ADNOC GROUP PROJECTS AND ENGINEERING

STRUCTURAL DESIGN BASIS – ONSHORE SPECIFICATION

Specification

AGES-SP-01-003

ص ب 898، أبوظبي، الإمارات العربية المتحدة
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GROUP PROJECTS & ENGINEERING / PT&CS DIRECTORATE

CUSTODIAN	Group Projects & Engineering / PT&CS
ADNOC	Specification applicable to ADNOC & ADNOC Group Companies

Group Projects & Engineering is the owner of this Specification and responsible for its custody, maintenance and periodic update.

In addition, Group Projects & Engineering is responsible for communication and distribution of any changes to this Specification and its version control.

This specification will be reviewed and updated in case of any changes affecting the activities described in this document.

INTER-RELATIONSHIPS AND STAKEHOLDERS

a) The following are inter-relationships for implementation of this Specification:

   i. ADNOC Upstream and ADNOC Downstream Directorates and

   ii. ADNOC Onshore, ADNOC Offshore, ADNOC Sour Gas, ADNOG Gas Processing. ADNOC LNG, ADNOC Refining, ADNOC Fertilisers, Borouge, Al Dhafra Petroleum, Al Yasat

b) The following are stakeholders for the purpose of this Specification:

   ADNOC PT&CS Directorate.

c) This Specification has been approved by the ADNOC PT&CS is to be implemented by each ADNOC Group company included above subject to and in accordance with their Delegation of Authority and other governance-related processes in order to ensure compliance

DEFINED TERMS/ ABBREVIATIONS / REFERENCES

"**ADNOC**" means Abu Dhabi National Oil Company.

"**ADNOC Group**" means ADNOC together with each company in which ADNOC, directly or indirectly, controls fifty percent (50%) or more of the share capital.

"**Approving Authority**" means the decision-making body or employee with the required authority to approve Policies & Procedures or any changes to it.

"**Business Line Directorates**" or "**BLD**" means a directorate of ADNOC which is responsible for one or more Group Companies reporting to, or operating within the same line of business as, such directorate.

"**Business Support Directorates and Functions**" or "**Non- BLD**" means all the ADNOC functions and the remaining directorates, which are not ADNOC Business Line Directorates.

"**CEO**" means chief executive officer.

"**Group Company**" means any company within the ADNOC Group other than ADNOC.

"Specification" means this Structural Design Basis Onshore Specification.

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GENERAL

1 INTRODUCTION

This Specification establishes the minimum criteria for structural engineering and design of facilities installed onshore (mainland and island). This document excludes the design criteria for pre-service conditions.

1.1 Purpose

This Specification contains the minimum criteria for structural engineering and design for the framework and foundations of all buildings, process structures and pipe racks and for the foundations of vertical vessels, horizontal vessels, heat exchangers, storage tanks, vibrating equipment, grade and elevated slabs and masonry structures. Miscellaneous plant structures such as pits, sumps and retaining walls are also covered by this Specification.

1.2 Definitions

Where used in this Specification, the following terms shall have the meanings indicated below unless otherwise clearly indicated by context of their use.

COMPANY	Abu Dhabi National Oil Company or any of its group companies. It may also include an agent or consultant authorized to act for, and on behalf of the COMPANY.
CONTRACTOR	The parties that carry out all or part of the design, engineering, procurement, construction, commissioning or management of the PROJECT. CONTRACTOR includes its approved MANUFACTURER(s), VENDOR(s), SUPPLIER(s) and SUBCONTRACTOR(s).
DESIGNER	The Engineering Division of the CONTRACTOR or the Consultant which performs the design of the element in question.
ITP	Inspection & Test Plan prepared by the CONTRACTOR/ MANUFACTURER, reviewed and approved by COMPANY, highlighting the principal hold and witnessing points during and after the process of the product realization (i.e.: manufacturing, fabrication, construction, installation), to ensure that the quality level of the product is within the acceptable design standards and requirements.
MANUFACTURER/ VENDOR/SUPPLIER	The party which manufactures and/or supplies the material/equipment and provides technical documents/drawings and services to perform the duties specified by COMPANY/CONTRACTOR.
MAY	Indicates a permitted option.
PROJECT	To be identified

PROJECT MANAGEMENT CONSULTANT (PMC)	Persons, firms, companies, or partnerships appointed by COMPANY to perform PROJECT Management services for the PROJECT, on behalf of the COMPANY.
PROJECT MANAGEMENT TEAM (PMT)	The COMPANY authorized party responsible for the overall day-to-day execution of the Project. The PMT is to serve as the liaison between the COMPANY and the CONTRACTOR(S) on the Project.
SHALL	Indicates a mandatory requirement.
SHOULD	Indicates a recommendation
SUBCONTRACTOR/ SUBVENDOR/SUBSUPPLIER	The party(s) which carry(s) out all or part of the design, procurement, installation and testing of the system(s) as specified by the CONTRACTOR/VENDOR.
TECHNICAL DEVIATION	A deviation requested by the CONTRACTOR, usually after receiving the Contract Package or Purchase Order.
TPA	Company contracted to undertake the third-party inspection & verification tasks (TPA) on behalf of ADNOC.
WORKS	CONTRACTOR's scope of work

1.3 Abbreviations

AISC	American Institute of Steel Construction
ANSI	American National Standards Institution
API	American Petroleum Institution
ASCE	American Society of Civil Engineers
ASNT	American Society for Non-destructive Testing
ASTM	American Society for Testing and Materials
AWS	American Welding Society
BDR	Blast Design Requirements
BS	British Standards
CMMS	Computer Maintenance Management system
DTI	Direct Tension Indicator
FGL	Finish Ground Level

GIS	Geographic Information System
HSE	Health, Safety & Environment
HPP	High Point of Paving
HVAC	Heating, Ventilation, Air Conditioning
ICC	International Code Council
ISO	International Organization for Standardization
PFP	Passive Fire Protection
PRT	Process Risk Tool
QA	Quality Assurance
QC	Quality Control
QCR	Quality Control Record
RCSC	Research Council on Structural Connections
UDL	Uniformly Distributed Load

SECTION A

2 REFERENCE DOCUMENTS

2.1 International Codes and Standards

The following Codes and Standards shall form a part of this Specification. When an edition date is not indicated for a Code or Standard, the latest edition in force at the time of the contract award shall apply.

AMERICAN ASSOCIATION OF STATE HIGHWAYS AND TRANSPORTATION OFFICIAL (AASHTO)

AASHTO LRFD	Bridge Design Specifications

AMERICAN CONCRETE INSTITUTE (ACI)

ACI 216.1	Code Requirements for Determining Fire Resistance of Concrete and Masonry Construction Assemblies
ACI 224.3R	Joints in Concrete Construction
ACI 301	Specifications for Structural Concrete
ACI 302.1R	Guide for Concrete Floor and Slab Construction
ACI 318M/318R	Building Code Requirements for Structural Concrete and Commentary
ACI 336.2R	Suggested Analysis and Design Procedures for Combined Footings and Mats
ACI 350M/350R	Code requirements for Environmental Engineering Concrete Structures and Commentary
ACI 530	Building Code Requirements for Masonry Structures and Commentary

AMERICAN INSTITUTE OF STEEL CONSTRUCTION (AISC)

AISC 303	Code of Standard Practice for Steel Buildings and Bridges
AISC 325	Steel Construction Manual
AISC 341	Seismic Provisions for Steel Buildings
AISC 360	Specification for Structural Steel Buildings

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI A14.3	Fixed Ladders – Safety Requirements

AMERICAN PETROLEUM INSTITUTE (API)

API 650	Welded Steel Tanks for Oil Storage, Appendix E

AMERICAN SOCIETY OF CIVIL ENGINEERS (ASCE)

ASCE 7-16	Minimum Design Loads and Associated Criteria for Buildings and Other Structures – Including Supplement 1
ASCE Task Committee on Seismic	Guidelines for Seismic Evaluation and Design of Petrochemicals Facilities
ASCE Task Committee on Wind Induced forces	Wind Loads for Petrochemicals and Other Industrial Facilities
ASCE Task Committee on Blast-Resistant Design	Design of Blast-Resistant Buildings in Petrochemicals Facilities

AMERICAN SOCIETY FOR NON-DESTRUCTIVE TESTING (ASNT)

ASNT-TC-1A	Recommended Practice for Qualification of Non-destructive Testing Personnel

AMERICAN SOCIETY OF SAFETY ENGINEERS (ASSE)

ANSI / ASSE A1264.1	Safety Requirements for Workplace Walking / Working Surfaces and their access; Workplace, Floor, Wall and Roof Openings; Stairs and Guardrails Systems

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM A6 / A6M	Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling
ASTM A36 / A36M	Specification for Carbon Structural Steel
ASTM A53 / A53M	Specification for Pipe, Steel, Blank and Hot-Dipped, Zinc-Coated, Welded and Seamless.
ASTM A123 / A123M	Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products

ASTM A143 / A143M	Standard Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement
ASTM A185 / A185M	Specification for Steel Welded Wire reinforcement, Plain, for Concrete reinforcement
ASTM A193 / A193M	Specification for Alloy-Steel Bolting Material for High Temperature Service
ASTM A307	Specification for Carbon Steel Bolts and Studs, 60,000 PSI Tensile Strength
ASTM A320 / A320M	Standard Specification for Alloy-Steel and Stainless-Steel Bolting materials for Low-temperature service
ASTM A325	Specification for Structural Bolts, Steel, Heat treated, 120/105 ksi, Minimum Tensile Strength
ASTM A490	Specification for Structural Bolts, Alloy Steel, Heat treated, 150 ksi, Minimum Tensile Strength
ASTM A500	Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
ASTM A615 / A615M	Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
ASTM A786 / A786M	Standard Specification for Hot-rolled Carbon, Low-alloy, High-strength Low-alloy and Alloy Steel floor plates
ASTM A830 / A830M	Specification for Plates, Carbon Steel Structural Quality, Furnished to Chemical Composition Requirements
ASTM A1011 / A1011M	Standard Specification for Steel, Sheet and Strip, Hot-rolled, Carbon, Structural, High-strength Low-alloy, High-strength Low-alloy with Improved Formability, and Ultra-High Strength
ASTM C90	Specification for Load-Bearing Concrete Masonry Units
ASTM C270	Specification for Mortar for Unit Masonry
ASTM C476	Standard Specification for Grout for Masonry
ASTM F436	Specification for Hardened Steel Washers
ASTM F959	Specification for Compressible-Washer-Type Direct Tension Indicator for use with Structural Fasteners

ASTM F1554	Standard Specification for Anchor Bolts, Steel, 36, 55 and 105 ksi yield strength

AMERICAN WELDING SOCIETY (AWS)

AWS D1.1/D1.1M	Structural Welding Code - Steel
AWS D1.4/D1.4M	Structural Welding Code – Reinforcing Steel

BRITISH STANDARDS (BS)

BS 4449	Steel for the reinforcement of Concrete. Weldable reinforcing Steel. Bar, Coil and De-coiled product. Specification
BS 4483	Steel Fabric for the Reinforcement of Concrete
BS 7419	Holding Down Bolts
BS 8004	Code of Practice for Foundations
BS 8007	Design of Concrete Structures for Retaining Aqueous Liquids
BS 8539	Code of practice for the selection & installation of post-installed anchors in concrete

BRITISH PUBLICATIONS

U.K. Concrete Society Technical Report No. 34.	Concrete Industrial Ground Floors
British Cement and Concrete Association Technical Report 550.	Design of Floors on Ground
British Cement Association Interim Note 11.	The Design of Ground Supported Concrete Industrial Ground Floor Slabs
CIRIA Publication C577.	Guide to the Construction of Reinforced Concrete in the Arabian Peninsula
CIRIA Publication C660.	Early Age Thermal Crack Control in Concrete
CIRIA Technical Note 21.	Control of Thermal and Shrinkage Cracking

EUROCODES (BS EN)

BS EN 1990	Eurocode 0 – Basis of Structural Design
BS EN 1991	Eurocode 1 – Actions on Structures
BS EN 1992	Eurocode 2 – Design of Concrete Structures
BS EN 1993	Eurocode 3 – Design of Steel Structures
BS EN 1994	Eurocode 4 – Design of composite steel and concrete structures
BS EN 1995	Eurocode 5 – Design of timber structures
BS EN 1996	Eurocode 6 – Design of masonry structures
BS EN 1997	Eurocode 7 – Geotechnical Design
BS EN 1998	Eurocode 8 – Design of structures for earthquake resistance
BS EN 1999	Eurocode 9 – Design of aluminium structures

INTERNATIONAL CODE COUNCIL (ICC)

IBC	International Building Code
ADIBC	Abu Dhabi International Building Code

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO 9001	Quality Management Systems – Requirements
ISO 9004	Quality management – Quality of an organization – Guidance to achieve sustained success

NATIONAL CONCRETE MASONRY ASSOCIATION (NCMA)

NCMA TEK	Manual for Concrete Masonry Design and Construction.

