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Design Basis for Civil and Steel Structures Works

REVISION DETAILS						
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1.0 GENERAL

1.1 Introduction

OIL & GAS Development Company Ltd. (OGDCL) is operating NASHPA Oil & Gas fields in Khyber Pakhtunkhwa of Islamic Republic of Pakistan. OGDCL intends to install LPG Recovery Plant, Compressors & Allied Facilities at this field.

1.2 Scope

This Design Basis covers general design criteria and characteristics of materials to be used for foundations, steel structures, concrete structures and buildings for Gas Processing, LPG Recovery Plant and Allied Facilities at Nashpa Oil Field.

2.0 DEFINITIONS AND ABBREVIATIONS

2.1 Definitions

Within this document the following definitions apply:

Project	NASHPA Gas Processing and LPG Recovery Plant PROC-FC-CB/NASHPA/PROJ-1247 /2015
Company/Owner	Oil & Gas Development Company Ltd.(OGDCL)
Consultant	Zishan Engineers (Pvt.) Ltd.
Contractor	Hong Kong Huihua Global Technology Limited Wholly owned Subsidiary of China OIL HBP Science and Technology Corporation Ltd
Manufacturer/Supplier/Vendor	Party(ies), which manufactures and/or supplies material, equipment and service to perform the duties as specified by CONTRACTOR in the scope of supply
Shall	Indicates a mandatory requirement
Should	Indicates a strong recommendation to comply with the requirement of this document

2.2 Abbreviations

The following abbreviations are used in this document:

Table2-1 Abbreviations

ACI	American Concrete Institute
AISC	American Institute of Steel Construction
API	American Petroleum Institute
ASCE	American Society of Civil Engineers

ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Society
BS	British Standards
EN	European Standard
AASHTO	American Association of State Highway and Transportation Officials
EPC	Engineering, Procurement & Construction
ISO	International Organization for Standardization
HPP	High Point of surrounding Paving
FGL	Finished Grade Level

3.0 REFERENCES

3.1 Codes and Standards

Doc. No.	Description
ACI 318-08	Building Code Requirement for Structural Concrete（ Published June 2008）
ACI301	Specifications for Structural Concrete
ACI 350	Code Requirements for Environmental Engineering Concrete Structures
ACI 351.2R	Foundations for Static Equipment
ACI 351.3R	Foundations for Dynamic Equipment
DIN 4024-1	Machine foundations; flexible structures that support machines with rotating elements
DIN 4024-2	Machine foundations; rigid foundations for machinery with periodic excitation
AASHTO	Guide for Design of Pavement Structures
AISC – ASD 89	Manual of Steel Construction, Allowable Stress Design, Ninth Edition
AISC 348-00	Specification for Structural Joints Using ASTM A325 & A490 Bolts
AISC 360-05	Specification for Structural Steel Buildings
ASCE 07-10	Minimum Design Loads for building and other structures
ASCE Publication	Design of Blast Resistant Buildings in Petrochemical Facilities
ASTM - A36	Standard Specification for Carbon Structural Steel
ASTM A307	Standard Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile

Doc. No.	Description
	Strength
ASTMA325M	Standard Specification for Structural Steel bolts, steel, heat treated 830 MPa minimum tensile strength.
ASTMA490M	Standard Specification for High-Strength Steel Bolts, Classes 10.9 &10.93 for Structural Steel Joints (Metric)
ASTM A497	Standard Specification for Steel Welded Wire Reinforcement, Deformed, for Concrete.
ASTM A563	Specification for Carbon Steel &Alloyed Steel Nuts
ASTM A185	Standard Specification for Steel Welded Wire Fabric, Plain, for Concrete Reinforcement
ASTMA615M	Standard Specification for Deformed &Plain Steel Bars for Concrete Reinforcement
ASTM C90	Standard Specification for Load-Bearing Concrete Masonry Units
ASTM C33	Standard Specification for Concrete Aggregates
ASTM C94	Standard Specification for Ready-Mixed Concrete
ASTM C150	Standard Specification for Portland Cement
ASTM C270	Standard Specification for Mortar for Unit Masonry
ASTM C494	Standard Specification for Chemical Admixtures for Concrete
ASTM C1017	Standard Specification for Chemical Admixtures for use in Producing Flowing Concrete
ASTM F436	Specification for Hardened Steel Washers
ANSI A12.1	Safety Requirements for Floor &Wall Openings, Railings &Toe boards
ANSI A14.3	Safety Requirement for Fixed Ladders
ANSI A64.1	Requirements for Fixed Industrial Stairs
ASME B1.13M	Metric Screw Threads : M Profile
AWS D1.1	Structural Welding Code
BS EN 1991-1-4 2005	Euro code 1: Actions on Structures -Part1-4 General Actions-Wind Actions
UBC-1997	Uniform Building Code
IBC-2012	International Building Code
API 650	Welded Steel Tanks for Oil Storage

