163.

7) Ridge ventilators, Roof air extractors

In case of Sheds, water tight & leak proof ventilators/ extractors shall be provided over roof to ensure required air changes as well as for hot air outlet in accordance with following philosophy:

Area	Design Philosophy
Ridge	Air driven/ operated ridge ventilators, ridge monitors,
Roof	Roof mounted air driven extractors/ turbo ventilators shall be provided

8) Canopy/Overhang

RCC Canopy/Overhangs shall be provided at all entrances for rain & sun protection. Size of the canopy/ porch shall be decided w.r.t. utility of the building and other aesthetic. Blast proof Control Rooms shall not have any projections with outer face of its walls except with false treatment for aesthetics of the building.

- 1) For all offices, control rooms (Non-Blast type), composite buildings/sheds accommodating offices, canopy shall be provided at all entrances. Size of the canopy shall be decided based on vehicle parking & pedestrian movement in addition to aesthetics of the building/shed.
- 2) Overhangs shall be provided over all exits. Size of the overhang shall be decided based on the aesthetics of the building/shed subjected to minimum of 1000 mm. Waterproofing & drainage provision shall be provided for the canopies & overhangs.

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9) Shading Devices

RCC Shading devices shall be provided over all windows, openable ventilators for rain & sun protection. These devices shall be in form of horizontal projections, vertical projected fins in addition as per building facade treatment. Minimum projection shall be 600 mm. The top surface of the shading devices shall be finished with cement plaster mixed with waterproofing (laid to slope) compound and shall be provided with GI spouts for drainage. Cinder filling to be avoided in projections of door, window, porch etc.

10) Parapet

Parapets shall be of brick work / RCC for all buildings with minimum 600 mm high for non-approachable roof and 1100 mm high for approachable roof from finished floor level after water proofing treatment.

11) Roof Gutter

Gutter with rainwater pipes or RCC shafts shall be provided for all the buildings/sheds with pitched roof for roof water drainage. Sizing of the gutter shall be based on area to be drained and number of outlets. Gutters shall be of RCC or sheet metal depending on type of structure. For Workshop/Warehouse shed with pre-coated roof sheeting, pre-coated sheets gutters may be provided and for big size of workshops/warehouse RCC shaft may be provided at the end of gutter.

Constructional details of rainwater gutters and downpipes and their fittings for drainage shall be as per the provisions given in IS: 2527.

For rain water harvesting system, site specific scheme shall be developed.

12) Rainwater pipes, Spouts

C.I. /PVC rainwater pipes (min. 110mm dia.) shall be provided for roof water drainage. Number of rainwater pipes shall be decided on the basis of roof area, slope and rainfall intensity. However, minimum 1 pipe of 110mm dia. shall be provided for every 42 sq.m of roof area. Finished terrace surface shall be even and slope in 1 in 48. Rainwater pipes shall be embedded in concrete / concealed as far as possible. RCC / PVC / GI spouts shall not be used for drainage of chajja/small canopies to avoid possibility of chocking (may be used for drainage of chajja / small canopies of ground floor).

13) Drainage Pipe for Air-Conditioning Units

Suitable arrangement shall be made in buildings for drainage of condensed water from Air-conditioning units.

14) Air Lock Lobby

This shall be provided for all entries with centrally air-conditioned spaces.

15) Entrance Lobby

Entrance lobby shall be provided as a common entrance for all buildings/sheds accommodating separate or similar functional spaces integrated together. Individual entries to such functional spaces shall be from this lobby by means of passages/corridors. Apart from common entry lobby, separate

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independent entries to these functional spaces shall also be provided if functionally required. Size of the entrance lobby shall be decided on the basis of volume of movement subjected to minimum requirement of 9.5 Sq.m.

16) Passages/corridors

Passages/corridors shall be provided to integrate various spaces. Width of the passages/ corridors shall be as per following schedule and / or as per the statutory requirement.

Singly loaded passage/corridor	Minimum 1200 mm
Doubly loaded passage/corridor	Minimum 1800 mm

But whenever passages/ corridors are to be used for equipment/ machinery/panels etc. the width shall be determined on the basis of equipment/machinery /panel sizes.

17) Service Entry

Separate service entry shall be provided for service areas such as kitchen, air-condition/ pressurization plant room, electrical rooms, battery & UPS room etc. A common service entry may be provided depending on spatial arrangement.

18) Air-Lock Lobby

Air-lock lobby shall be provided to all entry & exits of pressurized areas.



19) Emergency exits

Emergency exits shall be provided for all the building/sheds as per statutory requirements. Emergency exits for individual function spaces such as console area, cable cellar, electrical room, switchgear hall shall also be provided. Emergency exits shall be located in such a manner that escape route is unobstructed & without passing through any other function areas. corridors/ staircases shall be provided as escape route to the emergency exits.

20) Staircases

Staircases shall be provided in multi floor buildings for vertical circulation & emergency exits. Number of staircases shall be based on building/shed sizes and emergency exit requirements. At least one staircase/cage ladder shall be provided for access to the roofs for maintenance.

Total number of staircases shall depend on travel distances to exit points as determined by the statutory regulations. However, at least one staircase shall be provided for every building as "ALTERNATE ESCAPE ROUTE".

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21) Railings

Railings (1100 mm high) shall be provided in stairs and in all unprotected openings in slabs as a safety device. Steel railings in high level loading/unloading bay of substations shall be of removable type. Parapets shall be given precedence over railings in roofs.

22) Toilets

Toilet shall be provided for all buildings/sheds having human occupancy. Toilet shall consist of Gents Toilet, Ladies Toilet (as per requirement) and separate drinking water enclosure and janitor space. Requirement of fittings & fixtures shall be as per National Building Code of India & Factory Act.). Toilet shall be provided in all buildings / sheds having human occupancy in accordance with following principle.

Parameter	Guidelines
Gents/Ladies Toilet	Gents/Ladies Toilet shall be provided in all buildings /sheds having human occupancy as per requirement.
Toilet for physically challenged	At least one number toilet for physically challenged shall be provided in each floor of Admin building, Canteen, Training Centre, Laboratory, Office buildings and in other human occupied buildings where physically challenged personnel can be deployed. Provisions shall be made for construction of toilets for physically challenged as per IS: 4963 & NBC.
Janitor	Each Toilet block shall be provided with suitable janitor facility.

Toilet plumbing, piping, etc. visible on external facade of building shall be visually concealed by means of shafts etc considering building aesthetics.

Drinking water enclosure (as required) shall be provided in all buildings /sheds having human occupancy. Drinking water facility may be provided in Pantry also.

23) Electrical Room:

Electrical Room may be provided to accommodate electrical/telephone main distribution box. However, depending on size, space requirement, the same may be mounted in wall recess.

24) Partitions

If required, partitions shall be provided for flexible space arrangement in Office spaces, Control room etc. The partitions shall be of removable type. Glazed panels shall be provided for visibility in the partitions as per requirement.

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25) False Ceiling

False ceilings shall be provided for following purposes: -

- To reduce room volume and hide ducting etc. for air conditioned spaces.
- To maintain acoustic level inside any space.
- To reduce habitable room, corridor, lobby, toilet heights located in high ceiling building/shed to a reasonable and satisfactory height of minimum 3000 mm.
- In fire-rated areas where walls and doors are required to be fire rated, false ceiling shall also have complementing fire rating. It is appreciated that false ceiling have limitations in their fire performance due to openings in them for lighting and air-conditioning. Therefore, alternative systems to prevent puncturing the ceiling must be employed.

26) Underdeck Insulation

Underdeck insulation below RCC roof and over false ceiling (both locations) shall be provided for air-conditioned office / space.

27) False / Cavity flooring

False/cavity flooring shall be provided to accommodate under floor cabling in instrumentation areas like console rooms, rack room, computer room, UPS room etc. Extent of false/cavity flooring shall be as per instrumentation requirements

Wherever applicable, False flooring shall be fire rated to the level of fire rating of the walls, doors and suspended ceiling in the compartment.

28) Waterproofing on roofs

Waterproofing on roofs shall be done using resin modified bitumen membrane with non-woven polyester felt or glass-fiber felt or approved equivalent.

29) Transformer Gate

Steel gate of suitable size in front of transformer bays in substations building shall be provided as per electrical requirement.

30) Fire water / Fire extinguisher

All buildings shall be provided with fire water network / fire extinguishers in compliance to statutory requirement.

3. Architectural Finishes

All the buildings shall be provided with Architectural finishes such as floor finishes, plastering & painting on walls & ceilings, doors/ windows/ ventilators, roof treatment, plinth protection etc. as below:

For the purposes of schedule of Architectural finishes, buildings are categorized into following types.