PORTLAND CEMENT ASSOCIATION (PCA)

PCA IS 003	Rectangular Concrete Tanks
PCA IS 072	Circular Concrete Tanks without Pre-stressing

RESEARCH COUNCIL ON STRUCTURAL CONNECTIONS (RCSC)

RCSC Committee Publication	Specification for Structural Joints Using ASTM A325 or A490 Bolts

US DEPARTMENT OF LABOR, OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA)

OSHA Regulations (Standard-29 CFR Part 1910)

2.2 ADNOC Specifications

The following ADNOC General Specifications, as available with respective Group Company and as applicable to the PROJECT, shall form a part of this Specification. When an edition date is not indicated for a document, the latest edition in force at the time of contract award shall apply.

Concrete Supply & Construction Specification	AGES-SP-01-001
Structural Steel Supply, Fabrication and Erection Specification	AGES-SP-01-002
Architectural Design Basis	
Anchor Bolts & Grouting	
Fireproofing	
Painting	
Galvanising	

2.3 ADNOC Standard Drawings

The following ADNOC standard drawings, as available with respective Group Company and as applicable to the PROJECT, shall form a part of this Specification. When an edition date is not indicated for a document, the latest edition in force at the time of contract award shall apply.

Concrete Works - General Notes

Steel Works - General Notes

Fire Proofing details

Anchor Bolts – Materials, Fabrication & Marking

Anchor Bolts – Details

Membrane Protection to Concrete Foundation and Pedestal

Ladders & Details

Stairways & Details

Handrail Details

Walkways & Details

Davit Details

3 DOCUMENTS PRECEDENCE

It shall be the CONTRACTOR's responsibility to be, or to become, knowledgeable of the requirements of the referenced Codes and Standards.

The CONTRACTOR shall notify the COMPANY of any apparent conflict between this Specification, design drawings, the related data sheets, the Codes and Standards and any other Design General Specifications noted herein. Resolution and/or interpretation of precedence shall be obtained from the COMPANY in writing before proceeding with the design/manufacture.

In the event of a conflict between documents, the following hierarchy of adherence shall be followed:

1) UAE Statutory Legislation and Regulations
2) ADNOC Code of Practices
3) Purchase Order or Contract documents including PROJECT drawings and Specifications
4) COMPANY General Specifications and Standards
5) International Codes & Standards

In case of conflict between documents in the same level of hierarchy, the most stringent requirement shall apply. Such interpretation of the most stringent requirement shall be subject to COMPANY's approval utilizing a technical query sheet. In all such cases of conflict, COMPANY's decision shall be final.

4 TECHNICAL DEVIATION CONTROL

Any technical deviations to the Purchase Order and its attachments including, but not limited to, the COMPANY's General Specifications shall be sought by the CONTRACTOR only through technical deviation request format. Technical deviation requests require COMPANY'S review/approval, prior to the proposed technical changes being implemented. Technical changes implemented prior to COMPANY approval are subject to rejection.

5 QUALITY PLANS

5.1 General

Quality plans shall address all aspects related to local conditions, such as climatic conditions, backup facilities, spare parts, transport possibilities, storage facilities, quarries, local MANUFACTURER/SUPPLIERs, test facilities (field laboratory).

Quality Management Systems shall comply with the applicable requirements of BS EN ISO 9001 “Quality Management Systems- Requirements” and BS EN ISO 9004, “Quality management – Quality of an organization – Guidance to achieve sustained success”. Written quality plans and procedures shall be submitted to the COMPANY for review and approval.

Materials should be obtained from the same source(s) throughout the work (including both trial and production mixes).

5.2 Inspection, Testing and Reporting

a) Inspection and Test Plans (ITPs) identifying the tests, frequencies, acceptance criteria, and responsibilities shall be prepared as part of the quality plan.

b) A reporting system of Quality Control Records (QCRs) shall be part of the quality plan.

c) The reporting system shall record all results obtained during the testing.

d) Weather conditions shall be recorded in the quality records.

e) The proposed ITPs and QCRs shall be included in the Quality Plan.

f) Standard forms of inspection and test plans shall be used as a basis for the development of the ITPs and QCRs supplemented by the requirements of the Specifications for the work to be executed.

g) The COMPANY reserves the right to make inspections of the source of supply of materials.

h) Prior to supply of any material to site the CONTRACTOR shall obtain COMPANY approval by submitting necessary documentation such as test certificates, source of supply, date of manufacture, etc.

5.3 Quality Control and Assurance

CONTRACTOR shall submit the material handling procedure, quality control program and inspection procedures documents to COMPANY for approval. CONTRACTOR’s Quality Management Systems shall comply with all the requirements of ISO 9001 “Quality Management Systems – Requirements” and ISO 9004 “Quality Management – Quality of an organization – Guidance to achieve sustained success”.

CONTRACTOR shall be solely responsible for quality control of all materials and workmanship. The quality system shall provide for the planned and systematic control of all quality-related activities performed during design, fabrication and erection of steel structures. Implementation of the quality system shall be in accordance with the PROJECT Agreement, CONTRACTOR’s approved Quality Manual and PROJECT Specific Quality plan.

The CONTRACTOR shall ensure that the FABRICATOR/VENDOR/MANUFACTURER shall always have in effect, a QA/QC program, which clearly establishes the authority and responsibilities of those responsible for the quality system. Persons performing quality functions shall have sufficient and well-defined authority to enforce quality requirements that they initiate or identify and to recommend and provide solutions for quality problems and thereafter verify the effectiveness of the corrective action.

Quality System and Quality Control requirements shall be identified and included in the CONTRACTOR's Purchase documentation. Based on these requirements, the FABRICATOR or VENDOR/MANUFACTURER will develop a QA/QC program, which shall be submitted to the COMPANY/CONTRACTOR for review and concurrence. The FABRICATOR or MANUFACTURER/VENDOR's QA/QC program shall extend to SUBCONTRACTORS or SUBVENDORS.

The CONTRACTOR shall submit certified reports of all tests as soon as the tests are completed satisfactorily.

COMPANY/CONTRACTOR reserves the right to inspect or to conduct a quality audit of materials, installation and workmanship standards and shall have unrestricted entry to the shop of the fabricator at all stages of manufacture and to witness any or all tests. The FABRICATOR or VENDOR/MANUFACTURER, 30 days after award but prior to the pre-inspection meeting, shall provide the COMPANY/CONTRACTOR with a copy of its Manufacturing and Inspection Plan for review and inclusion of any mandatory COMPANY/CONTRACTOR witness or hold points.

The COMPANY/CONTRACTOR may reject improper, inferior, defective, or unsuitable materials, installation and workmanship. All materials and workmanship rejected shall be repaired or replaced by the FABRICATOR as directed by the COMPANY.

CONTRACTOR to develop the Criticality Rating (CR) System the design checking levels and minimum requirements for shop inspection, testing and material certification. CONTRACTOR shall develop a list of Criticality ratings for all equipment items. Regardless of the Criticality Rating COMPANY/CONTRACTOR shall review the FABRICATOR/VENDOR's documentation to ensure compliance with the requirements of the AGREEMENT

SECTION B

6 TECHNICAL REQUIREMENTS

Not Applicable

7 ADDITIONAL SPECIFIC REQUIREMENTS

Not Applicable

SECTION C

8 ENVIRONEMENTAL DATA AND SITE CONDITIONS

8.1 Meteorological Data

Meteorological data shall be in accordance with COMPANY/PROJECT basic engineering design data.

8.2 Topographical, Underground and Geotechnical Surveys

The facilities shall be designed in accordance with the recommendations made in the topographical survey, underground detection survey and geotechnical investigation reports approved by the COMPANY.

The information contained in the existing Topographical survey/GIS data and the geotechnical investigation reports provided by COMPANY (if any) shall be considered for guidance only. All such information shall be validated by CONTRACTOR prior to start of design.

9 DESIGN AND DRAWINGS

COMPANY review and/or approval of design and drawing shall neither relieve the CONTRACTOR from his obligations of meeting the PROJECT requirements / COMPANY Specifications nor from responsibility of defective work resulting from errors or omissions on the approved design drawings.

9.1 Design

The CONTRACTOR shall prepare and submit for COMPANY approval the design criteria including the basic arrangement, design methodology and all assumptions prior to the start of the detailed design. Subsequently, the design calculation report shall be submitted and comprise the following as a minimum:

a) Cover page with a report title, document number, Project / Contract No., Date and revision mark, document prepared by, checked by and approved by columns.

b) The Table of Contents.

c) Introduction, Assumptions if any, Design Philosophy and design criteria.

d) Applicable Codes, Formulas, Graphs/Tables, Loading tables with loading location diagrams.

e) References to literature, etc., for subjects not covered by applicable codes.

f) The software used for analysis and design with native input and output files.

g) List of design parameters used.

h) Analytical model of the structure used for computer analysis.

i) Calculated loads and load combinations as per the classification in section 10.

j) Forces in the main structural members (axial loads, bending moments, shear and torsion), joint loads, support reactions.

k) Strength and Serviceability design with summary of design ratios.

l) Design Summary and Conclusions.

m) List of Attachments/Annexures in support of design calculations.

9.2 Drawings

9.2.1 General

a) Design drawings shall comply with COMPANY CAD Manual and drafting procedure, as applicable.

b) Only drawings marked "Approved for construction" duly signed by COMPANY's representatives shall be used at the site for construction.

c) Drawings shall be submitted together with the relevant calculations under one transmittal, including those required for submission to local authorities.

d) CONTRACTOR shall provide to COMPANY native soft copy of all drawings along with PDF copy. All revisions shall be clearly highlighted and clouded for easy identification and / or review.

9.2.2 Concrete Drawings

a) The general information/data shall be shown as 'General Notes' on the right-hand side of the drawing.

b) The 'General Notes' shall state the following:

1) All Dimensions are expressed in millimeters.
2) All Levels are expressed in meters, with reference to the highest point of paving/grade.
3) Concrete grade used in the design.
4) Reinforcing steel bar grade used in the design.
5) Bar diameters are expressed in millimeters.
6) Concrete blinding (location, grade, and thickness).
7) Polyethylene sheeting, if applicable (location and grade).
8) The concrete cover on bars (type of construction, location and thickness).
9) The list of reference drawings and related documents stating their title and number.

10) The legend of the CONTRACTOR'S reinforcing bar calls out.

c) Bill of quantities of the main materials such as concrete, reinforcement, blinding, etc. shall be indicated

d) Bar Bending Schedule shall always be prepared by the CONTRACTOR and checked by DESIGNER prior to installation/concrete work.

9.2.3 Structural Steel Drawings

a) General arrangement drawings shall show the complete structure with all main dimensions and the sections.

b) The CONTRACTOR shall prepare structural steelwork detailed design drawings which shall be submitted to COMPANY for approval prior to preparation of shop drawings.

c) The CONTRACTOR shall prepare workshop/ fabrication drawings, based on detailed design drawings, incorporating sufficient information for the proper fabrication of the steel work, including connection details and their design structural calculation, together with marking drawings for erection purposes and all drawings necessary for setting out pockets and anchorage materials (including holding down bolts) to suit the steelwork.

d) All members to be fireproofed shall be marked with (FP).

e) The base plate drawing shall show all dimensions and details of the base plate including holding-down bolts, which shall be taken into account in the design of the (concrete) foundation.

9.3 Steel Structures

9.3.1 General

Structural Steel Design shall be in accordance with AISC 360 'Specification for Structural Steel Buildings' & AISC Steel construction Manual, or the British Standards - BS EN 1993-1-1 'Design of Steel Structures'.