Doc. No.	Description
API2218	Fireproofing Practices in Petroleum and Petrochemical Processing Plants
BS 8002	Earth Retaining Structures
BS 8004	Code of Practice for foundations
BS 8007	Design of Concrete Structures for Retaining Aqueous Liquids
BS 8110 Part-1	Structural use of concrete
BS 8666	Specification for Scheduling, Dimensioning, Bending and Cutting of Steel Reinforcement for Concrete
BS 6399	Design Loads for buildings and other structures
ACI347	Guide to Formwork for Concrete
ACI 304.1R	Guide for the Use of Preplaced Aggregate Concrete for Structural and Mass Concrete Applications
ACI 304.2R	Placing Concrete by Pumping Methods
ACI 304.3R	Heavyweight Concrete: Measuring, Mixing, Transporting, and Placing
ACI 304.4R	Placing Concrete with Belt Conveyors
ACI 304.6R	Guide for Use of Volumetric-Measuring and Continuous-Mixing Concrete Equipment
ACI 304R	Guide for Measuring, Mixing, Transporting, and Placing Concrete
ACI 305.1	Specification for Hot Weather Concreting
ACI305R	Guide to Hot Weather Concreting
ACI 214.4R	Guide for Obtaining Cores and Interpreting Compressive Strength Results
ACI214R	Guide to Evaluation of Strength Test Results of Concrete
ACI543R	Design, Manufacture, and Installation of Concrete Piles
ACI SP-214	Polymers in Concrete: The First Thirty Years
ACI SP-66	ACI Detailing Manual

3.2 Project Specifications, Procedures and drawings

Particular reference is made to the following project specifications:

[1]	General Notes for Reinforced Concrete Works
[2]	General Notes for Steel Structures

[3]	Specification for Coating and Painting
[4]	Specifications for Plain and Reinforced Concrete
[5]	Specifications for Structural Steel works
[6]	Tender Drawings

4.0 DESIGN LOADING

The following loads and forces shall be considered, where applicable, in the design of structures and foundations.

Loads and Force	Symbols
• Dead Load	DL
• Live Load	LL
• Wind Load	WL
• Seismic Load	EL
• Empty Load	EE
• Operating Load	EO
• Test Load	ET
• Friction Load	FF
• Dynamic Load (Vibratory Equipment)	DYL
• Impact Load	IL
• Traffic Load	TL
• Crane Load	CR
• Explosion/Blast Load	BL
• Piping Load	PL
• Piping Anchor Load	AL
• Soil Pressure Load	SL
• Liquid Pressure Load	LPL
• Thermal Load	THL
• Bundle Pull Load	BPL

4.1 Dead load (DL)

Dead load is the self-weight of structures and the weight of all materials permanently fastened there to or supported thereby, such as pipes, insulation and walkways.

4.1.1 Density of Materials

The following materials and their density are adopted for the design:

Material	Density (kN/m^3)
Reinforced Concrete	25
Cement screed finishes	23
Glass	27
Well-compacted soil	18
Structural Steel	78.5
Water	10
Dense concrete fireproofing	25
Lightweight concrete fireproofing	13-16

4.1.2 Dead Weights of Structural Elements

Grating（Bearing Bar 32x3）	0.35 kN/m^2
Checkered plate (5mm thk.)	0.50kN/m^2
Handrail	0.20 kN/m
Ladder without cage	
➢ for 70X10thk post	0.17kN/m
➢ for PFC100 post	0.28 kN/m
Ladder with cage	
➢ for 70X10thk post	0.30 kN/m
➢ for PFC100 post	0.38 kN/m

4.2 Live Load (LL)

Live loads shall be defined as the weight of all movable loads such as personnel, tools, miscellaneous equipment, and stored material.