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Type A	Important buildings like, Main Administration building, Main Control Room, Main Gate House, Laboratory, First Aid Building, Training Center, Canteen Building, Inspection Building, Air Quality Maintenance Station, Office Blocks of all buildings etc. in Plant and non-plant area.
Type B	Non plant buildings like, Fire Station, Bank, Secondary Security/Gate Houses, Scale Room, Utility Control Room, Store etc. and buildings like Substation/ Switchgear room, MCC, Satellite Rack Room, Field Operators Cabin, Entrance gate & Time house/ Access control etc. which are not included in other categories.
Type C	Buildings like DG Shed, Receiving Station, Analyzer Room, Pump Houses, Compressor House, Process Building/Sheds and buildings like Watch Tower, Cement Godown, Storage Shed, Parking Shed etc
Other	Extension/ Modification portion of any existing building

3.1 External Finishes

3.1.1 External wall, RCC Surfaces

The schedule of Architectural finishes shall be finalized w.r.t the Type of Buildings from among the following by selecting the respective finishing options or a combination of the options:

Type "A" Buildings	<input type="checkbox"/> Plain cement plaster and surface textured coating (Granular or Flakes type). <input type="checkbox"/> Cement plaster and Anti-algal weatherproof, acrylic emulsion paint with silicon additives. <input type="checkbox"/> Sand Stone / Granite Stone cladding. (to arrest fall of the cladding, properly designed & suitable anchoring to be provided) <input type="checkbox"/> GRC / GRC Jaali Cladding. <input type="checkbox"/> Structural Glazing.
Type "B" Buildings	<input type="checkbox"/> Plain cement plaster and surface textured coating (Granular or Flakes type). <input type="checkbox"/> Cement plaster and Anti-algal weatherproof, acrylic emulsion paint with silicon additives.

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Type "C" Buildings	Cement plaster and Anti-algal weatherproof, acrylic emulsion paint with silicon additives.
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3.2 Internal Finishes

3.2.1 Floor Finishes

The schedule of Architectural finishes shall be finalized w.r.t the Type of Buildings from among the following by selecting the respective finishing options or a combination of the options:

Entrance lobby, Reception, Lounge, Waiting area of Type "A" Buildings	<input type="checkbox"/> Granite Stone (slabs only) <input type="checkbox"/> Marble Stone (slabs only) Flooring shall be with Pattern.
Office area of Type "A" Buildings	<input type="checkbox"/> Vitrified Tiles (full body type) <input type="checkbox"/> Laminated Wooden Flooring (with min. AC4 class)
Circulation areas of Type "A" Buildings (Corridor/ Passage etc. except Entrance lobby)	<input type="checkbox"/> Granite Stone (slabs only) <input type="checkbox"/> Marble Stone (slabs only) <input type="checkbox"/> Vitrified Tiles (full body type)
Staircase of Type "A" Buildings	<input type="checkbox"/> Granite Stone (slabs only) <input type="checkbox"/> Marble Stone (slabs only) With friction grip strips or similar anti-skid arrangement at edge of treads.
Entrance lobby, Reception, Lounge, Waiting area of Type "B" Buildings	<input type="checkbox"/> Vitrified Tiles (full body type) <input type="checkbox"/> Kota Stone
All Office areas of Type "B" Buildings	<input type="checkbox"/> Vitrified Tiles (full body type) <input type="checkbox"/> Kota Stone
Circulation areas of Type "B" Buildings (Corridor/ Passage etc.)	<input type="checkbox"/> Granite Stone (slabs only) <input type="checkbox"/> Marble Stone (slabs only)

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except Entrance lobby)	<input type="checkbox"/> Vitrified Tiles (full body type) <input type="checkbox"/> Kota Stone
Floor areas of Type "C" Buildings	<input type="checkbox"/> Vitrified Tiles (full body type) <input type="checkbox"/> Kota Stone
Staircase of Type "B" & "C" Buildings	<input type="checkbox"/> Granite Stone (slabs only) <input type="checkbox"/> Kota Stone With friction grip strips or similar anti-skid arrangement at edge of treads.
Toilet, Drinking water area of Type "A", "B" & "C" Buildings	<input type="checkbox"/> Granite Stone (slabs only) <input type="checkbox"/> Vitrified Tiles (full body & anti-skid type) <input type="checkbox"/> Ceramic tile flooring (anti-skid type)
Kitchen, Pantry, Dining Hall	<input type="checkbox"/> Granite Stone (slabs only) <input type="checkbox"/> Vitrified Tiles (full body type) <input type="checkbox"/> Kota Stone With, Granite stone counter top (kitchen & pantry)
False flooring	Solid core false flooring with High pressure laminate
Electrical Room, A.C. Plant Room, Loading / Unloading Bays, Storage area, Equipment Handling areas	Heavy duty flooring (Vacuum de-watering flooring in large Rooms/ areas)
Record room/ Areas	<input type="checkbox"/> Vitrified Tiles (full body type) <input type="checkbox"/> Kota Stone
Battery Room & Chemical Handling Areas	<input type="checkbox"/> Acid Resistant tiles <input type="checkbox"/> Chemical / Abrasion Resistant Epoxy coating

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Note:

1. Only the back of CRT and small channel in front for carrying the cables of CRT etc. shall be provided with false flooring. The area in front of panels shall have Vitrified tiles or as specified.
2. Skirting shall be provided in all areas which shall be of same material as that of flooring. Panel dividers shall be provided in cement concrete flooring.

3.2.2 Internal Wall Finishes

The schedule of Architectural finishes shall be finalized w.r.t the Type of Buildings from among the following by selecting the respective finishing options or a combination of the options:

Entrance lobby, Reception, Lounge, Waiting area of Type "A" & "B" Buildings	<input type="checkbox"/> Granite stone cladding (in Slabs) <input type="checkbox"/> Heritage / Unitile / Spectrum Surface texture over cement plaster (in selected areas) <input type="checkbox"/> Cement plaster, POP punning & Plastic emulsion paint.
Office areas of Type "A" & "B" of Buildings	Cement plaster, POP punning & plastic emulsion paint. Partitions shall be modular type, with pre-laminated board & / or glazed.
Circulation areas of Type "A" & "B" Buildings (Corridor/ Passage etc. except Entrance lobby)	<input type="checkbox"/> Granite stone cladding (in Slabs) <input type="checkbox"/> Cement plaster, POP punning & Plastic emulsion paint.
Office area of other buildings	Cement plaster, POP punning & Oil Bound Distemper. Partitions shall be modular type, with pre-laminated board & / or glazed.
Console Room	Granite Stone cladding / dado up to 1500mm height and Cement plaster, POP punning & plastic emulsion paint above.
Rack Room, U.P.S. Room, Computer Room, Operators' Room, Shift In-charge Room, Supervisor Room, Instrumentation Calibration Room etc.	Cement plaster, POP punning & plastic emulsion paint

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Electrical Room, A.C. Plant Room, Loading / Unloading Bays, Storage area, Equipment Handling areas, Switchgear Room etc.	Cement plaster & Oil Bound Distemper
Battery Room	Up to 2500mm height: <input type="checkbox"/> Acid Resistant tiles <input type="checkbox"/> Chemical / Abrasion Resistant Epoxy coating With Oil Bound Distemper above 2500mm height.
Toilet, Drinking water area of Type "A" & "B" Buildings	Dado up to Ceiling / False Ceiling: <input type="checkbox"/> Ceramic Tile <input type="checkbox"/> Vitrified Tile (full body type) <input type="checkbox"/> Granite Stone (slabs only)
Toilet, Drinking water area of Type "C" Buildings	Ceramic tile dado up to ceiling
Kitchen, Pantry, Dining Hall	Dining Hall Dado up to 2100mm: <input type="checkbox"/> Ceramic Tile <input type="checkbox"/> Granite Stone (slabs only) <input type="checkbox"/> Wall Paneling With Cement plaster, POP punning & plastic emulsion paint above 2100mm. Kitchen / Pantry Dado: Ceramic tile dado up to ceiling

Note:

Grooves in plaster shall be provided at all junctions of different material cladding and as per external façade treatment. POP moulding shall be provided in "A" & "B" type buildings as per Architectural scheme.

3.2.3 Internal Ceiling Finishes:

The schedule of Architectural finishes shall be finalized w.r.t the Type of Buildings from among the following by selecting the respective finishing options or a combination of the options:

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Entrance lobby, Reception, Lounge, Waiting area of Type "A" & "B" Buildings	False Ceiling: <input type="checkbox"/> Gypsum Board <input type="checkbox"/> Metal Tile <input type="checkbox"/> Aluminium Panel / Strip
Office area of Type "A" & "B" Buildings	False Ceiling: <input type="checkbox"/> Gypsum Board <input type="checkbox"/> Mineral Fibre Tile
Circulation areas of Type "A" & "B" Buildings (Corridor/ Passage etc. except Entrance lobby)	False Ceiling: <input type="checkbox"/> Gypsum Board <input type="checkbox"/> Aluminium Panel / Strip
Other areas of Type "A" & "B" Buildings	Cement plaster, POP punning & plastic emulsion paint
All areas of Type "C" Buildings and Other Buildings	Cement plaster with Oil bound distemper
Other Air-conditioned areas where False Ceiling is required	Gypsum Board False Ceiling

Note:



1. Office area, Corridors circulation areas to be provided with false ceiling.
2. For Other areas – Architectural scheme shall be followed.
3. False ceiling to be provided in Air conditioned areas of other types of buildings also depending upon the requirement.