Design by inelastic or plastic analysis as in AISC code or British EN Standards shall not be used for steel design. Plastic analysis for accidental design situation may be used only with COMPANY approval.

9.3.2 Structural Frames and Bracing System

a) Generally, only pinned column bases shall be used in the design of steel structures. The use of fixed base plates for certain type of pipe racks and buildings, where necessary due to deflection considerations, shall be permitted subject to COMPANY approval.

b) Where headroom, access, or equipment arrangement will permit; wind and other lateral loads on a steel structure shall preferably be carried to the foundations through vertical X-bracing or K-bracing placed in both the longitudinal and transverse column lines.

c) As a second option, the lateral loads may be resisted through moment resisting frames (rigid frames) in one direction and vertical X-braced or K braced frames in the other direction. Application of rigid frame systems in two orthogonal directions shall be avoided.

d) Bracings shall be arranged in plan such as to minimize the torsional effects, and at the same time to allow free expansion in both directions (bracings preferably to be located at the middle of each segment in the longitudinal direction).

e) Diagonal members where practicable, shall be arranged concentrically about the force resultant line. The connections wherever possible, shall be arranged so that their centroid lies on the resultant of the forces they are intended to resist. When this condition cannot be achieved, the members and connections shall be designed to resist any local bending due to the eccentricity of the force.

f) Compression bracing for steel structures shall normally be designed with wide flange and structural tee shapes. For tension bracing, single angle or structural tees may be used. When using structural tees in compression, the design shall include bending induced by eccentrically loaded connections.

g) Back to back angles/channels, because of maintenance difficulties, shall not be permitted as structural members. Rods/cables as bracing members shall not be permitted.

h) Use of pipe sections as bracing members, if found advantageous for some structures, may be permitted with adequate connection details and subject to COMPANY approval.

i) Braces for structures subject to vibration from equipment shall be designed as compression braces.

j) The slenderness ratio for all the structural steel members (including bracings) shall be equal or less than 200.

k) The minimum thickness of any part of a rolled section for use as a structural element (open or closed sections) shall not be less than 6mm. However, for small supports / secondary supports (such as electrical and instrument supports), the minimum thickness shall be governed by design and shall be adequate to have required connection bolts / welds.

l) The minimum thickness of any part of a rolled section for use as a non-structural element (closed sections) shall not be less than 3mm.

m) Horizontal bracing shall be provided in the plane of a floor, platform, or walkway, when necessary to resist lateral loads or to increase the lateral stiffness of the floor, platform, or walkway. Floor grating shall not be assumed to resist lateral loads in diaphragm action. Floor plate shall be investigated before it is considered to resist loads in diaphragm action.

n) In a floor system, beam compression flanges shall be considered to be fully braced when a concrete slab is cast to match the bottom face of the compression flanges on both sides, and when checkered plate is welded to the compression flanges. Grating is normally clipped or bolted and therefore shall not be considered as adequate compression flange bracing. In such cases, additional vertical and/or horizontal bracing in the floor system shall be provided.

o) Bar joist floor and roof systems are generally considered to be too light for heavy industrial plant work. However, when approved by COMPANY, bar joist systems may be used on a project.

p) Steel Structures shall be designed so that the surfaces of all parts will be readily accessible for inspection, cleaning and painting. Pockets for depressions which would hold water shall have drain holes or be otherwise protected. Bracings that provide structural stability located within the fireproofing zone shall also be fireproofed similar to other members. Fireproofing loads shall be considered under dead loads in the structural design.

9.3.3 Structural Connections

a) Connection types (bolted or welded) shall be considered aiming towards minimizing site assembly activities. Shop connections shall generally be welded, and field connections shall normally be bolted. However, when required or approved by COMPANY, welded field connections may be used.

b) All structural connections (Bolted & Welded) shall be designed in accordance to COMPANY Specification for Structural Steel Supply, Fabrication & Erection, AGES-SP-01-002

9.3.4 Joints in Structural Steelworks

a) The joints in a Steel structure shall be located to least impair the integrity and strength of the structure. The location of joints shall be shown on the drawings with accompanying details of each joint type. Any deviations from locations indicated in construction documents shall be approved by COMPANY.

b) Expansion joint shall generally be provided at about 42.0m for steel pipe racks and structures.

9.3.5 Secondary and ancillary steel structures

Walkways, platforms, staircases, ladders and hand railing design and arrangement shall comply with HSE, operational requirements stipulated by COMPANY and detailed in accordance with relevant COMPANY Specifications and standard drawings.

9.4 Reinforced Concrete Structures and Foundations

9.4.1 Concrete Structures

a) All Concrete structures shall be designed in accordance with ACI 318 / ACI 318M or BS EN 1992, except as specified otherwise in this Specification. COMPANY Specification for Concrete supply and construction and ACI 301 shall be used during design, installation and inspection of concrete.

b) Concrete for environmental engineering concrete structures (e.g. concrete structures intended for conveying, storing, or treating water, wastewater, or other liquids and non-hazardous materials such as solid waste, and for secondary containment of hazardous liquids or solid waste.) shall also be designed in accordance with ACI 350 / ACI 350M as applicable.

c) Concrete structures for Liquefied Natural Gas (LNG) facilities shall also be designed in accordance with NFPA 59A as applicable. Concrete structures for the containment of refrigerated liquefied gases shall also conform to ACI 376 / ACI 376M, as applicable.

d) Underground structures such as basements, rectangular tanks, sumps, and pits shall be designed in accordance with the latest referenced PCA bulletins and/or BS8007. The design of such structures shall include the effects of ground water pressures and buoyancy.

e) Precast and Prestressed concrete shall be designed in accordance with PCI MNL-120 and are subject to COMPANY approval.

9.4.2 Foundation Design

a) Foundations shall be designed in accordance with ACI 318 & ACI 301 or BS EN 1992.

b) Foundations design includes type of foundations, minimum depth of foundation, soil parameters, etc. Sub-grade preparation and earthworks shall be as per recommendations made in geotechnical investigation report. Where possible, the founding level of the foundations shall be kept at a uniform level.

c) All foundations shall be placed on seal (blinding) slabs. The seal slabs shall be placed on firm, undisturbed soil. Some seal slabs, however, may be placed on well-compacted earth fill, if approved by the COMPANY. In such cases, the engineering drawings shall specify the kind of fill material and degree of compaction required as per COMPANY specification for earth works. Also, the extension of fill material beyond the edge of foundation shall be 1.0m minimum.

d) Anchor bolts shall be cast along with the foundation concrete without provision for pockets/anchor boxes. Pockets/anchor boxes shall be permitted by the COMPANY for certain specific cases only, on valid justification.

e) The minimum depth of foundation (measured to the bottom of RC footing) shall be 0.60m below FGL for minor foundations such as pipe sleepers, instrument and electrical supports, signposts, cross over platforms and equipment foundations weighing less than 1MT. For other foundations, depth of foundation shall be as per applicable Geotechnical recommendations and underground services routing subject to a minimum depth of 1.0m from FGL.

f) Foundation design (sizing and stability) shall be based on serviceability load combinations.

g) Foundations shall be minimum 250mm thick with two layers (top and bottom) reinforcement.

h) All foundations shall be proportioned to minimize general and differential settlements.

i) All foundations adjacent to underground pressurized pipes shall be sufficiently lowered to a depth below the pipe or shall be protected in such a way to prevent washout of soil from underneath the foundation. Minimum 1.0m distance shall be maintained between foundation edge and pressure pipe to allow maintenance on the pipe.

j) Overlapping of foundations (one over another at different levels) shall not be permitted unless alternative arrangement is not feasible. In such cases suitable additional loading shall be considered in the design of lower level foundations and additional protection measures to be agreed with the COMPANY. Consideration shall be given to the proximity of adjacent or existing foundations and underground services when determining the level of the underside of the foundation. In no case adjacent excavation shall be made below bottom elevation of existing foundation.

k) No piping/cables shall pass through a foundation, unless for the equipment to be fixed on the same foundation itself. If some existing piping/cables are found in the way of new foundations, the foundation shall be relocated. If relocation of the foundation is found to be not feasible then rerouting of pipe/cables shall be proposed to the satisfaction of COMPANY.

l) CONTRACTOR shall consider the relative merits of pre-casting structural concrete elements such as small foundations, manholes, culverts and small structures. Precast foundation design shall include calculations for lifting and handling stresses.

m) Pile Foundations shall be considered where soil structural behavior can be affected by liquefaction from excessive vibrations such as those generating from high frequency vibrating equipment in high water table zones or soil condition is very poor. Recommendations provided in PROJECT Geotechnical Report shall also be followed.

n) Machine foundation shall be designed in accordance with CP 2012-1, ACI 351 or DIN 4024 with further reference to section 14.3 of this document.

o) Hollow core slabs are not preferred in RCC building slab construction due to its shortcomings such as special detailing at the connection with supporting beams, low ductility, semi-rigid diaphragm action, limitation for future modifications (opening for new services, etc.), risk of losing the high strength due to the damage of any strand, introduction of several joints in the slab, etc. In any case Hollow Core Slabs shall not be used for Blast Resistant buildings.

9.4.3 Concrete Durability

a) Concrete shall be designed in accordance with the durability requirements of Section 9.2.5.2 (e) of COMPANY Specification for Concrete Supply & Construction (Doc. No. AGES-SP-01-001) consistent with ACI 318-19 / ACI 318M-14, Chapter 19 or BS EN 1992-1-1 Clause 4.3, Annex E and other related clauses.

b) CONTRACTOR shall determine exposure class based on the severity of the anticipated exposure of structural concrete members for each exposure category in accordance with ACI 318-19 / ACI 318M-14, Table 19.3.1.1 or BS EN 1992-1- Table 4.1.

c) Environmental engineering concrete structures shall also be designed in accordance with the durability requirements of ACI 350 / ACI 350M, Chapter 4, as applicable.

d) In case the requirements specified in the stated standards contradicts with the requirements stipulated elsewhere in this Specification, then the most stringent shall apply.

9.4.4 Crack Prevention in Concrete Structure

a) To prevent the cracks and to control the stress limits, the size of concrete element and amount of reinforcement shall be such that it should promote the serviceability of structure for long service life.

b) Cracks in concrete shall be controlled by the efficient use of combinations of reinforcement sizes, spacing and cover.

c) Calculation of crack widths shall consider both load (flexural) and restraint (due to thermal and shrinkage effects) which induces cracking.

d) To reduce flexural cracking, it will be necessary to use reduced allowable stresses in the reinforcement.

e) Horizontal re-bar in walls and faces of large elements shall be on the outside of the vertical reinforcement for more effective crack control.

9.4.5 Concrete Cover

a) Concrete cover to reinforcement shall be measured as the distance between the outside of the outermost reinforcement (including links) and the nearest external surface of the concrete members (excluding finishes).

b) All concrete cover shall conform strictly to the minimum values specified in the Section 9.5.2 of COMPANY Specification for Concrete Supply and Construction, Doc. No. AGES-SP-01-001.

c) Required covers shall not be reduced by provision of protective coatings, membranes or by membrane protective screed.

d) If the fire resistance of more than 2.0. Hours is required, the cover shall be as determined in accordance to ACI 216.

9.4.6 Reinforcement

a) The reinforcement required in concrete structural elements shall be in accordance with ACI 318 & ACI 301 or BS EN 1992. All reinforcement shall be fully detailed including bar bending schedules for fabrication. Reinforcement shall be adequately detailed to eliminate congested areas, i.e. laps to be staggered.

b) The reinforcing bars shall be placed on both faces in both directions for all concrete sections with a thickness of 250mm or more. In addition, minimum reinforcement shall be placed in other faces if the thickness is more than 600mm.

c) All concrete faces for miscellaneous concrete elements (non-structural) – e.g. duct banks, guard rail foundations, etc. shall be provided with minimum reinforcement for shrinkage and thermal.

d) Preference shall be given to the use of smaller diameter reinforcing bars at closer spacing and bundle reinforcement shall be avoided. Fabric reinforcement mesh in concrete shall be used for paving.

e) Where the overall depth of the beam is equal to or greater than 700mm, longitudinal reinforcement of 16mm dia. bars shall be provided at a spacing not exceeding 250mm on the side-faces of the beam.

f) Diagonal reinforcement shall be placed at each re-entrant opening to prevent cracks emanating from corners.

g) The minimum size and maximum spacing of reinforcement shall be as defined below:

   1) Minimum size of main rebar shall be 16mm for columns & beams and 12mm for footings, slabs and walls.