Live loads shall be uniformly distributed over the areas. Live Load recommended for different areas shall be as follows:

Access Walkways	5.00 kN/m^2
Operating Platforms	5.00 kN/m^2
Stairways & Landings	4.00 kN/m^2

Flat roofs (not be used as working or storage area)	2.00 kN/m^2
Flat roofs (for roof mounted equipment)	5.00 kN/m^2
Pitched Roofs	2.00 kN/m^2
Work Area/Plant at Grade	10.00 kN/m^2
Control Rooms	10.00 kN/m^2
Electrical Substations (raised floor)	10.00 kN/m^2
Light Storage Areas	5.00 kN/m^2
Heavy Storage Areas	10.00 kN/m^2
Battery Rooms	10.00 kN/m^2
Laboratories	5.00 kN/m^2
Office Areas	3.00 kN/m^2
Prayer Hall	5.00 kN/m^2
Other floor finishes	1.5 kN/m^2

4.3 Wind Load (WL)

Wind pressure shall be calculated according to UBC 1997 vol. 2 chapter 16 Division III, based on the value of basic wind speed of 45 m/sec, Exposure C and importance factor Iw=1/1.15.

4.3.1 Design Wind Pressures

Design wind pressures for buildings, structures and elements shall be determined for any height as below:

P = Ce Cq qs Iw

Where,

Ce = combined height, exposure and gust factor coefficient as per Table 16-G of UBC Vol.2-1997

Cq = pressure coefficient for the structure or portion of structure under consideration as per Table 16-H of UBC Vol.2-1997

Iw = importance factor as per Table 16-K of UBC Vol.2-1997 = 1/1.15.

P= design wind pressure

qs = wind stagnation pressure at the standard height of 10m as per Table 16-F of UBC Vol.2-1997

4.3.2 Wind Load on Building/Shelter

Wind load on buildings and shelters shall be computed and applied to the procedures outlined in UBC-97.

Design Wind Pressure = Ce.Cq.qs.Iw (Section 1616 from UBC-97)

Where,

Ce= combined height, exposure and gust factor coefficient (Table 16-G from UBC-97)

Cq =Pressure coefficient for the structure or portion of structure under consideration (Table 16-H from UBC-97)

Method 1 (as per clause 1621.2) shall be used for shelters and Method 2 (as per clause 1621.3) shall be used for buildings.

Iw=Importance Factor (Table 16-K from UBC-97)

qs=Wind stagnation pressure at the standard height of 33 feet (Table 16-F from UBC-97)

4.3.3 Wind Load on Equipment

For storage tanks, wind loadings shall be applied over foundations as per loadings provided by Mechanical Department.

For equipment provided by vendor, wind loads (for both wind shear and moment) shall be provided by Equipment Vendor in its general arrangement and \shall be used for designing of foundations / structures etc.

4.4 Seismic Load(EL)

Seismic loads on steel structures, concrete structures and foundations shall be calculated according to UBC 1997, based on seismic Zone 2B (Seismic Zone Factor Z=0.2 as per Table 16-I) with Importance Factor (I) of 1.0/1.25.

For un-factored loading combinations, used for stability and soil pressure checks, design seismic forces, being a strength design base shear, shall be reduced by a 1.4 factor, as per section 1612.3.

For factored loading combination, used for concrete strength design, design seismic forces shall not be factored.