3.3 Doors, Windows & Ventilators:

The schedule of Doors, Windows & Ventilators shall be finalized w.r.t the Type of Buildings from among the following by selecting the respective options or a combination of the options:

3.3.1 Doors

Entrance / Exit doors of Type A & B building	<input type="checkbox"/> Block board flush shutter with decorative Teak veneered finish / laminated finish on both sides.
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	<input type="checkbox"/> Powder coated Aluminium glazed shutter.
Circulation area doors for All Type of Buildings (If not subjected to any statutory norms etc.)	<input type="checkbox"/> Powder coated Aluminium door Glazed with etching.
Office area doors for All Type of Buildings	<input type="checkbox"/> Block board flush shutter with lamination on both sides. <input type="checkbox"/> Powder coated Aluminium glazed shutter.
Toilet / WC / Bath	<input type="checkbox"/> High pressure laminated partition system <input type="checkbox"/> Powder coated Aluminium glazed shutter <input type="checkbox"/> uPVC glazed shutter
All doors of Electrical Room, A.C. Plant Room, Battery Room	Pressed steel frame with Pressed steel shutter
Inside Control Room / Satellite Rack Room building	Fire Check door with minimum 2 hours rating as required in perfect partition wall separating various fire zones: <input type="checkbox"/> Glazed steel Fire check door, <input type="checkbox"/> Solid type steel fire check door (with 300mm x 300mm vision panel), <input type="checkbox"/> Wooden, Teakwood veneered fire check door (with 300mm x 300mm vision panel)

Irrespective of above schedule, Fire check doors (minimum 2 hours rated) shall be provided wherever required as per OISD/ Statutory requirements.

Rolling shutters shall be provided in equipment areas like Switchgear/MCC Room, Workshop, Ware House etc. where opening size for door exceeds 2500 x 2700mm (height).

Doors/windows/ventilators shall be complete with all fittings & fixtures for easy smooth operation & locking facility.

3.3.2 Windows & Ventilators:

Windows/ventilators of Type "A" Buildings	<input type="checkbox"/> Glazed, powder coated Aluminium window <input type="checkbox"/> uPVC glazed Window
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	Ventilator with SS frictionless hinges / sliding shutters
Windows/ventilators of Type "B" Buildings	<input type="checkbox"/> Glazed, Anodized Aluminium window <input type="checkbox"/> uPVC glazed Window Ventilator/ sliding shutters
Windows/ventilators of Type "C" Buildings	Anodized Aluminium window / ventilator / sliding shutters

3.4 Roof Treatment:



- ♦ Polyurethane (PU) water proof coating, single component,
 - ♦ Polyurethane (PU) water proof coating, two components,
 - ♦ Atactic Polypropylene modified bituminous waterproofing membrane,
 - ♦ EPDM (Ethylene Propylene Diene Monomers) Coating,
 - ♦ Brick bat coba,
- or any other treatment as specified.

Selection of roof waterproofing treatment shall be decided based on site location, rainfall intensity and other climatic factors.

3.5 Sanitary Fittings & Fixtures

All the plumbing fixtures including toilets, faucet aerators and showerheads shall be preferably fixed with low-flow plumbing fixtures (in line with Green Building requirements) that save substantial amounts of water compared to conventional fixtures while providing the same utility.

Water Closet (European) for type "A" Building	Wall hung type white European type WC
Water Closet (European) for type "B" & "C" Building	Pedestal type white European type WC
Water Closet (Indian)	Orissa pan type white WC
Wash basins for type "A" buildings	Round/ Oval shape Wash basin white/ coloured above granite type counter with photocell operated electronic sensors.

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Wash basins for type “B” buildings	Counter type wash basin on platform
Wash basins for type “C” buildings	Wall hung Wash basin
Urinals for Type-A	With Electronic Sensor (Premium Luxury Model)
Urinals for Type-B & C	Standard Wall Hung type
Plumbing fixtures	Stainless steel bib cock, stop cock etc. fittings for Type “A” building, CP brass for type “B” & “C” buildings

Note:

All toilets shall be provided with “Geysers” and automatic “No touch Hand drier”.

3.6 Roofing (Sheds/Workshops)



Precoated, profiled colour coated alloy / Galvalume / Zinalume steel sheeting shall be of clip-lock arrangement.

3.7 Cladding

Precoated, profiled colour coated alloy / Galvalume / Zinalume steel sheeting shall be of clip-lock arrangement.



4. General requirements

- 1) All free edges of chajjas and slab projections shall have drip mould in plaster 50 mm wide and 20 mm drop unless the need is resolved in some other manner.
- 2) Sunken Floor slab in WC areas, toilet, pantry, kitchen floor slabs shall be avoided. Pipes shall be camouflaged by using false ceiling. However, where required, floor slabs in WC areas shall be sunk by 500 mm and toilet, pantry, kitchen floor slabs shall be sunk by 200 mm at all levels (including terrace, where future extension is envisaged).
- 3) All supporting framework members of partition walls within false ceiling areas shall go up to roof level, partitions shall go up to false ceiling level except where there are fire compartment wall where it shall be from floor to ceiling.
- 4) Preferably all cut outs in slab shall be provided with 200 high curb. Gaps in floor cut outs shall be sealed with fireproof material for fire safety.
- 5) Roofs of RCC buildings should have mild slope towards rainwater gutters.

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- 6) All instrument / Electrical cable trenches at the junction of the building (outside) shall be covered with precast RCC slab.
- 7) Walls on steel beams shall be constructed after wall below and up to the steel beam is constructed. This shall appear in the 'Notes' if applicable.
- 8) Plinth beams level shall clear trenches if any.
- 9) Water tanks, AC plant, Cooling tower, Chiller units etc., where required, shall be located on building roof as far as possible and it shall be positioned and supported to transfer its load on to beams and columns and not to the slab. Such facilities should not be visible from outside. Suitable side cladding shall be provided for this purpose.


Note: Various Architectural finishes/items, Sanitary fitting & fixtures, door/window schedule etc. indicated here are as per prevailing system in various units of Refineries. Any other preference of the owner not covered here shall also be considered.

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PART-D GENERAL CIVIL



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1. **Scope:**

This document covers engineering design basis for General Civil works such as compound wall, fencing, site grading, roads, pavements, storm water drainage, water supply, waste collection & disposal system, tank farm dyke, tank foundations, etc.

Order of Precedence:

- 1) Statutory Provisions
- 2) P&IDs
- 3) Engineering Design Basis
- 4) IS Codes/ IRC Codes

2. **Codes & Standards:**



Latest editions of codes and standard as referred in the above section shall be followed:

Statutory Provisions:

1. Environmental guidelines for sitting of Industry published by Ministry of Environment and Forest.
2. The Environmental Protection Act, 1986
3. Petroleum rules (for Hydrocarbon storage under Chief Controller of Explosives of PESO).
4. The static and mobile Pressure Vessels (unfired) rules- (For pressure storage of Gases under Chief Controller of Explosives).
5. Director General of Civil Aviation (DGCA) Rules.
6. Manual for Water Supply and Treatment (by Ministry of Urban Development)
7. Manual on Sewerage and Sewage Treatment (by Ministry of Urban Development)
8. Specification for Road & Bridge Works (Published by IRC on behalf of the Government of India, Ministry of Road Transport & Highway)

Abbreviations:

Code	Description
CBR	California Bearing Ratio
CRWS	Contaminated Rain Water Sewer
FGL	Finished Ground Level
HFL	High Flood Level
HPP	Highest Pavement Point

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IRC	Indian Road Congress
MSA	Million Standard Axle
MSL	Mean Sea Level
OWS	Oily Waste Sewer
PCC	Plain Cement Concrete
RCC	Reinforced Cement Concrete
WMM	Water Mix Macadam
WBM	Water Bound Macadam
EWS	Environment, Water & Safety

3. **Overall Plot Plan:**

As per piping design basis

4. **Site Grading:**

- All the tree roots and vegetation shall be grubbed up and removed from site.
- The grading of the area shall be done by cutting and filling with the following:

Cutting area	Thoroughly rolled and compacted
Filling area	Compacted in layers not exceeding 30 cm in loose thickness to achieve min. 95% of max. Proctor dry density as per IS: 2720 Part-VII
Finished Ground Level	As per site requirement


- Site grading philosophy shall be based on following:

Unit HPP	+4.36m above MSL
----------	------------------

- Slope in Graded Area:

1	General Site Grading	1 in 500 to 1 in 1000
2	Micro grading (after completion of major construction for road corridors)	1 in 200 to 1 in 500
3	Tank Farms	1 in 100 to 1 in 500

Top of road, top of paving, FFL will be taken to match with the existing unit / road.

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Micro grading shall be carried out by the Contractor over graded areas to bring the FGL to indicated levels including provision of required slopes and finishes.