2) Minimum size of all other rebars such as stirrups and ties shall be 10mm unless otherwise specified in PROJECT documents.

3) Maximum spacing of main reinforcement in slabs, footings and walls (provided for flexure/tension/compression) shall be 200mm in any direction, while the distribution reinforcement (provided for shrinkage/temperature stress control) spacing shall not exceed 250mm.

4) Maximum spacing of stirrups and ties in beams, columns and pedestals shall not exceed 200mm.

5) A horizontal single layer of steel reinforcement shall be provided at the top of pedestals or slabs. This shall be of 12mm dia. reinforcement spaced at 200mm in both directions.

9.4.7 Joints in Concrete works

a) The joints in a concrete structure shall be located to least impair the integrity and strength of the structure. The location of all joints shall be shown on the drawings with accompanying details of each joint type. Any deviations from locations indicated in construction documents shall be approved by COMPANY.

b) Expansion joint shall normally be provided at about 40m for buildings and 25m for other concrete structures such as retaining walls, concrete pipe racks etc. Where load transfer is required at a joint, shear keys/intermittent shear keys, diagonal dowels, or shear friction may be used.

c) The number and location of construction, contraction or isolation joints shall be determined considering the followings:

1) Influence of climatic conditions

2) Selection and proportioning of materials

3) Mixing, placing, and curing of concrete

4) Degree of restraint to movement

5) Stresses due to loads to which an element is subjected

6) Construction techniques

7) Lateral stability of the structure

d) Construction joints in beams, columns, or pedestals shall be avoided as much as practicable.

e) Isolation joints shall be provided around all equipment foundations and pedestals.

9.4.8 Pedestals

a) The minimum horizontal dimension of the pedestal shall accommodate the following:

1) Concrete cover to anchor bolts without any fouling with rebars.

2) Grout is to be sloped 1:1 away from the bottom outside corner of the column base plate grout.

3) Top of all pedestal heads shall be sloped 1:20 away from the baseplate grout.

4) Minimum distance from edge of base plate to edge of concrete shall be 100mm.

5) Minimum distance from edge of the grout to edge of concrete shall be 75mm.

b) Unless specified (by other discipline) otherwise, the minimum pedestal height (excluding grout) shall be as follows:

1) 150mm above HPP in paved areas.

2) 300mm above FGL in unpaved areas.

9.4.9 Stress Raisers

Complicated plan shapes which cause stress raisers shall be avoided. Large and sudden changes of cross-section i.e. wall junctions and counterforts in the middle of bay lengths shall be avoided. Joints shall be positioned as near to these stress raisers as possible or two separate sections shall be cast. Provide appropriate extra reinforcement where stress raisers are unavoidable.

Casting-in pipes, box-outs, notches in the middle of bay lengths shall be avoided.

9.4.10 Anchor Bolts & Base Plates

a) Anchor bolts design shall be in accordance with COMPANY specification for Anchor bolts & Grouting.

b) Anchor bolts shall be designed to resist the entire shear load. The friction resistance between base plate and concrete shall not be considered for shear transfer from base plate to pedestal.

c) Due to bolt hole tolerance, only 50% of anchor bolts shall be used to transfer the shear force. However, Shear force can be transferred equally to all anchor bolts by using a plate washer welded to the base plate between the anchor bolt nut and the top of the base plate. The plate washers shall have holes, maximum 1.5mm larger than the anchor bolt diameter. Also, the thickness of the plate washer shall be designed to safely transfer the shear force.

d) Where it is not feasible to accommodate required number of anchor bolts within the pedestal cross sectional area due to high shear, other type of shear anchor connector such as shear key can be used. Shear key may be used by welding to the base plates. Design calculations and justification shall be provided to the COMPANY for approval.

e) Minimum size of anchor bolts shall be 20mm dia. for structural columns and typical equipment and 16mm dia. for small pumps, crossovers, small pipe supports, and guardrails.

f) Minimum thickness of column base plate shall be 16mm including corrosion allowance.

g) A corrosion allowance of 3mm shall be required for all anchor bolts and base plates.

h) Post-fixing bolts (mechanical fasteners of expansion type or chemical fasteners installed with resin) may be used for miscellaneous supports such as handrails, ladders, minor pipe supports, electrical and instrumentation supports, HVAC duct supports, building fire water deluge system supports, building doors & windows, gates and fences. Post-fixing bolts for any other application shall be allowed only for certain specific cases with valid justification subject to COMPANY approval.

i) Post-fixing bolts shall be installed strictly in accordance with the MANUFACTURER's instruction.

9.4.11 Pits and Tanks

a) Recommendations by PCA IS 003 and IS 072 for rectangular and circular tanks shall be adhered to.

b) As a minimum requirement, for liquid retaining structures, the recommendations of ACI 224.3R and ACI 302.1R or BS 8007 – Section 5 "Design, Detailing and Workmanship of Joints" shall be adhered to.

c) All construction joints shall be designed, detailed and shown on the drawings by the DESIGNER or SUBCONTRACTOR for CONSTRUCTION with COMPANY approval.

d) The use of sequential bay wall construction shall not be permitted.

e) Where continuous construction is necessary, the method of 'Temporary Open Sections' as specified in BS 8007 C1.5.5 shall be used. Such open sections shall not be more than 1.0m and shall contain the "Lapped' section of reinforcement.

f) Unless roofs are insulated, these sections are subject to extremely high daytime temperatures and lower night temperatures. Consideration shall be given to the use of insulation or reflective coatings (e.g. aluminum).

9.4.12 Paving

The paving shall be designed and constructed in accordance with COMPANY Specification for Roads and Pavings.

9.5 Concrete Masonry Structures

Masonry shall be designed in accordance with ACI 530, ASCE 5 or BS EN 1996 or TMS 402.

9.6 Grouting

Grouting shall be in accordance with COMPANY Specification for Anchor bolts & Grouting.

9.7 Fireproofing

The structures and equipment located within the PFP (Passive Fire Protection) Zone shall be fireproofed, where required by safety analysis. Fireproofing for bolted/welded connection block-outs where applicable, shall be in accordance with the COMPANY Specification for Fireproofing and Standard Drawing for Fireproofing Details.

9.8 Clearance and Accessibility

a) Minimum clearances for Equipment, Structures, Platforms and Supports shall be in accordance with the COMPANY Specification for Design, Layout and Drawing.

b) Where sufficient clearance from the edge of the road could not be maintained, structural members shall be protected against impact by means of appropriate barriers, as per safety requirements.

10 LOADS

10.1 Dead Load

a) Dead load is defined as the weight of all permanent construction including structural self-weight, walls, foundations, floors, roofs, ceilings, partitions, stairways and fixed service equipment. For heavy industrial work, this would include equipment, vessels including internals, pipes, valves, and accessories; electrical and lighting conduits, switchgear; instrumentation, fireproofing; insulation; ladders; platforms; and other similar items. Weight of equipment shall be derived from the MANUFACTURER'S data sheets and shall include auxiliary machinery and piping. Equipment and piping shall be considered empty of product load when calculating dead load. The gravity weight of soil overburden shall be considered as dead load.

b) Unless more determinate load information is available in PROJECT documents and requires otherwise, for pipes up to 8" (200mm) diameter, the empty dead load of piping on pipe racks shall be considered as a minimum 1.0 kN/m^2 over the plan area including empty and future spaces of each tier of pipe rack. Loads from pipes larger than or equal to 10" (250 mm) diameter shall be considered as actual concentrated loads at their actual locations.

c) In case the actual estimated uniformly distributed load is less than 1.0 kN/m^2 then the minimum design empty dead load on racks shall be considered as 1.0 kN/m^2 per rack.

d) Empty dead load of piping over unutilized portion of pipe rack shall not be included in the analysis for structural stability.

e) A uniformly distributed dead load of 1.0 kN/m^2 per level of cable trays shall be considered for cable trays.

10.2 Operating (Product) Load (Live Load)

a) Operating loads shall be defined as the forces exerted by any liquids, solids or viscous materials present within the vessels, equipment, or piping during normal operation. Unusual loading that occurs during regeneration or upset conditions shall also be considered. Operating loads shall have the same load factor as Live load.

b) Unless more determinate load information is available in PROJECT documents and requires otherwise, for pipes up to 8" (200mm) diameter, the operating (product) load of piping on pipe racks shall be considered as 1.0 kN/m^2 minimum over the plan area including empty and future spaces of each tier of pipe rack. Loads from pipes larger than or equal to 10" (250 mm) diameter shall be considered as actual concentrated loads at their actual locations.

10.3 Test Load (Dead Load)

a) Test load is the empty weight of process equipment, vessels, tanks, and/or piping plus the weight of the test medium contained in a set of simultaneously tested piping system/equipment.

b) The test medium shall be as specified in the contract documents or as specified by COMPANY. Unless otherwise specified, a minimum specific gravity of 1.0 shall be used for the test medium or a distributed load of 2.0 kN/m^2 (dead plus content) over the plan area including future spaces of the supporting piping tier for pipes less than or equal to 8” (200mm) diameter.

c) Loads from pipes larger than or equal to 10” (250mm) diameter shall be considered as actual concentrated test loads in their actual locations. Cleaning load shall be used for test dead load if the cleaning fluid is heavier than the test medium.

d) Equipment and the segment of pipes that will be simultaneously tested shall be included for load calculations.

e) If more than one piece of equipment is supported on the structure, the structure shall only be designed on the basis that one piece of equipment will be tested at any one time, and that the others will either be empty or still in operation unless otherwise specified by COMPANY.

f) Design shall include loads and load combinations that occur during the testing of piping, equipment and structures.

g) Test dead load shall be incorporated in the design of the supporting structure.

10.4 Live load

Live load is defined as the weight superimposed by the use and occupancy of the building or other structure, but not permanently attached to it. For industrial design, live load can be defined as the load produced by personnel, moveable equipment, tools, and other items placed on the structure, but not permanently attached to it.

Unless specified otherwise, the minimum live load values in (kN/m^2) shall be as given in Table 10-1 below.

Table 10-1 – Minimum Live Load Values [(1)]

Type of Structure	Live Loads	
	Min-UDL (kN/m^2)	Min-Point Load (kN)
Walkways – Framing Design	3.0	4.5
Walkways – Grating Design	5.0	4.5
Operating platforms (Other than compressor and generator Platforms)	5.0	7.5
Trench covers (non-vehicular)	5.0	10.0
Roof:		
Accessible Roofs	2.0	-
Inaccessible Horizontal Roofs and Inclined Roofs	1.0	-
Sand on Roof (min.)	0.8	-
Storage [(2)]:		
Light Storage	6.3	-
Heavy Storage	12.5	-
Bulk Storage	40.0	-
Compressor and Generator Platforms:		
Floor Framing (determine from use but never less than)	5.0	-
Floor Grating and Slabs	10.0[(3)]	-
Substation Switchgear Room, Electrical Equipment Room:		
Entire floor slab shall be designed for greater of a) and b) below: a) Uniform load specified here as Min-UDL b) Greatest equipment load per unit area (as per MANUFACTURER's equipment load)	10.0	-
Battery rooms - up to 2 Tiers Battery Rack	10.0	-
Battery rooms - 3 Tiers Battery Rack	14.0	-
Battery rooms - 4 Tiers Battery Rack	17.5	-
Battery rooms - 5 Tiers Battery Rack	20.0	-
Mechanical, Electrical, Instrument Workshop building	20.0	-

Type of Structure	Live Loads	
	Min-UDL (kN/m^2)	Min-Point Load (kN)
Miscellaneous:		
Offices, first-aid buildings, guard houses, toilets, wash and locker rooms, analyser houses, control rooms, computer rooms, instrument auxiliary rooms, laboratory rooms	3.0	-
Canteens, Lunchrooms, Stairs, Halls	4.0	-
Library and Filing room	7.5	-
Stairs and Ramps	5.0	-
Auditorium	5.0	-
Conference & Meeting rooms	4.0	-
Training Centres, Corridors	5.0	-
Hand railing: 0.75 kN per linear meter applied horizontally at the top of railing, or a horizontal force of 0.9 kN at any one point.		
Notes: 1) Uniform loads and concentrated loads shall not occur simultaneously. 2) These are typical values and shall be verified for actual use of the structure and as per the weight provided by the equipment VENDORs. 3) For floor grating and slabs being subjected to a concentrated load from either the installation or removal of equipment.		