4.4.1 Seismic Parameters

UBC reference	Factor	Coefficients
Table 16-I	Zone factor	Z =0.2
Table 16-J	Soil Type	Sc (to be verified with Geotechnical report)
Table 16-Q	Seismic coefficient, Ca	Ca =0.24 (to be verified with Soil Type)
Table 16-R	Seismic coefficient, Cv	Cv =0.32 (to be verified with Soil Type)

4.4.2 Horizontal Component of Seismic Force

The total design base shear in given direction as per equation 30-4 of UBC Vol 2-1997 is

$$V = \frac{CvI}{RT}W$$

The total design base shear shall not exceed the following (eqn 30-5 of UBC Vol 2-1997):

$$V = \frac{2.5CaI}{R}W$$

The total design base shear shall not be less than the following (eqn 30-6 of UBC Vol 21997):

$$V = 0.11CaIW$$

Time period is calculated as per clause 1630.2.2 of UBC-97

Time period from method A, TA =$Ct(hn)^{3/4}$

hn = Height of structure above base

Ct = 0.0853 for steel moment resisting steel frames

Ct = 0.0731 for RC moment resisting frames & steel braced frames

Ct = 0.0488 for other buildings

R =numerical co-efficient (per Table 16-N of UBC 1997)

=5.6 for Ordinary Steel Braced Building Frame System (For shelters and pipe/bridge rack design along the ordinary braced frame only)

=4.5 for Ordinary Steel Moment Resisting Frame System (for shelters and pipe/bridge rack design along the moment resisting frame only)

For equipment, seismic loads shall be provided by Equipment Vendor in its general arrangement (for both seismic shear and moment) and shall be used for designing of foundations and structures etc.

For storage tanks, seismic loadings shall be applied over foundations as per loadings provided by mechanical department.

4.5 Empty Load(EE)

This load includes the weight of equipment and/or piping without any product. It is to be considered as a dead load.

4.6 Operating Load(EO)

This load includes the weight of equipment/pipe (including platforms and ladders attached to the equipment), solids and/or liquids normally inside the equipment and connected pipes. This load includes also the weight of piping together with the fluids present inside during normal operation.

In static calculation this load shall be considered as a dead load.

4.7 Test Load(ET)

Equipment test load is the weight of the equipment and/or piping plus the weight of water necessary to perform the hydraulic test. Equipment shall be tested one at a time. In static calculation this load shall be considered as a dead load.

4.8 Friction Load (FF)

Friction Forces are the forces resulting due to contact between the two materials.

Friction coefficients shall be as follows:

- Concrete to soil = 0.57
- Steel to steel = 0.30
- Steel to concrete = 0.40
- Steel to Teflon = 0.15
- Stainless Steel to Teflon = 0.06
- Teflon to Teflon = 0.10

4.9 Dynamic Load (DYL)

Foundations supporting rotating machinery such as reciprocating compressors etc. shall be designed to safely withstand static loads plus vibratory loads. Vibratory loads (unbalanced forces) shall be obtained from the vendor, if not to be ignored, in consultation with manufacturer.

Machine/equipment loads shall be governed by the manufacturers' specifications. Loads to be considered shall be both static and dynamic. The loading for the following machines/equipment shall be applied for the dynamic analysis taken into account:

(1). Gas Turbine and Compressor Loads

(2). Generator Loads

(3). Any other vibrating equipment

Dynamic analysis shall be performed for foundations supporting vibrating equipment, weighing more than 25kN in accordance with the latest codes based on the dynamic properties of soil and foundation materials and soil-structure interaction.

Foundations shall be designed such that the natural frequency of the foundation/soil system is either 25 % under or over the operating frequency of the machine, the maximum amplitude at resonance shall not exceed 0.02mm

4.10 Impact Load (IL)

The design load for structures handling moving loads shall include an impact allowance (for the maximum crane wheel loads) as specified in the AISC Manual as follows:

- For pendant-operated overhead traveling crane support girder and their connections 10%.

The lateral force on crane runways to provide for the effect of moving crane trolley shall be not less than 20% of the sum of weights of the lifted load and of the crane trolley, but exclusive of other parts of the crane. The forces shall be assumed to be applied at the top of the rails, acting in either direction normal to the runway rails, and shall be distributed with due regard to lateral stiffness of the structure supporting the rails.

The longitudinal tractive force shall be not less than 10% of the maximum wheel loads of the crane applied at the top of the rail, unless otherwise specified.