5. Roads:

Cross section of roads shall be designed, including roads for crane access, as per IRC 37. However, the minimum section to be adopted shall be as given below under 'Road Width' (pt. g). Ruling gradient shall be 1 in 30. In case contractor proposes to use existing roads for erection purposes, the same should be strengthened to cater for erection loads. Contractor shall ensure that use of existing roads does not hinder normal activities in existing plants. The contractor shall repair any damage to existing roads or other facilities, at the earliest, at no extra cost.

a. Roads and Paving classification:

Plant road and paving shall be classified as under:

- Asphalt Road
- Concrete Paving
- Gravel Paving



Concrete Paving is further classified under Pt. 6 - "Concrete Pavement".

Road Classification:

The following road classifications shall be used for the design of roads within the Plant Site.

- Primary Road : A main traffic arterial or tanker truck or semi-trailer truck route.
Traffic density (0 – 15 nos.) exceeding 3Ton shall be taken for design consideration.
Around loading area and weigh bridge traffic density (15 – 45 nos.) 3Ton shall be taken for design consideration.
- Secondary Road : A road subject to regular operational or maintenance traffic but not subject to high traffic volume.
- Service Road : A road, which service remote areas or maintenance track, or provide access for firefighting equipment.
- Access ways : A road or distinctly delineated travelled way which provides access to equipment in congested areas

During normal operation, the maximum axle load shall be **10.2Tonnes** for primary & secondary road During Construction; the maximum Crane Wheel load shall be **10 Tonnes**.

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Design speed:

Geometric design of roads within plant limits shall be based on the following design Speeds.

Primary Roads for semi-trailer truck traffic	50km/h
Other Primary Roads	40km/h
Secondary Roads	30km/h
Service Roads	25km/h

Passing sight distance shall not be assumed as a limiting design criterion.



Note: The actual speed limits will be less than these values.

Note:

- Roads susceptible to spillage of petroleum products specifically roads in loading gantry area shall be of RCC.
- Plant roads / Access roads shall be of widths as per plot plan and 1.0m shoulders on both sides.
- The surface slope of roads shall be 2.5% from the centre to both road edges.
- The shoulders shall be sloped with 3%.
- The Longitudinal gradient of roads shall not be more than 5% on Heavy Duty roads and 10% on Light Duty roads.
- The road crown elevation shall be minimum 450 mm above Finished Ground level.
- Minimum 8.0 m clearance to underside of pipe racks at overhead road crossing, shall be provided.

b. Road Width:

Location	Roadway	Carriageway
Main roads for product movement	16.0m	14.0m
Road around unit	12.5m /10.5m /9.0m	10.5m /8.5m /7.0m

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Road for high lift crane	16.0m	14.0m (considering 12m outer width of crawlers of standard 650MT crane capacity OR As per the requirement)
Plant approach road	9.0 m	7.0 m (two lane)
Roads around tank- farm	7.5 m	5.5 m.
Patrolling roads (along boundary walls)	6.0 m	4.0m
Access to Building	5.5 m	3.75m
Footpath	1.5 m	1.5 m. walkway

c. **Camber:** 1 in 40.

d. **Radius of Curve:**



Radius of Curve	Road width
15 m.	16.0 m wide roads and high lift crane roads.
12 m.	7.5m, 9.0m & 12.5m wide road
8 m.	5.5m & 6 m. wide road.

e. **CBR to be used for design:** As per Geotechnical recommendation.

f. **Design Standard:** IRC 37 (using 2 msa and design CBR)

g. **Road finish:**



Class	Layer	Road Way (m)	Carriage Way (m)	Material	Thk. (mm)
	Surface	9.0 / 10.5 / 12.5 / 16.0	7.0 / 8.5 / 10.5 / 14.0	Dense Bituminous concrete	50

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Class	Layer	Road Way (m)	Carriage Way (m)	Material	Thk. (mm)
Primary / Plant Approach Road	Shoulder	2 x 1m		75mm thick WMM in Grade-II aggregates	50
	Base course		-	WMM in Grade-II aggregates (2 layers of 75mm thk.)	150
	Sub-base		-	WMM in Grade-I aggregates (2 layers of 150mm thk.)	300
	Sub-grade		-	Compacted sub-grade	-
Secondary Road (around tank farm)	Surface	7.5	5.5	Dense bituminous concrete	50
	Shoulder	2 x 1		75mm thick WMM in Grade-II aggregates	50
Secondary Road (around tank farm)	Base course		-	WMM in Grade-II aggregates (2 layers of 75mm thk.)	150
	Sub-base		-	WMM in Grade-I aggregates (2 layers of 100mm thk.)	200
	Sub-grade		-	Compacted Sub-grade	-
Patrol Road (Along	Surface	6.0	4.0	Dense bituminous concrete	50

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Class	Layer	Road Way (m)	Carriage Way (m)	Material	Thk. (mm)
boundary wall)	Shoulder	2 x 1		75mm thick WMM in Grade-II aggregates	50
	Base course		-	WMM in Grade-II aggregates (2 layers of 75mm thick.)	150
	Sub-base		-	WMM in Grade-I aggregates (2 layers of 100mm thick.)	200
	Sub-grade		-	Compacted sub-grade	-

Note:



Width of all types of roads, shoulders / berm road elevation of all new roads shall be in line with existing Refinery roads. Thickness of new roads sections should not be less than that of existing as followed in refinery for different uses.

6. Concrete Pavement:

a. Pavement Slope:

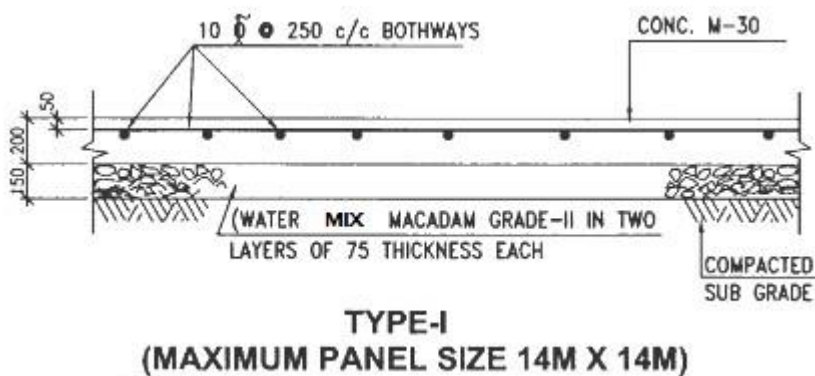
Concrete Paving shall be sloped (along length) steepest to 1:100 unless otherwise shown in detail engineering drawing. Slope of the sub-grade shall be prepared to match with the slope of pavement.

Pavements below the pipe racks, pipe way bridges should have proper slope towards storm water drain to avoid accumulation of water. Suitable gap between wall of pipe-way bridges and sleepers shall be left for smooth drainage.

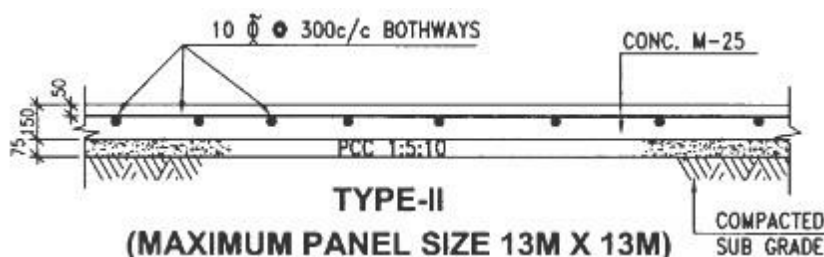
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b. **Type:**

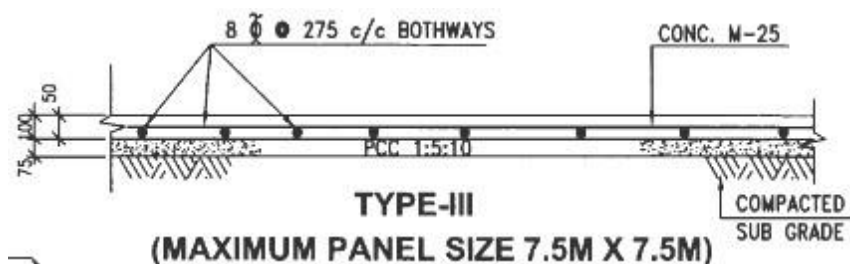
Type-I: 200 mm thick, RCC M30





Type-II: 150 mm thick, RCC M25



Type-III: 100 mm thick, RCC M25





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Area	Type
Vehicular movement area	
Process Unit	Type-I (200 mm thick) RCC M30 (Two layers of 75mm thick WMM as sub-base course)
Utilities	Type-I (200 mm thick) RCC M30 (Two layers of 75mm thick WMM as sub-base course)
Non- Vehicular movement area	
Process Unit & Tank Farm Area	Type-II (150 mm thick) RCC M25
Utilities	Type-II (150 mm thick) RCC M25
LPG Sphere, Bullet area	Type-III (100 mm thick) RCC M25
Off-site pump station	Type-III (100 mm thick) RCC M25
<i>Note: 75mm thick PCC 1:5:10 as sub-base shall be provided for Type- II & Type-III pavement.</i>	
Truck Movement area (Solid & Liquid Product)	Type-I (200 mm thick) RCC M30 (Two layers of 75mm thick WMM as sub-base course). (This is the minimum requirement, the design shall be done as per actual load condition and the same shall be provided). Heavy Duty Paver Block wherever suitable can also be considered.
Truck Movement area & Road Loading/Unloading gantry	Type-I (200 mm thick) RCC M30 (Two layers of 75mm thick WMM as sub-base) (This is the minimum requirement. The design shall be done as per actual load condition and the same shall be provided).
Pipe Rack	PCC M20 (100 mm thick) Where crane movement for maintenance is envisaged, paving shall be designed for the loads arising from the same.
Footpath	Interlocking Precast concrete blocks

Notes:

- 1) Sub-grade below RCC pavement shall be compacted to 95% of Laboratory dry density as per IS: 2720 Part-VIII and the slope of sub- grade shall be same as top of pavement slope. Geogrid & Geosynthetics may be used in sub-grade layers as per geotechnical recommendations, site

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suitability & design requirements.