10.5 Truck Load (Live Load)

a) Bridges, culverts, pipe protection slabs, trenches, and underground installations at road crossings shall be designed to withstand HS20-44 or HL-93 loading as defined by AASHTO HB Standard Specifications for Highway Bridges. Where rig/special vehicle movement is expected the related loads shall be considered in the design.

b) Maintenance or construction crane loads shall also be considered. Crane loads shall be assumed at their maximum values including lifting capacity as well as the maximum horizontal loads caused by braking or acceleration.

c) Mobile crane loads shall be the greater of either, moving wheel loads plus impact or the maximum outriggers reaction at full lifting capacity.

d) For the design of each structural element the most unfavorable position of the crane or other moving loads shall be considered. For moving loads an appropriate impact factor shall be applied in accordance with AASHTO standard specifications. Truck or crane loads shall have the same load factor as live loads.

e) Impact shall not be included in loads transferred to footings or to those parts of piles or columns that are below ground.

f) At least one road leading to the main process area(s) shall be designated as a heavy equipment route and bridges/culverts including other underground facilities shall be designed for the maximum expected loading condition caused by transportation of heavy equipment.

10.6 Wind Load

a) In general, all plant equipment and structures shall be designed for wind loads in accordance with ASCE 7-16 or BS EN 1991-1-4. Wind parameters shall be as given in Table 10-2 below, unless otherwise specified in PROJECT design basis:

Table 10-2 – Wind Load Parameters

ASCE 7-16	BS EN 1991-1-4
Basic wind speed corresponding to a 3-sec gust wind at 10m above grade (calculated based on 3 sec gust wind of 44.5 m/sec with 50-year return period) shall be as follows: a) Strength design associated with a load factor of 1.0 (Structure, Cladding and Foundation Design): Risk Category I: 52.4m/s Risk Category II: 56.3m/s Risk Category III: 60.2m/s Risk Category IV: 62.5m/s b) Serviceability design (checks for Deflection/drift, Crack width, Foundation bearing pressure, Overturning, Sliding and Uplift): 1) Wind speed shall be as per above Strength design, divided by square root of 1.60. Risk Categories based on use/occupancy of buildings and structures (specified in Table 1.5-1) are associated with the following return periods: Risk Category I: return period of 300 years Risk Category II: return period of 700 years Risk Category III: return period of 1700 years Risk Category IV: return period of 3000 years	The fundamental value of the basic wind speed for use in BS EN 1991-1-4 (Equation 4.1) shall be 31.2 m/s corresponding to 10-min mean velocity at 10m height in open field with 50-year return period (calculated based on 3 sec gust wind of 44.5 m/sec with 50-year return period).

<table>
<tr><th>ASCE 7-16</th><th>BS EN 1991-1-4</th></tr>
<tr><td>Exposure Category = C

Risk Category shall be as below:
a) In general, for hydrocarbon facilities that present a substantial risk to human life in the event of failure or those essential for safe/continuous operation of plants such as: structures in process area/utilities, process buildings, manned buildings, etc., Risk Category shall be III or IV as approved by COMPANY.
b) For polymer/petrochemical facilities, Risk Category II shall be followed subject to COMPANY approval.
c) For structures that has no direct risk to human life in the event of failure such as un-manned stores, car park shed etc., Risk Category shall be II subject to COMPANY approval.</td><td>Terrain Category = II

The Exposure Factor, Ce(Z) in Equation 4.8, is illustrated in Figure 4.2 as a function of height above the terrain and a function of terrain category.</td></tr>
<tr><td colspan="2">Typical Wind load calculations as per ASCE 7-16 & BS EN 1991-1-4 are provided in Appendix-3 for guidance</td></tr>
</table>

b) Wind shall be considered acting from any direction and no structural shielding effect of adjacent vessel or structure shall be considered without COMPANY approval.

c) Wind and earthquake loads shall not be assumed to act concurrently.

d) Wind loads shall be separately computed for all supported equipment, ladders, and stairs except for vessels as explained hereafter.

10.6.1 Wind loads on vessels

a) If detailed information (number of platforms, platform size, piping, ladder, etc.) is unknown at the time of design of the foundation/piles, the following approach may be used:

1) For the projected width, add 0.46 m to the vessel diameter to account for ladders, nozzles and piping (200mm or smaller) and add the diameter of the largest line coming from the top portion of the vessel.

2) For pipes outside the projected width of the vessel (defined in 1 above) larger than 200mm, including insulation, use the projected area of the pipe and use a force coefficient (Cf) of 0.7.

3) For pipes inside the projected width of the vessel (defined in 1 above) larger than 200mm, including insulation, and more than five(5) pipe diameters from the vessel surface, add the projected area of the pipe and use a force coefficient (Cf) of 0.7.

4) For platforms, use the projected area of the support steel and a force coefficient (Cf) of 2.0.

5) For handrails, use a force coefficient of 2.0. Where the railing extends beyond the vessel, the projected area of two sets of railing systems for the projection beyond the vessel shall be used.

b) No reduction shall be made for the shielding effect of vessels or structures adjacent to the structure under consideration.

c) For multi-story equipment supporting (process) structures, wind load shall be computed on the full projected area perpendicular to wind of the occupied stories, considering a force coefficient of 1.0. Alternatively, wind loads on individual areas of equipment, piping, and structure with coefficient corresponding to each area can be considered.

d) As per ASCE 7-16, Building and structures when any one or more of the following apply will require a dynamic response analysis:

1) The height of the building/structure is over 120m.

2) The height is greater than 4 times its minimum effective width.

3) The lowest natural frequency of the building or other structure is less than 0.25Hz.

10.6.2 Wind loads on Pipe racks

Wind on the pipe rack shall be calculated as outlined below.

a) Transverse and longitudinal wind loading on the pipe rack columns, beams, and struts shall be based on no shielding.

b) Transverse wind loads on the piping and cable trays at each pipe rack tier shall be:

$P = C_f * q * A$

Where:

A = L * (D + 10%W)

And:

P = transverse wind load
W = width of the pipe rack
A = tributary area
L = frame spacing
D = largest pipe diameter in tier (including insulation); total exposed height of the cable tray
C_f = 0.7 for Pipes, 1.8 for Cable trays
q = wind velocity pressure

c) The methodology of calculating wind load on cable trays as above is applicable to pipe rack tiers that are carrying cable trays exclusively.

d) For pipe configurations, such as, when there is a change in elevation / direction of the piping, the wind loads on exposed area of pipes in longitudinal direction shall be considered.

10.7 Earthquake / Seismic Load

a) In general, all plant equipment and structures (buildings) shall be designed for earthquake loads in accordance with IBC 2018 / ASCE 7-16.

b) When calculating the seismic load, full operating loads (content) of piping and equipment shall be considered.

c) Site specific ground motion acceleration values for short period (0.2 sec) and 1 sec corresponding to ASCE 7-16 shall be used as available for some ADNOC sites. As a reference, Design Spectral Accelerations for Das Island, Zirku Island and Artificial Island (Zakum field) are as given in Table 10-3 below:

Table 10-3 – Design Spectral Acceleration for Das Island, Zirku Island and Artificial Island (Zakum field)

Spectral Acceleration	Das Island	Zirku Island	Artificial Island (Zakum Field)
Site Class	D	C	D
Short Period Design Spectral Acceleration at 0.2 sec, S_{DS}	0.25g	0.216g	0.33g
Design Spectral Acceleration at 1.0 sec, S_{D1}	0.128g	0.117g	0.154g

d) Seismic Hazard Assessment (SHA) shall be conducted if deemed required by PROJECT requirement, to develop site specific ground spectral acceleration parameters for short period 0.2 sec and 1.0 sec period.

The design shall also take into account the effects of the following where applicable:

1) Earthquake-induced liquefaction of the strata.

2) Hazard from tsunami in coastal regions.

e) In case of non-availability of site-specific ground spectral acceleration parameters, structures shall be designed based on ASCE 7-05 and Abu Dhabi International Building Code (ADIBC 2013) subject to COMPANY approval.

10.7.1 Seismic Parameters

Seismic parameters are defined as per Table 10-4 below:

Table 10-4 – Seismic Parameters for ASCE, IBC, and ADIBC Codes

Parameter	For ASCE 7-16 / IBC 2018 reference / Values	For ASCE 7-05 / ADIBC 2013 reference / Values
Site Class	D, or as per Site Geotechnical Investigation Report	D, or as per Site Geotechnical Investigation Report
Maximum Considered Earthquake Ground Motion of 0.2 sec (Ss) Spectral response Acceleration	As per Site specific Geotechnical and Seismic Hazard Assessment (SHA) report	As per Abu Dhabi International Building Code (ADIBC)
Maximum Considered Earthquake Ground Motion of 1.0 sec (S1) Spectral response Acceleration	As per Site specific Geotechnical and Seismic Hazard Assessment (SHA) Report	As per Abu Dhabi International Building Code (ADIBC)
Seismic design category based on short-period response accelerations	As per ASCE 7-16 Cl. 11.6 / IBC 2018 Cl. 1613.2.5	As per Abu Dhabi International Building Code (ADIBC)
Seismic design category based on 1-second period response acceleration	As per ASCE 7-16 Cl. 11.6 / IBC 2018 Cl. 1613.2.5	As per Abu Dhabi International Building Code (ADIBC)
Long-Period (Transition period)	8 Seconds for United Arab Emirates (UAE)	8 Seconds for United Arab Emirates (UAE)
Response Modification Factors, R	For building structures 'R' shall be obtained from Table 12.2-1 of ASCE 7-16.	For building structures 'R' shall be obtained from Table 12.2-1 of ASCE 7-05.
	For non-building structures that are not similar to buildings (such as vessels, heat exchangers, etc.), the R factors shall be obtained from Table 15.4-2 of ASCE 7-16.	For non-building structures that are not similar to buildings (such as vessels, heat exchangers, etc.), the R factors shall be obtained from Table 15.4-2 of ASCE 7-05.

Parameter	For ASCE 7-16 / IBC 2018 reference / Values	For ASCE 7-05 / ADIBC 2013 reference / Values
Importance factor, I	1.50 for Risk Category IV, 1.25 for Risk Category III and 1.0 for Risk Category II • In general, for hydrocarbon facilities that present a substantial risk to human life in the event of failure or those essential for safe/continuous operation of plants such as: structures in process area/utilities, process buildings, manned buildings, etc., Risk Category shall be III or IV as approved by COMPANY. • For polymer / petrochemical facilities, Risk Category II shall be followed subject to COMPANY approval. • Also, for structures that has no direct risk to human life in the event of failure such as un-manned stores, car park shed etc., Risk Category shall be II subject to COMPANY approval.	1.50 for Occupancy Category IV, 1.25 for Occupancy Category III and 1.0 for Occupancy Category II • In general, for hydrocarbon facilities that present a substantial risk to human life in the event of failure or those essential for safe/continuous operation of plants such as: structures in process area/utilities, process buildings, manned buildings, etc., Occupancy Category shall be III or IV as approved by COMPANY. • For polymer / petrochemical facilities, Occupancy Category II shall be followed subject to COMPANY approval. • Also, for structures that has no direct risk to human life in the event of failure such as un-manned stores, car park shed etc., Occupancy Category shall be II subject to COMPANY approval.

10.8 Crane / Impact Load (Live Load)

a) Crane loads shall be in accordance with provisions of ASCE 7-16 and BS EN 1993-6. Crane loads shall be considered as live loads and shall be applied on the supporting structure with their maximum values for the following cases;

1) Operational capacity
2) Test capacity
3) Lifting capacity

b) Self-weight of the crane/monorail assembly (without lift load) shall be considered as Dead Load. Live load on crane support girders shall be taken as the maximum wheel loads from the mechanical data sheet provided by the crane SUPPLIER.

c) Structural member supporting the crane or other moving loads shall be designed to cater for the most unfavorable positions of the crane or other moving loads (to maximize the design forces). These structural members shall be designed considering the impact factors given in Table 10-5 below, unless higher values are recommended by crane VENDOR.