4.10 Traffic Load (TL)

The access roads shall be specified according to the plant requirements, for roads and bridges pavement design, AASHTO shall be used.

4.11 Explosion/Blast Load (BL)

Structures to be designed against explosion loads shall be designed to withstand imposed loads such that adjacent structures/buildings and passing personnel are not damaged/injured.

Any building and structure exposed to blast load shall be designed to withstand a blast load provided by the vendor. In absence of time dependent impulsive load from vendor, equivalent to a pressure of 25KN/m² shall be applied.

Wind or earthquake loads shall not be combined with blast load.

4.12 Piping Load (PL)

The effects of loads due to piping including insulations/covering/fireproofing etc, gases/liquids flowing through pipes shall be taken into account. Actual loads to be taken directly from piping stress analysis report.

Maximum piping load shall include the weight of all pipes, valves, fittings, insulation, etc., and the weight of contents.

Piping Loads shall be taken as Live Loads.

4.13 Piping Anchor Load (AL)

Loads on structures and foundations, caused by the expansion/contraction of equipment or pipes, such as anchor and guide loads (AF) produced from thermal expansion, internal pressure, and surge shall be considered as dead loads. Anchor pipe forces shall be obtained from the pipe stress analysis department.

4.14 Soil Pressure Load (SL)

The pressure exerted by soils shall be considered when its effect to the pit, pond and retaining wall design is significant. Parameters of soil pressure coefficients shall be taken from Soil Investigation final Report.

Passive soil pressure may be taken into account for the foundations subject to horizontal load such as wind load, anchor forces or blast load.

4.15 Liquid Pressure Load (LPL)

The pressure exerted by water shall be considered when its effect to the pit, pond and retaining wall design is significant.

Static water pressures in the aqueous retaining structures shall be considered where applicable.

4.16 Thermal Load (THL)

Thermal loads are forces caused by changes in temperature including those forces caused by expansion or contraction of structures, equipment, piping etc. A temperature differential of 55^{o}C shall be considered for determination of these loads.

4.17 Bundle Pull Load (BPL)

A longitudinal force representing bundle pulling shall be applied at the center of the tube bundle. The fixed saddle only shall support such force. Bundle pulling shall be considered equal to the weight of the bundle or to 10kN, whichever is bigger.

Bundle pull load for exchangers shall be equal to 0.1 kip per inch of Diameter of the tube bundle plus 30% of the bundle weight

In case of stacked equipment, most critical case will be considered for designing of foundation and piers

5.0 LOAD COMBINATIONS

Foundations and structures shall be designed with adequate safety margins to withstand various load combinations, For Strength design of RCC Structures, factored load combinations of UBC shall be used and for Serviceability design un-factored load combinations of UBC / ACI shall be used. For designing of Steel Structures, AISC "Manual of Steel Construction, Allowable Stress Design, Ninth Edition" 1989 shall be used, for which un-factored load combinations to be used as of UBC / AISC.

Generally Load Combinations Conditions shall be as follows:

- Dead long-term
- Dead + Live long-term
- Operating long-term
- Dead + Seismic short-term
- Empty + Wind load short-term
- Operating + Wind load short-term
- Erection load + Wind load short-term
- Hydrostatic Test load short-term
- Start-up/Shutdown load short-term
- Vehicle load short-term

6.0 REINFORCED CONCRETE WORKS

6.1 Materials

6.1.1 Concrete Grades

Material quality for reinforced concrete shall be in accordance with ACI 318-08 "Building Code Requirements for Structural concrete".

Concrete works shall be designed using following characteristic strength on cylinder at 28 days (ASTM C39):

- Substructure f'c = 21 N/mm^2
- Superstructure f'c = 28 N/mm^2
- Lean concrete f'c = 10 N/mm^2

6.1.2 Reinforcing Steel

Deformed reinforcing steel bars shall be Grade 60 (minimum yield strength fy = 416 N/mm2) according to ASTM A615.

6.1.3 Anchor Bolts, Plates and Steel Inserts

All embedded items shall be ASTM A36 material or equivalent. Inserts, anchors and embedded items required for adjoining work or for its support shall be placed prior to concreting.