- 2) In case of poor soil, black cotton soil, treatment below base shall be carried out as per soil investigation report.
- 3) For crane movement area pavement shall be designed as per loading and soil data. Hardstand suitable for 650T crane (or any other higher capacity crane actually deployed for erection) capacity with ringer attachment and or with sky horse attachment for handling heavy equipment/ machinery shall be constructed to suit erection scheme. It may be partly or totally dismantled as per requirement.
- 4) Hard surface of PCC M20 (100 mm thick) shall be provided below all pipe rack/ pipe track. This shall extend 600 mm on either side for track width less than 6 m, 900 mm on either side for pipe track having width 6 M or more and it shall have approach @ 500 m c/c from nearest road. Hard surface of PCC M20 (100mm thick) of size 1Mx1M shall be provided with proper approach near drain point of offsite piping, near drinking water installations, at washing facilities and at other places as required / instructed by Engineer in charge.
- 5) Removable type RCC precast slab with leak proof joints using bitumen fill in all concrete pavement covering underground piping shall be provided for maintenance/ inspection of pipes.
- 6) Pavement and trenches including covers in process unit shall be suitable for Hydra crane movement.
- 7) The surface of concrete paving exposed to corrosive chemicals shall be protected with the suitable anti-corrosive / chemical resistant material / coating which shall be selected and applied fully in accordance with the manufacturer's specification.
- 8) All edges of concrete paving adjacent to manholes and catch basins shall be suitably thickened.
- 9) Raised concrete kerbs shall be provided wherever necessary to contain the spillage before conveying them to the appropriate drainage system. Kerbs shall be 100 mm thick & 100 mm in height.

c. Reinforcement:



Reinforcement shall conform to the requirement of IS: 432, IS: 1139 and IS: 1786 as relevant. The dowel bars shall conform to Grade S 240 (with yield strength 240MPa) and main bars (deformed/plain) shall conform to Grade Fe-500 deformed steel bars as per IS 1786 / IS 432. If steel mesh is used, it shall conform to IS: 1566.

Temperature reinforcement shall be provided as per the provisions of IRC: 15.

The area of steel required per meter length of joint shall be computed as per IRC -15.

d. Joint arrangement:

Expansion joint: In concrete paving, expansion joints shall be arranged at maximum interval of 14m for Type-I pavements and 13m for Type-II pavements. The joints shall be 20 mm wide and filled with

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bitumen impregnated fibre boards, with the top 25 mm filled with flexible bituminous joint sealing compound.

Heavy-duty paving shall be provided with dowel bars. The dowel bars shall be provided in the direction of traffic (longitudinal). Design of Dowel bars shall be done as per provisions given in IRC: 58. Following shall be design considerations:

- 1) Mild steel round bars.
- 2) Dowel bars shall be bonded into concrete on one side of the joint and its other half length shall be prevented from bonding with concrete.
- 3) One half of the dowel bar is painted with a bond-breaking layer of bitumen. This bond-breaking layer shall preferably be provided on opposite sides of the joint in adjacent dowel bar. In case of transverse expansion joints, the unbonded portion of the dowel is provided with expansion cap at the end. Cotton waste or other compressible material shall be inserted but not tightly packed before fitting the cap over the painted end of the dowel bar so that there is sufficient gap between the bar end and the inside of the cap.



For slabs of thickness less than 150mm, no dowel bars may be provided.

Isolation joint: Isolation joints shall be provided around equipment foundations, pedestals and columns within the paved area. The joints shall be 20 mm wide and filled with sand, with the top 25 mm filled with flexible bituminous joint sealing compound.

Construction joint: Concrete for paving shall be laid in alternate panels. Maximum panel size shall be 14m x 14m for Heavy Duty Paving and 7.5m x 7.5m for light duty paving. Construction joints shall be provided in Light duty paving at 7.5m c/c. The top portion of joints shall be 10 mm wide and 40 mm deep and filled with flexible bituminous joint sealing compound.

7. Site Finish:

Sr. No.	Area	Finish
1	Operating Area (Units)	Concrete Pavement
2	Non Operating Area (Units)	Concrete Pavement
3	Road	Bitumen finish with WMM base.
4	Approaches: For Plant Units	Concrete Pavement
5	Approaches: For balance facilities	Bitumen finish with WMM base
6	Footpath	Interlocking Pre-cast concrete blocks
7	Tank Farm (Inside dyke)	Impervious concrete (PCC) of grade M25 above a layer of HDPE sheet and stone soling base.

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8	Between Unit & Roads (Except approach road to units & approaches to fire hydrant)	Other compacted earth surface
9	Parking including truck parking	RCC Concrete Pavement min. 250 thick
10	Truck Loading / Unloading area	Concrete Pavement
11	Pipeways	PCC M 20
12	Open storage / Main areas	Other compacted earth surface
13	Sphere area (with Kerb wall)	min. 100 mm thick PCC, M20
14	Coke storage	RCC pavement
15	Coke truck loading	RCC pavement



8. Drainage Descriptions

Wastewater originating from the site shall be classified into the following categories, defined by the source, type and level of contamination:

- Clean Storm water (SS)
- Sanitary Sewer (DS)
- Oily Water Sewer (OWS) / Continuously Oil Contaminated (COC)
- Contaminated Rain Water Sewer (CRWS) / Accidentally Oil Contaminated (AOC)
- Chemical and Non-Neutral Wastewater
- Miscellaneous Drainage

9. Storm Water Drainage:

- Storm water drainage system in the plant shall be designed and constructed to completely collect, convey and dispose off the storm water as well as the uncontaminated waste water from the plant. Drainage system shall also be capable to collect firewater run-off based on firefighting demand. These shall be hooked up to nearest storm water drain along existing roads. Contaminated and uncontaminated areas of units in line with licensor's recommendations to be identified and the same will be approved. The Licensor's requirements for drainage, for various facilities shall be adhered to.
- At the road crossing the storm water drain shall be in precast box culvert type with 25% provision for future expansion. This shall be designed for class A or class AA IRC loading whichever is stringent.
- Materials for storm water drain/ ditches are as follows:

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Type	
Units	Rectangular type
Other Area	Rectangular and/or Trapezoidal type
Construction	
Rectangular ditches (Unit)	RCC
Rectangular ditches (offsite)	RCC
Trapezoidal ditches	PCC Lining
Pipe	Concrete pipe for road crossing

Note:

- ♦ Tank farm drainage shall be provided in such way that the storm water discharge shall be either sent to storm water drain or to the contaminated rain water sewer (CRWS / AOC) by providing valve pit outside the dyke wall depending on its contamination.
- ♦ An oil catcher with baffle wall type arrangement shall be on storm water ditch before it leaves the battery limit of the complex.

d. Discharge Quantity of Storm water:

Rainfall data: (a) for 1-hour period	125 mm in 1 hour (max)
Rainfall data: (b) for 24-hour period	335 mm in 24 hours (max) (rainy season is from May to November)

The following rational method equation shall be used to calculate design quantities of storm water.

$$Q_r = (1/360) \times C \times I \times A.$$

Where,

Q_r : Design quantities of storm water (m^3/sec)

C : Run-off coefficient (As per the below table)



I : Design rainfall intensity (mm/hr), 1-hour period shall be refer from above table (max.)

A : Catchment area (ha)

Design Velocity of Drains: Min.= 0.6m/s

Max.= 2.4m/s.