Table 10-5 – Impact Factors

Crane Type/ Category	Crane Impact Loads		
	Vertical Impact Load	Horizontal Impact Load	
		Transverse	Longitudinal
Cab Operated Travelling Crane	25%	20%	10%
Hand Operated Monorails, Hoists & Davits	10%	5%	5%
Light Machinery, Shaft or motor driven	20%	-	-
Reciprocating machinery or power driven	50%	-	-
Elevators - Lifts	100%	-	-
Hangers supporting Floors and Ceilings	33%	-	-

d) The vertical impact factor shall be applied on the maximum wheel loads.

e) The transverse horizontal load shall be calculated by multiplying the specified impact load factor with sum of the weights of the rated capacity of hoist, crane trolley, cab and hooks. Apply one-half of the load at the top of each rail at all wheel locations, acting in either direction, normal to the runway rails.

f) The longitudinal horizontal load shall be calculated by multiplying the specified impact load factor with the maximum wheel loads due to the weights of lifted load, hook, crane trolley and crane and crane frame (including wheel carriage) and shall be applied at the top of the rail.

g) The crane runway girder and supporting structure shall be designed for simultaneous effects of vertical and horizontal (transverse and longitudinal) crane loads as above. Crane girder shall be designed for crane stop forces provided by VENDOR.

10.9 Dynamic Load

Dynamic Loads are generated on supporting structure or foundation, by rotary/reciprocating machinery during their operation. The structure or foundation supporting a compressor, turbine, pump or other machinery having dynamic unbalance forces, shall be designed to resist the peak loads specified by the MANUFACTURER and the vibration amplitudes of the supporting structure or foundation shall be kept within acceptable limits. For further details on vibration analysis and design refer to section 14.0. (Vibration Analysis).

10.10 Thermal Load (Live Load)

Thermal load shall be defined as those forces caused by a change in temperature. Thermal load results from both operating and environmental conditions. Such forces shall include those caused by vessel or piping expansion or contraction, and expansion or contraction of structures.

10.10.1 Structure Thermal Load (Self Straining)

a) Loads and displacement shall be based on the difference between ambient temperature and installed temperature. Ambient temperature shall be taken as the minimum ambient temperature or the maximum ambient temperature as applicable to account for controlling effects of contraction or expansion.

b) Increase in temperatures of steel exposed to solar radiation shall be made by adding a minimum of 20°C (35°F) to the average temperature of a structure.

c) For a given location, structures shall be designed for the following Delta increase or decrease in the temperature:

+ve Delta = Summer Average Temp - Winter Monthly Mean Installation Temp + Solar Radiation Temp.

-ve Delta = Summer Monthly Installation Temp - Winter Average Temp + Solar Radiation Temp.

d) In absence of the above information, following shall be considered:

Temperature variation of +/- 35°C for Fully and Partially Exposed Structures and, +/- 25°C for Fully Enclosed Structures.

10.10.2 Piping Thermal Load

10.10.2.1 Thermal Friction Load

a) Loads arising from friction due to the thermal effect of pipes expansion or contraction on structural members shall be considered as follows:

1) At each pipe support beam, longitudinal thermal friction loads acting parallel to the run of pipe shall be calculated as a percentage of total operating piping loads (vertical - dead plus content) based on the number of pipes supported by the beam as per Table 10-6.

Table 10-6 – Piping Thermal Friction Loads

Number of Lines on Support	**Friction Load as a Percentage of Total Piping Operating Loads (vertical - dead plus content)**
1	40%
2 or 3	30%
4 to 6	20%
> 6	10%

2) Transverse frictional loads due to piping shall be considered as 10% of total piping operating loads (vertical - dead plus content) per tier of pipe rack / pipe supports.

3) Longitudinal and transverse friction loads shall be applied together. These loads as specified above shall be considered for Local Member Check only. Unless a higher load is justified, 50% of the total specified local friction loads shall be considered for global design of the pipe support system (i.e., pipe rack frames, tie beams, bracings, and foundations).

b) For a given support, if considering only larger lines and ignoring smaller lines results in greater loads, then these forces, calculated based on the associated percentage of piping operating weight as per Table 10-6, shall be used instead of considering all the lines.

c) For local beam design, only the top flange shall be considered effective for resisting horizontal loads unless the pipe anchor engages both flanges of the beam.

d) For individual pipe support (such as T-support, goal post, etc.) supporting few lines, full friction load corresponding to number of pipes supported as per Table 10-6 shall be considered for both Global and Local checks.

e) Frictional forces need not be included in wind and seismic load combinations but shall be combined with anchor and guide loads.

f) Load factors for piping friction loads shall be same as live loads.

10.10.2.2 Anchor and Guide Loads

a) The Pipe Stress Group shall advise pipe guide and stop (anchor) loads, typically for pipes greater than 8” diameter (200mm). For pipes where anchor loads are not supplied by the Pipe Stress Group (for example, pipes up to and including 8” diameter), anchor loads may be estimated on the following basis:

1) 5% of the piping operating weight (dead + content) for a distance equal to the total length of the structure, applied at one anchor bay beam location and acting parallel to the run of pipes. The piping weight used in this calculation will exclude any piping for which the Pipe Stress Group has already provided anchor/ guide loads. For example, for a 60 m length rack with blanket loads applied, the estimated net anchor load will be 5% x 60 x (2.0 kN/m) = 6 kN/m.

2) At each pipe support beam, a nominal force of 5% of the pipe operating weight (dead + content) supported by the beam shall be applied perpendicular to the run of pipes. The piping weight used in this calculation will exclude any piping for which the Pipe Stress Group has already provided anchor/guide loads.

b) All anchor and guide loads shall be included in the Global Analysis and transmitted into the pipe rack frames, tie beams, bracings, and foundations, and shall be combined with wind and seismic loading.

c) Load factors for piping anchor and guide loads shall be same as live loads.

10.11 Surge Load (Live Load)

a) Forces due to surging action of liquids or fluidized solids in process equipment or piping shall be considered in the design of structures.

b) Magnitude and direction of Surge Loads in equipment shall be as per equipment specification and shall be provided by equipment MANUFACTURER/PROJECT Process discipline engineer. Magnitude and direction of Surge Loads in piping shall be advised by piping discipline for each pipe rack module.

c) Surge loads shall be considered as a live load. Surge loads need not be combined with wind or seismic loads. Calculations and design to resist such forces shall be submitted to COMPANY for review.

10.12 Erection Load (Dead Load)

a) Erection loads are temporary forces caused by the installation or erection of equipment or structures. The erection dead load for equipment is the fabricated weight of the equipment (excluding all attachments, trays, internals, insulation, fireproofing, agitators, piping, ladders, platforms, etc.) and is generally obtained from the respective equipment and vessel VENDOR's drawings plus the weight of the foundation. The foundation weight is the combined weight of the footing, pedestal, and overburden soil.

b) Loading and supporting conditions during erection shall be in line with proposed erection and transportation procedures. Constructability studies shall be done to determine construction loads.

c) All possible loading conditions during erection shall be considered and, for any member of a structure, the most unfavourable shall be taken into account. The loads of scaffolding, including the wind loads, shall be taken into account for the design of the structure.

d) Heavy equipment lowered onto a supporting structure can introduce extreme point loads on structural members, exceeding any operating or test load. After placement of equipment, the exact positioning (lining out and levelling) can also introduce extreme point loads. This potential loading condition shall be considered in design calculations where appropriate. The above shall be interpreted on the basis of CONTRACTOR's practical experience and MANUFACTURER's/VENDOR's information and allowed for in the design calculations.

e) Beams and floor slabs in multi-storey structures, e.g. fire decks, shall be designed to carry the full construction loads imposed by the props supporting the structure immediately above. A note shall be added on the relevant construction drawings to inform the field engineer of the adopted design philosophy.

10.13 Maintenance Load (Live Load)

a) Maintenance loads are temporary forces caused by the dismantling, repair, replacement, or painting of equipment or structure. The areas specified for maintenance (e.g., heat exchanger tube bundle servicing) shall be designed to support for the applicable live loads (e.g., Maintenance loads including Bundle Pulling forces).

b) Elevated floor areas shall be designed for maintenance loading. Grating thickness shall be designed to allow for heavier load movement for maintenance equipment.

c) Area of flat roofs that could support mechanical equipment (e.g., HVAC) shall be designed to include loads that are produced during maintenance (i.e., by workers, equipment, materials).

d) Structures and Foundations supporting heat exchanger subjected to bundle pull load (for both mechanical bundle pull and manually bundle pull) shall be designed for the horizontal bundle pull load. The force required to remove the tube bundle from a shell and tube heat exchanger shall be assumed to act along the horizontal centreline of the exchanger in longitudinal axis and shall have a value of 1.5 times the weight of the bundle, but not less than 9 kN or not exceeding the weight of the exchanger. (Note: Heat exchanger empty dead load will be reduced during bundle pull because of the removal of the exchanger head. Bundle pull shall not be combined with wind or earthquake).

e) The portion of the bundle pull load at the sliding end support shall be equal to the friction force at the support or half the total bundle pull load, whichever is less. The remainder of the bundle pull load shall be resisted at the fixed end support. For stacked exchangers, the load shall be applied at the centre of the top bundle.

f) Floors, platforms, walkways and staircases used for operational / maintenance purposes (other than Compressor and Generator Platforms) shall be designed for a minimum Live Load as per section 10.4 or derived from the MANUFACTURER/ SUPPLIER / VENDOR's data, whichever is higher.

g) Platforms where heavy maintenance may occur shall be designed for a minimum uniform live load as per section 10.4 or derived from the MANUFACTURER / SUPPLIER / VENDOR's data, whichever is higher. That uniform loads and concentrated loads do not occur simultaneously.

h) The maintenance loads as applicable shall be added to live loads in load combinations matrix given in Table 11-2 and Appendix 2

10.14 Miscellaneous Load

Miscellaneous loads shall be defined as loads that do not fit into the categories listed in this section, however required for structure or foundation design. Such load shall be properly considered under relevant primary loads and load combinations.

10.15 Differential Settlement Load (Dead Load)

The variability of the soil strata and loading result in differential settlement. Where the ground condition at founding level is different for foundations in the same structure, also differential settlements would occur.

The deflections, bending moments, shear and axial forces in structural elements generated due to differential settlement shall be included in the structural design based on the foundation type and as specified in the soil investigation report. This load shall be treated as dead load.

10.16 Earth / Hydrostatic Load and Buoyancy Load (Live Load)

a) Soil loads shall consist of lateral earth pressures. Earth pressure (wherever applicable) shall be calculated for all loading condition (as defined below in section 10.16. e.) and in accordance with the relevant geotechnical report which should include soil properties such as bulk density, cohesion, and active and passive pressure coefficients.

b) Surcharge loads depending on the location and vehicle approach also need to be considered. The minimum load applied shall be 10 kN/m^2.

c) Where the bottom of a structure or foundation/pit extends below water level, either temporary or long-term, buoyancy and hydrostatic pressures shall be accounted for in the design. The buoyancy load is equal to the weight of the volume of displaced water.

d) When evaluating the impact of buoyancy, a structure or vessel shall be considered as empty (e.g., without operating contents but including insulations).

e) Structures such as pits/ tanks shall be checked for all the following three conditions:

1) Empty condition with soil backfill on the outside including external ground water effect.
2) Full water inside without soil backfilling (test load condition).
3) Full water inside and soil backfilling on the outside.

Hydrostatic water pressures on retaining walls and underground structures shall be considered up to the maximum possible level of retention.

Crack width limitations shall be considered in the design of operating condition only.

f) Reinforced Concrete bund walls shall be designed for accidental load condition when the bund is completely filled with water to the crest. Only the hydrostatic fluid acting in the outward direction and gravity loading needs be considered.

g) The highest ground water level specified by the PROJECT shall be used for design when checking stability under earthquake loads.

h) When checking stability under wind loads, ground water level shall be taken at the grade.

i) For submerged structures the dry and submerged dead weight shall be calculated including any anticipated marine growth.