Material for anchor bolts shall conform or be equal to the following and shall be hot dip galvanized according to ASTM:

- ASTM A307M Grade A for bolts (fy = 248Mpa, Ft = 400 Mpa) or A325 (fy = 558 Mpa, Ft = 724 Mpa)
- ASTM A563M Grade A for nuts
- ASTM F436M Circular type for washers

6.1.4 Grout

- Non-shrink cementitious grout:

Static equipment, structural steel base plates shall be placed on non-shrink cementitious grout and as indicated in drawings.

Non-shrink cementitious grout shall be prepared and applied strictly in accordance with the manufacturer's instructions.

The compressive strength of the grout shall exceed 40 N/mm^2 at 7days and 60 N/mm^2 at 28 days.

- Non-shrink Epoxy grout:

The grout shall be applied beneath heavy-duty industrial machinery subjected to heavy dynamic or mobile loads, rotating and reciprocating equipment and as indicated in drawings.

The tensile strength shall exceed 15 N/ mm^2, flexural strength 28 N/mm^2 and compressive strength 80 N/ mm^2 at 7 days.

6.2 Concrete Cover

Minimum concrete cover of reinforcing bars shall be as follows:

Cast-in-place concrete (non prestressed)

- Concrete cast against and permanently exposed to earth directly: 75mm
- Concrete not exposed to weather or in Contact with ground directly: 40mm
- Concrete cover exposed to earth or weather directly:
  - Wall panels: 40mm
- Concrete cover for Super Structure:
  - Column, Beam: 40mm
  - Slab: 20 mm
  - Pedestal Top Cover: 25 mm

Precast concrete (manufactured under plant control conditions):

- Concrete exposed to earth or weather:
  - Column, Beam & Wall panels: 40mm
  - Slab: 20 mm
  - Pedestal Top Cover: 25 mm
  - Other members: 50 mm

6.3 General Design Criteria for Reinforced Concrete Works

All concrete works shall be designed in accordance with ACI 318-08 for the loads and load combinations specified in the section 4 & 5 of this design basis.

6.3.1 Reinforcement Details

All bar arrangement such as spacing, lapping, anchorage and reinforcement details shall be carried out according to the requirements of ACI 318-08.

All pad / blocks shall be reinforced on all faces.

6.3.2 Minimum depth/thickness of beam and Slab:

Minimum thickness of Non-prestressed beams or one-way slabs unless deflections are calculated, shall be:

	Minimum thickness, **h**			
	Supported	**One end Continuous**	**Both ends Continuous**	**Cantilever**
Member	Members not supporting or attached to partitions or other construction likely to be damaged by large deflections			
Solid one way slabs	l/20	l/24	l/28	l/10

For two way slab, the minimum thickness shall be calculated as per ACI Code 318 chapter 9 & 13.

6.3.2 Maximum Permissible Computed Deflections:

Type of member	Deflection to be considered	Deflection limitation
Flat roofs not supporting or attached to nonstructural elements likely to be damaged by large deflections	Immediate deflection due to live load LL	**/ /180**
Floors not supporting or attached to nonstructural elements likely to be damaged by large deflections	Immediate deflection due to live load LL	**/ /360**
Roof or floor construction supporting or attached to nonstructural elements likely to be damaged by large deflections	That part of the total deflection occurring after attachment of nonstructural elements (sum of the long-term deflection due to all sustained loads and the immediate deflection due to any additional live load)	**/ /480**
Roof or floor construction supporting or attached to nonstructural elements not likely to be damaged by large deflections		**/ /240**

6.3.3 Crack Width for Water Retaining Structures:

Crack width shall be limited by an increase in the amount of reinforcement used, by reducing the stress at the service load level and by limiting reinforcement spacing.

Cracking check shall be carried out according to ACI 318-08. In particular for water tight structures, provision of ACI350 shall be applied.