Surface Condition	Run off
Roof	0.75 to 0.95
Concrete Road Paving	0.95 to 1.00
Asphalt Road Paving	0.80 to 0.90

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Gravel Road Paving	0.50
Soil / Green Belt	0.40
Compacted Area such as tank farm / offsite areas / expansion area	0.70

e. Hydraulic Design:

The velocity and quantity of hydraulic flow in open drains or underground pipes shall be calculated by using the Manning formula as:

$$V = \left(\frac{1}{n} \right) * R^{2/3} * I^{1/2}$$

$$Q = A \times V$$

Where,

V : Velocity (m/sec)

n : Coefficient of Roughness (As per below table)

R : Hydraulic Radius (m)



I : Slope of channel

Q : Discharge Quantity (m³/sec)

A : Hydraulic section (m²)

Typical Coefficient of roughness:

Nature of Surface	Coefficient of roughness 'n' Range
Concrete Pipe	0.011 - 0.013
Corrugated Metal Pipe	0.019 - 0.030
Vitrified Clay Pipe	0.012 - 0.014
Steel Pipe	0.009 - 0.011
Monolithic Concrete	0.012 - 0.017
Cement Rubble	0.017 - 0.025
Brick	0.014 - 0.017
Laminated Treated Wood	0.015 - 0.017
Open Channels:	
Lined with Concrete	0.013 - 0.022
Earth, Clean after weathering	0.018 - 0.020
Earth, with grass & some weeds	0.025 - 0.030

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Excavated in rock, smooth	0.035 - 0.040
Excavated in rock, jagged & irregular	0.040 - 0.045
Natural Stream Channels:	
No boulders or brush	0.028 - 0.033
Dense growth of weeds	0.035 - 0.050
Bottom of Cobbles with large boulders	0.050 - 0.070

- ◆ Storm water drainage shall be designed as flowing full and sanitary and other pipes shall be designed as flowing 2/3 full. (Sanitary flow shall be designed for 3 times average flow).
- ◆ Minimum depth of drain shall be kept as 300mm.
- ◆ Minimum width of rectangular drains shall be as follows:

For depth \leq 500mm	: 300mm
For depth $>$ 500mm	: 500mm

f. Design Details and Materials:



a. Surface drain:

For storm water drains, the following specification shall be adopted:

- ◆ Shape: Drains in process (unit) area shall be rectangular RC drain. Secondary drains of Rectangular shape to be provided. Main drains of Rectangular / Trapezoidal shape shall be provided in other area except Process (Unit) Area.
- ◆ Material of Construction:

Trapezoidal drains	Earth ditch type with PCC (M20) lining for both horizontal and sloped portion.
Rectangular drains	R.C.C. (M25) Concrete (within process area & other area).

- ◆ 75 mm thick leveling base layer M7.5 concrete to be provided.
- ◆ All drains are open type.
- ◆ Design minimum freeboard of 100 mm.
- ◆ Adequate slope to be provided to meet velocity & discharge requirements and such that no silting / scouring occurs. In general, the following slope may be adopted:
 - i. Slope of main drain = \leq 1:1000.

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ii. Slope of secondary drain = $\leq 1:750$.

iii. Slope of tertiary drains = $\leq 1:500$.

b. Culverts:

- ◆ Storm water drains shall cross the road by suitable precast / cast-in-situ box culverts as the case may be. Material of construction of culverts shall be as below:

Box culverts: R.C.C. construction (M25 concrete grade).

- ◆ The top of bottom raft of the box culvert shall be sloped and connected to the nearest storm water drain in a manner so that any water coming into the box culvert shall be drained off. Alternate suitable arrangement (e.g. filling up of the box culvert till FGL etc.) may be adopted so as to ensure that no water gets accumulated inside the box culvert.

c. Catch Basin:

- ◆ Catch basin shall have a minimum internal dimension of 600 mm x 600 mm.
- ◆ The bottom level of catch basin shall be lower than 150 mm from the invert level of the lowest connected pipe.
- ◆ The surface travel of the drainage prior to entering catch pit shall be limited to 15 m.
- ◆ The maximum area per catch pit shall be 150 m².
- ◆ Cover for catch basin shall be of Galvanized gratings.

d. Trenches:

a. Electrical Cable Trench:

- ◆ Sand filled R.C.C. trenches shall be provided with pre-cast RC covers.
- ◆ Wherever trench crosses storm water drains, trenches shall be taken below drains.

b. Pipe Trenches:



- ◆ R.C.C. trenches shall be provided with pre-cast RC cover as per piping requirement.

Cable trenches shall be filled with sand as indicated in relevant electrical drawings. If trenches are filled with sand then no inserts plates shall be provided within the trenches.

In paved areas, the top of cable trench will be flush with finished floor level. Covers shall overlap walls and joints with paving shall be sealed to prevent water entry.

In unpaved areas, walls shall be raised above ground level by 100 mm.

Trench floors shall be provided with a nominal slope to drain pits, where any water entering trenches can be collected and be drained to the nearest contaminated rain water sewer / storm water sewer. The trench bed shall have a slope of 1 in 750 along the run and 1 in 250 perpendicular to the run.

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Trench covers shall be designed for the vehicle load relevant to the area where the trench is located.

Cable trench shall be of leak proof construction (un-cracked design). All the construction joints of cable trenches i.e. between base slab to base slab and the junction of vertical wall to base slab shall be ensured for water tightness.

e. Culverts and Road Crossings:



Pipe Culvert- Under road	RCC pipes (Class NP -3 as per IS:458)
Pipe Culvert- Under Rail lines	RCC pipes (Class NP -4 as per IS:458)
Storm Water Box culverts	RCC Precast / Cast-in-situ Construction

10. Water System:

a. Drinking water System:

Drinking water supply to building shall always be from overhead tank. Connection from Direct pumping header shall not be allowed. Suitable instruments for water tank over flow control to be provided.

- i. Rate of water supply: 135 lpcd (litres per capita per day).
- ii. System: Underground ring main with D. I. (Ductile Iron) pipes and fittings for dia 8" and above and G.I. pipes and fittings for dia 6" and below. All U/G GI pipes shall be coated with anticorrosive black paint.
- iii. Drinking water piping network shall be laid U/G in a closed loop wherever possible. Isolation valves shall be provided at junctions. Valve pit shall be provided for valves in underground drinking pipes.
- iv. Min. Clear Cover: 600 mm in open areas.
1200 mm below road crossings.
- v. Storage: Overhead tank of R.C.C. construction / PVC. In case of PVC tank, insulated type (PUF) tanks shall be considered. Capacity - 12 hours, based on average daily demand.
- vi. Disinfection Method: ClO₂ based method shall be used.
- vii. Drinking water system capacity shall be such that leakage and wastage etc. are accounted so that shortage of drinking water may not occur. It is suggested to keep 25% design margin to take care of above losses.

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b. Underground piping:

- All underground process pipes if otherwise not specified shall be C.S. pipes and shall be provided with corrosion resistance protection.

11. Sewers:



Process drains shall be oily water sewers, closed blow down sewers or chemical sewers. These shall be provided as per OISD 109 and as per Mechanical / Piping design basis. Sizing layouts, Material Specifications, corrosion protection etc. will be as per Mechanical / Piping design basis.

Oily water sewers carry water contaminated with oil, e.g. from reflux drums, separators, cooling / quench water or compressor / pump, process wash water, floor and paving drains in oily areas etc. These are conveyed either to WWTP or oil separators by means of U/G steel pipes through sealed man holes.

Blow down are liquid streams containing water / oil / chemicals that are required to be drained from process equipment under different operating situations like startup, shutdown etc. Hydrocarbon blow down systems are closed piped systems in which streams are collected in underground blowdown drums and then pumped to respective slopes / field tanks.

Chemical sewers carry effluents containing chemicals which require separate treatment from oily water streams. These are generally corrosive and require pipes of materials resistant to corrosion or lined pipes.



- Storm water drains shall not be combined with oily waste sewer (OWS)/ Contaminated Rain Water Sewer (CRWS)/ Sanitary Waste Sewer (SWS) / combined sewer system.
- OWS/ CRWS within process unit from the equipment and area around equipment pumps (by providing curb wall) shall be collected and shall be sent to Effluent Treatment Plant (ETP). OWS from tank farm and other off sites areas shall be sent to ETP by gravity.
- Initial 30 minutes of contaminated rainwater from the process unit areas (where rain is likely to get contaminated) shall be sent to ETP through separate sewer (CRWS). After 30 minutes, it shall be routed to storm water open drain via oil catcher by using two way valve system.
- RCC drain with HDG grating shall be provided all around the unit pavement to collect non-contaminated water. This drain shall be connected to main plant drain through double valve pit arrangement. In case of accidental contamination, in generally non-contaminated areas, the flow can be diverted to CRWS via double valve pit.
- Tank farm drainage shall be provided in such a way that the storm water discharge shall be either sent to storm water open ditch or to the contaminated rain water sewer (CRWS) by providing valve pit outside the dyke wall depending on its contamination. The discharge from tank farm shall be released to ETP through gravity sewer at controlled rate to CRWS by operating two way valve system.