10.17 Blast Load

a) Transient dynamic loads on the buildings from the blast effects of an explosion are specified as Peak side-on overpressure with corresponding impulse or duration. It shall be obtained from a Process Risk Tool (PRT) (or QRA / equivalent risk assessment) corresponding to the approved frequency as per HSE/ADNOC requirements unless other blast overpressure and duration values specified by COMPANY.

b) The following parameters shall be used to define the blast load using methods described in the ASCE Report 'Design of Blast Resistant Buildings in Petrochemical Facilities':

   1) Peak side-on positive over-pressure, positive phase duration, rise time and the corresponding positive impulse;

   2) Peak side-on negative pressure, negative phase duration, and the corresponding negative impulse.

c) Alternatively, in the absence of a dedicated report obtained from Process Risk Tool (PRT) (or equivalent risk assessment), Blast loading shall be based on ASCE Design of Blast-Resistant buildings in petrochemical facilities and preliminary information provided by Process Safety.

d) Buildings having blast pressure less than 2.1 kN/m^2, do not require special provisions with regards to explosion resistance.

e) It shall be assumed that the blast loads shall act simultaneously on and over one blast ward-wall, sidewalls, and the roof. The blast shall be considered as striking from any direction for design of the building and relevant load cases shall be considered accordingly. These loads act with applicable dead and live loads. Suction on the walls and roof shall be taken as 50% of positive pressure loads and shall not be taken in combination with positive pressure loads.

f) Structural components, doors, windows or appurtenance on an exterior surface of a blast resistant building shall be designed for the blast loading applicable to that surface.

g) Building Blast Design Requirements (BDR) data sheet shall be prepared for each building and submitted to COMPANY for approval. Refer Appendix –1 for typical BDR data sheet.

h) Unless otherwise noted in the BDR data sheet, building shall be of cast-in-situ reinforced concrete construction (frames, walls and roof). Occupied buildings subject to very toxic (acute and chronic) gas clouds exposure shall be designed and detailed to prevent gas entry from a plant emergency. For building configuration and other architectural requirements of blast resistant buildings refer COMPANY Specification for Architectural Design.

i) For further details on 'Requirements for Blast Resistance Design', refer to section 15.

10.18 Future Load (Dead/Live Load)

a) Future loads, due to pipe rack extensions shall be considered by CONTRACTOR.

b) Pipe racks and their foundations shall be designed to support loads associated with full utilization of the available space on piping and cable tray levels for operating load combinations.

c) Where, future piping details are not known, unoccupied areas in pipe racks shall be designed for the maximum of the following two load scenarios, to allow for future pipework/cable tray that may be required for future expansion as indicated in PROJECT design basis to include a space allowance for future items:

   1) The same intensity of piping load as applied for the design of adjacent areas within the same pipe rack tier/level shall be applied to the future space areas. The applied load shall include the pipe vertical and horizontal forces (i.e. anchor stop / line stop / guide / friction loads). The operating dead loads for cable tray shall be considered as minimum 1.0 kN/m^2 per level of cable trays.

2) The minimum piping operating load of 2.0 kN/m^2 shall be considered. 50% of this shall be considered as pipe content load and rest as pipe dead load. The pipe horizontal forces (i.e. anchor stop / line stop / guide / friction loads) shall also be applied as directed by the piping engineer. The operating dead loads for cable tray shall be considered as minimum 1.0 kN/m^2 per level of cable trays.

11 LOAD COMBINATIONS

11.1 General

Unless otherwise specified in PROJECT document, the load combinations for strength, allowable stress and serviceability design of foundations and structures shall be carried out in accordance with ASCE 7-16, ACI 318M, ANSI/AISC 360 or alternatively BS EN 1991, 1992 and 1993.

11.2 Load Combination Lists and Tables

a) Loads shall be combined as specified in Tables 11-2 for the primary loads as listed in Table 11-1, and appropriate load factors shall be applied as per applicable design codes. The Load Combinations specified in Table 11-2 below shall be developed for typical process structures, pipe racks and buildings.

Table 11-1 – Load List

Load List	Abbr.
Weight of Structure	DL
Empty Weight of pipe, Vessels and Equipment	DL_{empty}
Hydrostatic Test Load Content only	DL_{Test}
Erection Load	ER
Maintenance Load	ML
Live Load	LL
Roof Live Load	L_R
Moving/Truck Load	LL_{move}
Operating Load of Vessel and Piping Content only (excluding empty weight of pipe/vessel)	LL_{op}
Wind Load	WL
Earthquake Load / Seismic Load - Vertical	E_V
Earthquake Load / Seismic Load - Horizontal	E_H
Crane/ Impact Load	CR
Dynamic Load	DY
Thermal Pipe Anchor & Guide Load	TL_{AG}
Thermal Pipe Friction Load	TL_F
Thermal Structure Self Straining Load	TL_{SS}
Differential Settlement	DS
Earth/ Water load	HY
Blast Load	BL

Table 11-2 – Load Combination Matrix

Primary Loads	Operation		Test	Erection	Earthquake/ Seismic	Empty	Blast[5]
	without wind	with wind					
	A	B	C	D	E	F	G
DL	x	x	x	x	x	x	x
DL_{empty}	x	x[1]	x	x	x	x	x
DL_{Test}			x				
ER				x			
LL_{op}	x	x[1]			x		
LL	x	x	x	x	x		x
L_R	x	x					
LL_{move}	x		x	x			
WL		x	x[3,4]	x[3,4]		x	
EQ (E_H & E_V)					x		
DY	x	x	x[2]		x		
TL_{AG}	x	x			x		
TL_F	x						
TL_{SS}	x						
CR	x		x	x		x	
DS	x	x	x		x	x	
HY	x	x	x	x	x	x	x
BL[5]							x

Notes:
1) The most unfavorable load combination shall be taken into account.
2) Only if the structure supports rotating equipment that will be in operation while a vessel is being tested with water.
3) Only 50% wind load shall be taken into account for test and erection load condition
4) The effect of wind forces acting on temporary scaffolding erected during construction, or later for maintenance, which will be transferred to the vessel or column shall be considered. When considering these effects, the actual projected area of the scaffold members together with the correct shape factor and drag coefficient should be used. As an initial approximation, the overall width of the scaffolding itself can be taken as 1.5 m on each side of the vessel or column with 50% closed surface and shape factor 1.0.
5) Blast condition shall be taken into account for the blast resistant design of buildings where applicable.
6) In the ultimate limit state design, due regard shall be given to the different load factors for the various load combinations and the adverse or beneficial effects of the basic load cases.
7) Any other load combinations deemed necessary as advised by COMPANY or as per codal requirement shall also be considered in the design calculations.
8) The maintenance loads shall be added to live loads in load combinations matrix as applicable.
9) Where live loads have a favourable effect, they shall be taken as zero.

b) The load combinations with load factors for Strength, Allowable Stress and Serviceability Design are provided in the Appendix-2. These are developed in accordance with ASCE 7-16 and BS EN 1990, 1991, 1992 & 1993 and are for general guidance only. The Engineer shall consider most critical combinations applicable for the relevant structure and shall obtain prior approval from COMPANY.

12 STRUCTURAL MATERIALS

12.1 General

Materials and specifications where not included in this Specification shall be in accordance with relevant COMPANY Specification. Other materials not mentioned in COMPANY Specifications may be considered subject to COMPANY approval.

The general types of material to be used are defined in the following sub-clauses.

12.2 Concrete

Concrete grade varies from C20 to C50 based on the type of application; refer to COMPANY Specification for Concrete Supply & Construction (Doc. No. AGES-SP-01-001).

12.2.1 Reinforcement Steel

For reinforcement in concrete works refer to COMPANY Specification for Concrete Supply & Construction (Doc. No. AGES-SP-01-001).

12.3 Structural Steel

Structural steel material Grade, Shapes, Minimum thicknesses, Cold formed Profiles, Bolts, Nuts and Washers, Welds, Handrail, Ladder, Grating, Stair Treads, Floor Plate, etc. shall be in accordance with COMPANY Specification for Structural Steel Supply, Fabrication and Erection (Doc. No. AGES-SP-01-002).

12.4 Anchor Bolts & Grouting

The type and material required for Anchor Bolts & Grouting shall be in accordance with COMPANY Specification for Anchor Bolts & Grouting.

12.5 Masonry

For masonry, refer COMPANY Specification for Masonry Works.

13 SERVICEABILITY DESIGN LIMITS AND SAFETY FACTORS

13.1 Deflection

13.1.1 General

The deflection of structural elements and lateral sway/drift of structure shall be checked for the most critical load combinations.

The allowable limits for deflections of the structural elements from applicable serviceability/allowable load combinations shall be as per Tables 13-1, 13-2 &13-3 below. If functional requirements of the structure impose stricter limits, then the same shall be considered in the design.

13.1.2 Allowable Vertical Deflection

The allowable limits for vertical deflections of the structural elements shall be as given in Table 13-1 below.

Table 13-1 – Allowable Vertical Deflections

Structure Type	Max. Allowable Deflection
Beams supporting equipment	L/500
Beams supporting brittle finishes, such as plaster ceilings	L/360
Cantilever beams (Overhang)	L/400
Beams supporting steel platforms, staircases, pipe racks, etc.	L/300
Beam supporting Overhead Travelling Crane (Gantry Girders, Runway Beams)	L/600(1)
Beam supporting Monorail	L/450
Grating	L/250
Notes: 1) Horizontal deflection of Crane runway beam shall be limited to L/500. If more stringent requirements for vertical and horizontal deflection are specified by the Crane MANUFACTURER, then the same shall be followed. 2) L: Represents the Span of Supporting Beams, Sheeting/Plate/Grating.	

13.1.3 Allowable Horizontal Deflection

The allowable limits for horizontal deflections of the structural elements shall be as given in Table 13-2 below.

Table 13-2 – Allowable Horizontal Deflections (1) & (2)

Structure Type	Max. Allowable Deflection/Drift
Occupied Buildings, Structures/Pipe-racks supporting equipment	H/300
Un-Occupied Buildings, Structures/Pipe-racks not supporting equipment	H/200
Structures supporting Overhead Cranes	H/400

Structure Type	Max. Allowable Deflection/Drift
Flagpole	H/50 [3]

Notes:

1) Limits in the table apply to:
   a) Drift between stories
   b) Drift of the structure as a whole
2) H is storey height or total height of the structure.
3) Second order effects due to deflection shall also be considered in the design of flag poles.

13.1.4 Allowable Deflection for Cladding System

Allowable deflection for cladding shall be as given in Table 13-3 below.

Table 13-3– Allowable Cladding Deflections [1]

Cladding System	Max. Allowable Deflection
Wall/Roof Sheeting	L/180
Purlins vertical deflection	L/300
Girts horizontal deflection	L/300

Notes:

1) L is the length or span

13.2 Stability Checks

The stability ratio checks shall be performed using service loads only and shall be determined as follows:

a) Stability ratio against Overturning ≥ Resisting Moment / Overturning Moment

Where:

Resisting Moment	=	Moment due to gravity loads (gravity loads reduced for buoyancy effects, where applicable)
Overturning Moment	=	Moment due to lateral loads

b) Stability ratio against Sliding ≥ Sliding Resistance / Sliding Force

Where:

Sliding Resistance	=	Force developed by friction between foundation and membrane due to gravity loads (gravity loads reduced for buoyancy effects, where applicable)
Sliding Force	=	Lateral loads causing sliding

13.2.1 Foundation Stability Ratios

a) Foundation design shall include the following two cases and the most adverse case shall be considered along with the effect of buoyancy, if applicable:

1) With soil overburden
2) Without soil overburden

b) The following shall also be considered for foundation stability checks:

1) When the soil overburden is not considered, the design wind speed shall be calculated considering 0.8 times the basic wind speed.

2) For earthquake service loads, the minimum 'stability ratio' against overturning and sliding shall be 1.2. However, reduction in overturning effects at the soil-foundation interface as permitted in ASCE/SEI 7-16, Section 12.13.4, shall not be used.

3) For the ASD load combinations with dead load factor of 0.6 in accordance with ASCE, the minimum stability ratio against overturning and sliding shall be 1.0

4) The case of stability check without soil overburden need not be considered in seismic load combinations.

13.2.1.1 Stability against Overturning

The stability ratio shall not be less than:

1) 1.5 when soil overburden is considered
2) 1.2 when soil overburden is not considered

The overturning and resisting moments shall be computed about the most critical axis of rotation of the foundation block at the soil concrete interface. There may be more than one axis of rotation.