6.4 Foundation Design

6.4.1 General Design Criteria and Details

The following design criteria shall be applied:

- Foundations shall be cast on a 50 mm thick lean concrete layer.
- Foundation pedestal for structural columns and equipment legs shall extend not less than 50 mm from edges of baseplates.
- Foundation for equipment such as pump and compressors shall extend not less than 100 mm form the edges of the baseplates unless otherwise specified on manufacturer's drawings.
- As general rule anchor bolts shall be installed before concrete casting. If necessary, adequate pockets shall be provided in the foundation when anchor bolts are installed later. Pockets shall be filled using non-shrinking grout.
- Allowable soil bearing capacity shall be taken as per the recommendation of Geotechnical Investigation report.
- Safety Factor for Stability of Foundations shall be as following:

Type of Structure	Factor of Safety Against Overturning		Factor of Safety Against Sliding	
	Erection	Operating	Erection	Operating
Retaining wall/Footing	1.5	2.0	1.5	1.75
Pipe rack	1.5	2.0	1.5	1.75
Fuel Tank	1.5	2.0	1.5	1.75

6.4.2 Static Equipment Foundations:

Loading data for foundations design shall be provided by the vendor. Load combinations for design of equipment foundations shall be as follows:

- Dead + Seismic
- Empty + Wind load
- Operating + Wind load
- Hydrostatic Test load
- Empty + Bundle Pull
- Operating + Friction load

Anchor bolt number, Dia, Bolt Circle Dia and other data related to fixing of equipment with foundation shall be provided by Vendor. Anchor bolt shall be designed in accordance with recommendation of ACI318.

6.4.3 Rotary Machinery (including Reciprocating) Foundations:

Rotary machinery may be supported either on a mono-block foundation or rigid elevated structure.

In case of vendor requirement for foundation design to be based on dynamic analysis, all required data for dynamic analysis shall be obtained from vendor and soil dynamic properties shall be taken from Geotechnical Soil Investigation report.

In absence of any specific requirement for dynamic analysis, the foundation shall be designed by weight ratio method.

Soil bearing pressure shall not exceed half of the net allowable values for a static load. For piled foundations, no reduction in allowable pile bearing capacity is required.

The foundation shall weigh more than 3 times of the centrifugal machinery such as compressors, pumps, and blowers whose weight are more than 2.5 ton or whose area of base skids are more than 2.5 $m^2$and more than 5 times in case of reciprocating machinery.

6.4.4 Tank Foundations:

R.C.C Ring wall tank foundations shall be designed using the guidelines given in API 650. Settlement design of the concrete tank foundations shall be in accordance with Soil report.

Leak detection system at bottom of tank shall be provided as per API 650.

6.4.5 Foundation for Steel Structures:

Foundation for steel structure shall be designed using support reactions from structure analysis. The load shall be transferred through base plate and anchor bolt to foundation elements. Depending on pin or fixed connection and using forces from analysis, anchor bolt shall be detailed and designed in accordance with recommendation of ACI-318.

6.4.6 Anchor Bolt Design:

Anchors bolts in concrete shall be used to transmit structural loads by means of tension, shear, or a combination of tension and shear between: (a) connected structural elements; or (b) safety-related attachments and structural elements. Safety levels specified here under are intended for in-service conditions, rather than for short-term.

Basic requirement of design shall be as follows:

- Anchors and anchor groups shall be designed for critical effects of factored loads as determined by elastic analysis.
- For nominal strengths related to concrete strength, modifications for size effects, the number of anchors, the effects of close spacing of anchors, proximity to edges, depth of the concrete member, eccentric loadings of anchor groups, and presence or absence of cracking shall be taken into account.
- Embedded Length of anchor bolt shall be determined based on the below factors:
  - Concrete breakout strength of anchor in tension
  - Pull out strength of anchor in tension
  - pull out strength of anchor in tension

- Concrete breakout strength of anchor in shear
- Concrete pry out strength of anchor in shear

In addition, anchors shall satisfy the required edge distances, spacing, and thicknesses to preclude splitting failure.

6.4.7 Box Culverts:

Box culverts design at road crossing, if required, shall be in accordance with AASHTO/Pakistan Highway Code.

6.4.8 Protective Coating to Surface of Concrete:

Two coats of bitumen shall be provided to all concrete surfaces where are directly exposed to earth to protect against sulphate and chloride attacks.