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- f. Configuration of sewer shall be done in such a way to have minimum depth of sewer. The exact depth shall be decided during detailed engineering. Any primary treatment, as required at Inside Plant Battery Limit (ISBL) as per Process licensor's recommendations/ process design package, shall be provided.
- g. Acidic waste shall be neutralized and discharged to Effluent Treatment Plant as per the design requirement. Required treatment as per process data sheet and design data shall be provided in Design Basis.
- h. Lining/coating to be provided over concrete and steel surfaces to protect them from the corrosive attack of chemicals in the form of leakages, spillages, overflows, washings etc. Acid/Alkali proof floor/drain lining shall be provided within and around the Caustic treatment/Handling/ Wash areas/ other chemical handling areas over RCC surface. The entire area shall be curbed by RCC kerb wall.
- i. All underground C.S. pipes shall be provided with corrosion resistance protection for service temperature up to 60°C as per specifications. All CBD lines with service temperature more than 60°C shall be provided with inorganic zinc silicate primer followed by HB coal tar epoxy coating. In addition, the CBD lines with more than 60°C shall be laid in stone/gravel bed minimum 300mm on either side on top & bottom. In no case these painted lines shall be buried in soil directly.
- j. Corrosion resistant protection given to underground CS pipe shall extend up to min. 500 mm. above/ beyond grade on both sides.
- k. Transformer oil (for oil filled transformer of 2000 liter) shall be drained as per provisions given in OISD 173.
- l. The maximum depth of sewer (invert level) shall be kept minimum possible. In case of high water table, the maximum depth shall be limited to 1.0 M below the water table.
If the above is not feasible to be achieved by gravity, the system shall be suitably supplemented with a pumping system.
- m. Where sewerage system is absent, septic tank/ soak pit shall be provided.
- n. Design of septic tank shall be as per the provisions of IS: 2470 Part-I & Part- II.
- o. If as per site requirement pre-cast septic tanks are to be provided specifications of IS: 9872 shall be followed.

Notes:

- ♦ All RCC pipes shall have socket & spigot joints. Suitable concrete supports at all socket/ spigot joints of underground piping shall be provided.
- ♦ OWS/CRWS of each process unit shall be collected in closed pit within the process unit battery limit and shall be sent to ETP as per process design basis. OWS system shall be kept sealed during construction period to avoid its use for drainage of construction water.

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- ◆ Any oil drain e.g. pump suction header drain shall be discharged to OWS even if it is intermittent.
- ◆ All exchanger drain shall be routed to OWS or CBD as per process design basis.

p. Types of Sewers and Disposal Method:

Oily sewer/ CRWS	Concrete channelling of 300mm around all pumps shall be done to regulate pump spill over to OWS.
Chemical Sewer	Neutralization pit and finally to storm water System or ETP as per design requirement
Acidic and Alkali	This waste shall be neutralized and discharged to ETP as per the design requirement.
Closed Blow Down	To CBD Drum
Cooling Tower Blow Down	To RO based DM Plant
Flare Blow Down	To ETP through OWS
Sanitary Sewer	Shall be collected in Pit/ Sump and subsequently pumped to existing ETP.



Note: All underground structures (manholes etc.) should have M-30 grade (As per IS:456) RCC concrete.

q. Underground Pipes:

- ◆ Underground pipes shall have a minimum diameter of 150 mm.
- ◆ Minimum depth of soil cover over sewer lines shall be 600 mm from the Finished Grade level to the top of pipe at road crossing and 300 mm at other areas.
- ◆ In case of minimum coverage is not kept at road crossing, alternative method like encasing by reinforced concrete around pipe shall be provided with the condition of the strength confirmation by structural calculation.
- ◆ Class NP3 R.C. Pipe shall be used for sanitary sewer.

r. Manholes:

- ◆ Design consideration of manholes shall be as per IS: 4111 Part-I and shall be leak proof construction.
- ◆ Manholes shall be installed for underground oily sewer pipe and sanitary sewer pipes at the junctions where the direction or slope is changed. The pipe shall be straight between the manholes. The manholes shall be provided at the maximum interval of 30m.
- ◆ Manhole construction shall be as follows:

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For Oily Sewer Manhole	1000mm x 1000mm RCC (minimum size) with Heavy Duty type Cast Iron round cover
For Sanitary Sewer Manhole	450mm x 900mm brick chamber with CI rectangular cover

- ◆ Top of manhole shall be as follows:

For Oily Sewer Manhole	Flush with paving in paved area. 300mm above ground in unpaved area.
For Sanitary Sewer Manhole	300mm above ground.

- ◆ Sealed Manholes shall be provided at the following locations:

- On unit oily sewer at unit battery limit, so that the unit area is cut off from any fire in offsite area or vice versa.
- Within the unit area sealed manholes should be provided at locations such that each sub-unit within the unit is isolated from the other areas. In case this demarcation is difficult, one sealed manhole for every 25 to 30M length of the main sewer should be provided.
- At change of direction of the line.
- At entry of branch line to manhole or mainline.
- Sealed manhole with vent pipes, seal type, shall be used for CS pipes up to 24 Inch diameter. For CS pipes greater than 24 Inch diameter, double compartment type sealed manholes shall be used.
- All sealed manholes shall have airtight covers and vents.



- ◆ Suitable Clean outs shall be provided at the ends and at the change of direction of branch headers (where manhole is not provided) for cleaning of sewers as and when required.

i. Design of contaminated rain water Sewer (Independent system):

The CRWS system collects contaminated rainwater, floor washings, condensate recovery drain, firewater etc. This system consists of RCC catch basin, underground piping (material shall be as per PMS), RCC manholes, vent pipes, flame arresters, CI manhole covers & frames, MS gratings, MS rungs, clean-outs holding pits etc shall be provided by "contractor" as required to complete system. Drainage of condensate steam from steam traps in plant area shall be properly designed.

Attempt shall be made to reduce the quantity of contaminated water by providing suitable means of segregating the clean and contaminated areas.

Arrangement shall be made to collect the entire quantity of contaminated water emanating

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from each plant area and install suitable means of physical separation of oil. CRWS line should hook up to the existing CRWS header. The oil-free water shall be discharged to the nearest storm water drain. This collection and treatment system shall be suitable to take care of maximum rate of contaminated water either due to rainfall or firefighting.

The contaminated rain water sewer shall be designed for the following combinations:

- ◆ Contaminated rain water or Fire water whichever is more. The quantities of contaminated rainwater shall be worked out based on the contaminated process area in the unit block.
- ◆ Sewer shall be sized flowing full with peak flows taking future requirements or 2/3 full without future requirements.

ii. Design of process water sewer / OWS (Independent system):

The sewer shall be designed based on the quantities of process waste specified by process department / Licensor. This OWS system consists of funnel, underground piping (material shall be as per PMS), RCC manholes, vent pipes, flame arresters, CI manhole covers & frames, MS gratings, MS rungs, clean-outs holding pits etc shall be provided by "contractor" as required to complete system.

a. General considerations

Trenches shall be provided all around the Compressor, DG, TGs, IA/PA compressor & other sources of oily water for collecting Oily floor wash with a Catch basin. The oily water will be sent to a common pit through underground pipes, which would be connected to the Oily Water Sewer system for disposal. The potential source of Oil contamination i.e. Compressor, DG, TG, IA/PA Compressor will be located inside the shed. So, rain water mixing is not envisaged.

For Storage Tanks, two-valve pit will be provided with connection to Storm Sewer & OWS outside the dyke wall. If the water is contaminated with Oil, it will be sent to the Oily water pit which would be connected to the Oily Water Sewer system for disposal.

Alternatively, Tank farm drainage shall be provided in such a way that the storm water discharge shall be either sent to storm water open ditch or to the contaminated rain water sewer (CRWS) by providing valve pit outside the dyke wall depending on its contamination. The discharge from tank farm shall be released to ETP through gravity sewer at controlled rate to CRWS by operating two way valve system.

For pumps requiring Lubrication, a small curb wall with connection to OWS through manholes will be provided.

For Hot Oil Storage, two-valve pit will be provided with connection to OWS & Storm Sewer & if the spillage is substantial, Oil can be collected in the drums with a barrel pump.

The RCC pit should be sized for 1 month holding capacity. This Hold-up should be available below

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the underground inlet nozzle.

b. Discharge Data

The branch sewers from processing areas should be designed for the greater of the following two situations,

- i) Rainfall plus process waste water with the sewer flowing at 2/3 of full depth.
- ii) Process waste water plus expected fire water runoff with sewers running full.

The design capacity of the trunk sewer should depend on the cumulative amount of used cooling water and condensate from various processing areas and the storm drainage from the paved areas and the largest tank dyke area. Trunk sewers generally drain large water shed; therefore, fire water flows are not governing for their sizing. However, this should be checked.

A PFD of the system shall be made identifying normal flow and design flow. The normal flow shall be equal to average process flow. After the design flows shall be identified, sewer shall be designed for running full.

c. Sewer Design

Sewers shall be designed as flowing full with peak flow taking future requirements or flowing 2/3 full without considering expansion. Minimum size of sewer shall be 150 mm.

All funnel drain shall be of minimum pipe size 100 mm dia. When 2 or more funnels join together, the OWS size shall be 150 mm.

The main oily waste sewer header shall not be less than 200 mm dia. All connections from funnel points shall be fire sealed.



Minimum velocity (at half full or running full) shall be 0.6 m/sec. If sewage consists of large quantities of sediments the minimum velocity shall be 1.0 m/sec. subject to a maximum of 2.4 m/sec.