7.0 STEEL STRUCTURES

7.1 Materials

7.1.1 Steel Structure:

Material for structural steel shall be as per ASTM A36 or other equivalent with minimum yield strength of 36 ksi .

7.1.2 Connections Bolts:

High-strength bolts-bearing type shall be per ASTM A325 Type 1 for bolts, A563 Grade DH for heavy hex nuts and F436 for washers, or grade 8.8 according to EN-ISO-898 or equivalent. Bolts, nuts and washers shall be compatible according to AISC requirements and shall be hot dip galvanized according to ASTM.

Common bolts shall be ASTM A307 Grade B with nuts ASTM A563 Grade A heavy hex or grade 4.6 or 5.6 conforming to EN-ISO-898 or equipment. They shall be used for joist, stair stringers, handrails and other support connections, and shall be hot dip galvanized according to ASTM.

7.2 General Design Criteria

The design of structural members and detailing of connections shall be per “Manual of Steel Construction, Allowable Stress Design, Ninth Edition" 1989.

Design of structures shall be carried out maximizing, where possible, the use of braced frames, taking into consideration the layout of equipment and piping,

Transverse steel beams carrying anchor loads shall be designed to resist the anchor load either by bending or by bracing.

7.2.1 Connections:

- Shop connections shall normally be welded.
- Field connections shall normally be as follows:

- Bearing type joint using high strength bolts with threads included in the shear plane.
- Secondary or lightly loaded members, such as joists, furring strips, girts, purlins, stairs, adders, handrails, etc., mild steel bolts shall be used.

7.2.2 Shear-keys:

In principle shear stress must not be transferred on foundation by anchor bolts. Shear design of steel structure base-plates shall meet the following criteria:

Shear-keys shall be provided under columns which transfer important shear loads (such as braced frames shelters with bridge-crane).

Shear can be transferred to foundation by friction for minor structures, such as walkways, shelters without bridge-crane, etc. In these cases the effective compressed area shall be calculated based on actual vertical load and moment. If the effective shear load exceeds the maximum shear transferred by friction, shear-key shall be foreseen.

Nominal stress for anchor bolts shall be as per AISC 360 Table J3.2:

Whereas shear is unavoidable combined shear and tension bolts check shall be carried out according to eq. J3-2 and J3-3a of AISC-360

7.3 Allowable Deflection Limit

Vertical deflection and Horizontal displacement shall not exceed the following:

Vertical Deflection:

- Beam Supporting floor: L/240
- Beams Supporting Pipe: L/240
- All Other beams: L/200
- Beam Supporting Equipment: L/500
- Beam Supporting Crane: L/600
- Cantilever Beam: L/180

Horizontal Displacement:

- Frames: H/300
- Cantilever Column: H/200
- Crane Column: H/600

7.4 Slenderness ratio

The slenderness ratio of compression/tension members shall not exceed the following values:

- Primary members in compression: 180

- Secondary members in compression: 250
- For tension bracing with L/r shall be less than: 300.

7.5 Expansion Joints

The thermal stresses due to climatic temperature change in the structural members shall be minimized by providing expansion joints at appropriate intervals. The intervals shall not be more than 60 m for steel pipe rack.

7.6 Types of Construction

The structures that support equipment or piping etc. shall be of a braced type in one direction and of a rigid-frame type in the orthogonal direction.

- Where braced frame construction does not constitute obstruction to access, operation and maintenance, braced frames in both directions may be used.
- Knee braced frames may be permitted, provided those braces do not present obstruction to pipe, personnel and maintenance.
- The hybrid construction (combination of reinforced concrete frame and steel frame) may be adopted in view of practicality and economy.

7.7 Allowable Stress Ratio

Combined Stress ratio of columns and beams shall not exceed the following:

- Column Stress ratio < 0.8
- Primary Beam Stress ratio < 0.8
- Secondary Beam Stress ratio < 0.9

8.0 DESIGN TOOLS AND SOFTWARE

Following software shall be used for Analysis and Design of Foundations and Structures:

- Staad Pro V8i
- SAP 2000 V 15
- Staad Foundation Advanced
- PROKON
- AutoCAD 2008
- Indoor Excel Design Spreadsheets