Sewers shall be designed for the sum of rain water and process water or fire water and process water whichever is more. Storm water quantities within tank farm areas shall not be included.

d. Cover

The maximum cover over pipes in unit areas shall be as below:

- i) 300 mm: For the sewer of sizes up to 150 mm from equipment drain points to nearest main header or manhole.
- ii) 450 mm: For main headers having size 150 mm and above, when located such that there is no chance of truck movement or crane movement over then.
- iii) 750 mm: For headers in open paved areas when crane or truck movement can be expected. (CS pipes shall also be encased with 150 mm thick concrete in this case).

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e. Vent Pipes

Sewers, in general, should be designed for gravity flow. In a tightly sealed system, a rise in water level would reduce the vapour space causing obstruction to flow. Therefore, vents shall be installed on the manhole to maintain atmospheric pressure in the sewer and to release vapours to safe locations. Following shall be ensured during design stage to ensure that accidental release of vapours do not create unsafe condition:

- i) At least one vent shall be installed on manhole for every 100 meter in offsite area,
- ii) Vents shall not be located near furnaces etc.
- iii) The vent of height shall be 3 metre above the nearest tallest structure within 15 metre radius.
- iv) In critical locations, the vent pipes should be provided with steam snuffing connections.
- v) Vents should be connected to VOC control system to minimise VOC emissions.

iii. Design of Sanitary Sewer:

The sanitary sewer shall be designed for 3 times the average flow flowing half full in case of lateral sewer and flowing 2/3 full in case of Main Sewers.

iv. Cover for Sewer Line:

- ♦ Minimum cover over sewer line shall be 600 mm.
- ♦ Under road, sewer shall be protected by concrete encasement and minimum cushion shall be 1200 mm.

v. Material of Construction for Manholes:


Oily water sewer & contaminated rain water sewer:

In units areas	RCC (M30) Manhole
In Offsite areas	RCC (M30) Manhole
Sanitary Sewer	RCC (M30) Manhole

All manholes for underground sewers shall be of RCC construction with round SFRC (Steel Fibre Reinforced Concrete) covers.

vi. Manhole Seal:

For trapping of gas or prevention of spread of fire through CRWS/ oily sewer from one area to another, a liquid seal of minimum 150 mm shall be provided in manhole along with suitable vents. Location of sealed manholes shall be decided accordingly. All vent pipes of sealed manholes shall be provided in line with OISD Guide lines.

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vii. Material of Construction for Sewers:

Oily Sewer- Within process units and Tankage areas	C.S. Pipes as per IOCL requirement and relevant PMC Piping Material Specifications
Oily Sewer- Offsite gravity sewer	C.S. Pipes / RCC Hume Pipe as per IOCL requirement and relevant PMC Piping Material Specifications
Oily Sewer- Offsite Main	C.S. Pipes / RCC Hume Pipe as per IOCL requirement and relevant PMC Piping Material Specifications
Acidic and Alkali sewer	HDPE (as per IS:4984)
Chemical Sewer	HDPE (as per IS:4984) / C.I. pipes (as per IS:1536 & 1537)
Sanitary Sewer- Toilet block up to inspection chamber	uPVC pipes (as per IS: 13592, 15328)/ CI pipes (as per IS: 3486/1729)
Sanitary Sewer- Gravity main & lateral	RCC class P1 (as per IS:458) Socket and spigot, rubber joints (Suitable concrete supports at all socket / spigot joints of underground piping shall be provided)
Sanitary Sewer- Pressure main	C.I.

Manhole for acid/ alkali sewer shall be provided with Acid/ Alkali proof lining.

12. Storage Tank foundation and Dyke Wall:

a. Foundation Type:

Storage tanks shall be supported on sand pads with stone column / pile foundation in accordance with the Geotechnical recommendations and as per guide drawing. The ring wall shall be concrete if tank anchoring is required otherwise ring wall shall be in crushed stone.

b. Anticorrosive layer:

Anticorrosive layer shall be provided as per specifications for tank pads of 50 thick premix carpet over 50 thick bitumen sand mixed with additions of kerosene / oil as required for temperature less than 80° C. If the temperature is more than 80° C, then tank pad shall be provided with thermal isolation.

c. Storage Tank Dyke Walls:

Dyke walls / Fire Walls shall be provided as per OISD 118. Dyke Walls shall be of RCC. Concrete

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grade M30 shall be used for Dyke walls. Dyke walls shall be designed for retaining liquid in case of rupture of the largest tank in the farm. The minimum and maximum height of dyke wall shall be as per relevant OISD. It shall have minimum 1000 mm wide walkway with hand railing at top of wall to enable persons to walk on the wall top. Stair cases at suitable location shall be provided to approach the walkway. If space permits, dyke walls shall be provided with ramps on both sides at suitable places, for movement of vehicles for tank cleaning purpose. Fire walls, if required shall be of RCC and shall be 600 mm high (min) or as drawings / as instructed. They shall only retain spillage to prevent fire spread.

13. **Fire Proofing:**

Fire proofing for steel structures and equipment supports that could collapse under fire condition and contribute to intensity of the fire shall be provided to meet the requirements of OISD 164 (Fire Proofing in Oil and Gas Industry).

Fire resistance of a material is defined by fire rating, evaluated through a fire test based on applied thickness and time taken to reach the defined critical steel temperature. Fire rating adopted is based on UL-1709 rapid rise fire tests of protection materials for structural steel, conducted by Underwriters Laboratory, USA. In this test, fire resistance of a material is evaluated on a W10x49 steel column as per UL-1709 fire curve and fire rating is published in a UL design number under XR category for thickness and time. In addition to the fire rating, under this test, material for exterior use is also evaluated for accelerated ageing, high humidity, salt spray, wet-freeze-dry cycling, acid spray, solvent spray etc.

Thickness of fireproof coating to be applied shall be based on the following:

- Type-I: In-situ cement concrete for application up to 1.8m from grade level for steel structures shall be applied with minimum 65mm thickness.
- Type-II: Structural steel members such as column, beam etc. which shall be protected for 2 hours from reaching critical temperature 538°C, shall be applied with vermiculite based lightweight cementitious fireproof of thickness corresponding to 2 hours fire rating as per respective UL design number under UL-1709 (XR category) subject to a minimum of 30mm.
- Type-III: For equipment skirts/ saddles/ supports (which shall be protected for 2 hours from reaching critical temperature 427°C), 2 hours fire rating as per UL design is not adequate as the UL-1709 test is based on 538°C critical temperature. Therefore, for the required fire protection from reaching 427°C, higher thickness shall be necessary. For this, fireproof thickness corresponding to 3 hours fire rating as per respective UL design number under UL-1709 (XR category) shall be adopted subject to a minimum of 30mm.

14. **Pipe Sleepers:**

The RCC sleepers for process piping and fire water lines shall be designed based on the soil bearing capacity (to be ascertained by site survey) and the horizontal/vertical loads of the pipes running full.

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The sleeper shall conform to standard (minimum requirement). Firewater piping sleepers shall be independent of process piping sleepers. Design of sleepers shall be done taking into account soil conditions as per soil investigation to be carried out.

15. **Electrical / Instrumentation Cable Road Crossing (ERC / IRC):**

ERC/IRC road crossing: PVC pipe conformed to IS: 4998 encased in concrete as per STEP standard.

RCC cable trenches shall be with precast cover designed to sustain the maximum load envisaged. Buried cable trenches shall be made, as per electrical / instrumentation standards. At crossings, electrical trenches shall be made below the instrumentation trenches. Wherever, storm water drains crosses the trenches, cable shall be taken below drains with RCC duct.

The cable crossing at roads & pipe way shall be either with group of PVC pipes (Min. dia. 150 mm encased with PCC M15) or RCC ducts. Clear cover over top of PVC pipe shall be 1200 mm. In case of less cover, RCC encasement shall be provided.

16. **Barricade:**

Barricading shall be provided near construction area to prevent damage to existing facilities. The barricade shall be within the proposed plot.

The height of the barricade shall be; minimum two meters above the highest point of active work. The barricade shall be properly designed/ constructed as per BIS codes. The barricade shall be made out of steel framework with galvanized iron sheets. Steel framework and its foundations shall be properly designed/ constructed as per BIS codes.

If required, the barricade shall also be provided with suitable piping arrangement to be connected to a pressurized water source to provide necessary water curtain. After completion of the work, barricading including its foundations shall be removed and the site made good.

17. **Specific Requirement:**

- Preferably all Buildings shall be designed as Energy Efficient building.
- Rain water harvesting shall be mandatory for all buildings.
Rain Water Harvesting systems shall be designed, operated & maintained in line with guidelines provided in Manual published by Central Public Works Department & Central Ground Water Board.
- Rain Water Recharging well shall be provided for the non-plant area for recharging the ground water

18. **Fire protection & Design consideration:**

The Fire Protection system shall be conceived to operate both in prevention and fighting mode, depending on the relevant actions selected, either manual or automatic. Details shall be as per guidelines provided in the tender document.