13.2.1.2 Stability against Sliding

a) Where sliding resistance is developed by friction only at bottom, the stability ratio shall not be less than:

1) 1.5 when soil overburden is considered
2) 1.2 when soil overburden is not considered

b) In cases where sliding resistance is developed by a combination of friction and passive resistance, the stability ratio shall not be less than:

1) 2.0 when soil overburden is considered
2) 1.5 when soil overburden is not considered

Note: The friction at bottom surface (not on sides) and passive resistance up to the bottom level of reinforced concrete only shall be considered for resistance.

13.2.1.3 Stability against Uplift

The uplift factor of safety shall not be less than:

1) 1.25 (with soil overburden)
2) 1.10 (without soil overburden)

Buoyancy effect shall be considered for the gravity loads, where applicable.

13.2.1.4 Additional requirement for Vertical Vessel or Stack foundation

In addition to the stability checks cited in the above sections, the following criteria against overturning shall be considered for vertical vessel or stack foundation:

1) At least 80% of the foundation shall be in compression for the design overturning moment during empty or, erection condition.

2) At least 90% of the foundation shall be in compression for the design overturning moment during normal operating condition with the exception of (3) below,

3) Foundations for tall vertical vessels (h/d>10), shall be in full compression (100%) for the design overturning moment during normal operating condition.

13.2.2 Retaining Wall Stability Ratios

13.2.2.1 Stability against Overturning

The stability ratio shall not be less than the following:

a) For sustained loading	= 3.5 for cohesive soils
	= 2.0 for cohesion less material
b) For sustained loading combined with temporary loading	= 2.0 for cohesive soils
	= 1.5 for cohesion less material

Resisting moment and overturning moment shall be taken about the toe of the retaining wall and bottom of footing.

13.2.2.2 Stability against Sliding

a) The sliding resistance of retaining walls shall be developed by either friction between the footing and membrane or by a combination of friction between the footing and membrane at the bottom and passive resistance on base/keys (up to the bottom level of reinforced concrete), provided that backfilled soil is compacted as per COMPANY Specification. The sliding stability ratio shall not be less than:

1) 1.5 when friction only is considered
2) 2.0 when friction and passive resistance is considered

b) Top 300mm soil on the toe side shall be excluded from both friction and passive resistance calculations.

c) The effects of buoyancy as applicable, shall be considered in the calculation of gravity loads.

d) The friction at bottom surface and passive resistance up to the bottom level of reinforced concrete only shall be considered for resistance.

13.2.3 Pipeline Anchor Blocks Stability Ratios

a) Pipeline anchor blocks shall be designed for the anchor forces obtained from pipeline stress analysis. The horizontal forces shall be resisted by net earth pressure, friction between the anchor block and bottom membrane. Soil parameters shall be as per Geotechnical report.

b) A minimum factor of safety of 2.0 shall be provided for sliding. The provision of base undulation is acceptable only for the pipeline anchor blocks with high thrust force to achieve a higher friction coefficient.

Note: The friction at bottom surface (not on sides) and passive resistance up to the bottom level of reinforced concrete only shall be considered for resistance.

13.3 Allowable Settlement

a) The allowable absolute and differential settlement limits for different types of foundations shall be as per Table 13-4 below:

Table 13-4 – Allowable Settlement Limits

Foundation Type	**Max. Allowable Settlement (mm)**	
	Absolute	**Differential**
Isolated Pad Footing (Square, Rectangular, Octagonal etc.)	25	10
Mat or Raft Footings	50	25
Tank Foundation (Ring Beam)	50	13[(1)]

Note:

1) Unless more stringent criteria is specified by the VENDOR/Mechanical discipline. The differential settlement is measured between the ends of any segment of 10.0m in circumference.

b) Allowable settlement of foundations shall also meet the recommendations of soil investigation report, approved by COMPANY.

13.4 Allowable Crack Width in Concrete Structure

a) All reinforced concrete shall provide for proper distribution of reinforcement to control flexural cracking.

b) Crack width shall be calculated using the applicable formula in BS/ACI codes.

c) The calculated crack width shall not exceed the values specified in Table 13-5 below:

Table 13-5 – Crack Width Limits

Structure with Exposure Condition	Max. Allowable Crack width (mm)
All liquid retaining structures	≤ 0.10
Structure buried and in contact with water, submerged, exposed to sea water	≤ 0.15
All other structures including foundations exposed to soil (above water table) and structures exposed to normal environmental condition	≤ 0.30

13.5 Coefficient of Static Friction

a) The coefficients of static friction for various materials in contact with concrete and steel shall be as listed in Tables 13-6 and 13-7 below:

Table 13-6 – Coefficients of Static Friction for Materials in Contact with Concrete

Surfaces in contact with Concrete	Co-efficient of Friction
Concrete to Soil	As per soil report but ≯ 0.40
Concrete to Membrane/Polythene sheets	0.20(1)
Note: 1. Greater value of friction coefficient shall be permitted subject to MANUFACTURER's recommendations based on material qualification testing and COMPANY approval.	

Table 13-7 – Coefficients of Static Friction for Materials in Contact with Steel

Surfaces in contact with Steel	Co-efficient of Friction
Carbon Steel to Carbon Steel	0.4
Carbon Steel to Concrete or Grout	0.6

Surfaces in contact with Steel	Co-efficient of Friction
Proprietary low friction sliding surfaces or Coatings (e.g. 'Teflon')	As per MANUFACTURER's Instructions but ≮ 0.10

b) Provision of low friction sliding surfaces (like PTFE) shall be avoided as much as possible especially at locations where it cannot be replaced, since the sliding surface deteriorates over time and lose its original function of low friction.

c) Whenever low friction sliding surface is used, co-efficient of friction of aged-sliding surface shall be obtained from the MANUFACTURER and the values shall be used in the design.

14 DYNAMIC ANALYSIS

14.1 General

a) This section pertains to foundation and support structure designs governed by dynamic loadings due to machinery vibrations. Foundations and support structures designed for machinery vibrations shall also be capable of withstanding all other loadings to which they may be subjected (i.e. wind, seismic, piping, temperature etc.).

b) Data required from MANUFACTURER/SUPPLIER.

The following data is required from the Machine MANUFACTURER/SUPPLIER:

1) Equipment, driver, rotors, coupling/gear, base plate and ancillary weights.
2) Center of gravities in x, y, z directions for the whole unit, equipment, motor, gear unit, rotors, base plate and ancillaries.
3) Equipment and driver speeds (rpm).
4) Power rating of equipment/driver.
5) Unbalanced forces with frequency and their locations (for both steady and unbalanced state).
6) Static (including wind/seismic loads) and dynamic loads.
7) Maximum permissible vibration limit (for both steady and unbalanced state).
8) Emergency (malfunction) loading, if any.
9) Maximum lift weight and clearances for maintenance.
10) Equipment foot print drawing showing overall base frame/plate dimension, orientation and location of anchor bolts & details, leveling screw plate, embedments, etc.

14.2 Vibration Analysis of Superstructure

a) The primary source of vibration in superstructures is harmonic unbalanced forces generated by rotating or reciprocating equipment. The final design should be such that vibrations will be neither intolerable nor troublesome to personnel and will not cause damage to the machine or structure or adjacent foundations, structures, or services.

b) For structures supporting machineries, a detailed three-dimensional harmonic (Time History) analysis shall be performed. The harmonic response analysis shall provide anticipated amplitudes of vibration, velocity and acceleration, as well as the force magnitudes in structural members. Appropriate amount of damping shall be estimated and considered in the analysis.

c) In General, for the structure having one or two degrees of freedom, all the natural frequencies of the structure shall be out of band of 0.7 to 1.3 times operating frequency of the machine supported on the structure.

d) In addition to the above, it shall also be demonstrated that the vibration amplitudes between 0.35 and 1.5 times the operating frequency are within the allowable values stated by the machine MANUFACTURER/SUPPLIER in order to account for the differences between the actual structure and the mathematical model and to ensure no resonance occurs.

e) The time history results shall be used to verify that the acceptance criteria set by the MANUFACTURER/SUPPLIER and acceptable limits of vibration for human comfort have been satisfied.

f) The depth of a steel beam supporting large open floor areas free of partitions or other sources of damping shall not be less than 1/20 of the span.

14.3 Vibration Analysis of Machine Foundation

Foundations for centrifugal machinery less than 375kW or reciprocating machinery less than 150kW or machinery weight less than 1.0T do not require a dynamic analysis. However, the foundation to machinery assembly weight ratio shall not be less than 3 to 1 for centrifugal machinery and 5 to 1 for reciprocating machinery. Foundations for machinery more than the above rating shall require a detailed three-dimensional vibration analysis and shall be sized based on both the static and dynamic analysis as described in the following sections.

14.3.1 Static Analysis

14.3.1.1 Basic Design

a) The design of machine foundation shall be in accordance with ACI 351-3R, DIN 4024, and CP 2012-1-1974.

b) The minimum thickness of foundation base slab shall be (0.6 + largest dimension of base slab/30) in meter.

c) The soil pressure under normal operating conditions shall not exceed 50% of allowable capacity for static loads and 75% of the allowable capacity for combined static and dynamic loads.

d) The mass ratio, (foundation weight divided by weight of machine with assembly), shall be more than 3 for rotating machinery and more than 5 for reciprocating machinery.

e) The maximum horizontal eccentricity between the center of gravity of the machine and foundation system and the centroid of the soil contact bearing area, in any horizontal direction, shall not exceed 5% of the corresponding foundation dimension.

f) The center of gravity of the machine and foundation system shall be as close as possible to the lines of action of the unbalanced forces to avoid several coupled response modes.

g) In case of pile foundation, the arrangement of piles shall be made in such a way that the centroid of combined foundation system coincides within 5% of the respective dimension of pile group.

h) The effect of vibration from other structures transmitted via the soil and ground water, allowing for water table fluctuations, shall be checked and taken into consideration during the design stage, if vibration transmission is deemed feasible.

14.3.1.2 Static forces

In addition to normal vertical loads, the following pseudo-static forces shall be considered to act at the centerline of the machine shaft for the static analysis of the machine foundations.

1) Vertical force equal to 50% of the total weight of each machine.
2) Transverse horizontal force equal to 25% of the total weight of each machine.
3) Longitudinal horizontal force equal to 25% of the total weight of each machine.

The above loads are not considered to act concurrently with one another when combined with normal operating loads.

14.3.2 Dynamic Analysis

In addition to static analysis, the following shall be considered for dynamic analysis of machine foundation.

a) The dynamic analysis (i.e. Harmonic Analysis) shall be based on a mathematical model wherein the weights of machine (from MANUFACTURER) including foundation and elasticity of the soil supporting the foundation (site specific soil dynamic properties from soil report) shall appropriately be represented. Appropriate amount of damping shall be estimated and considered in the analysis. The response of the soil supporting the foundation shall be based on “Elastic Half-space Theory”.

b) In addition to the test value of soil dynamic shear modulus, the foundation system shall also be analyzed for the upper and lower bound values of soil shear modulus values as 1.25 and 0.75 times the test value provided in the geotechnical report. The geometric damping when used shall not exceed 70% of the theoretical value for all modes of vibration.

c) Multi degree of freedom systems shall be considered for machine foundation if a single degree of freedom system does not lead to an acceptable mathematical representation of the structure. The cumulative mass participation of analytical model shall be more than 95% for good mathematical representation of structure.

d) When there is more than one rotor, amplitudes shall be computed with the rotor forces assumed in-phase and 180 degrees out-of-phase to obtain the maximum translational and torsional amplitudes.

e) When piles are used, the pile dynamic properties, damping and resistance shall be determined using standard publications and internationally recognized method.

14.3.2.1 Unbalanced Dynamic Forces

a) The exciting or unbalance dynamic forces shall be taken as the greater of the value obtained from the equipment MANUFACTURER or the value determined from the following relation:

Unbalanced dynamic force (kN) = [Rotor Speed (rpm) x Rotor Weight (kN)/6000]

b) For the vibration analysis of structures and foundations of rotating/reciprocating equipment the exciting forces shall be taken as the maximum values that, according to the MANUFACTURER/SUPPLIER of the equipment will occur during the lifetime of the equipment.

14.3.3 Permissible Frequency Limits

a) Generally, none of the natural frequencies of the foundation shall be within a band of the operating frequency of the supported machinery. The frequency band between 0.8 times the operating frequency and 1.2 times the operating frequency shall be avoided.

b) In multi-degrees of freedom analysis, frequencies associated with each mode with effective mass (mass participation factor) greater than five percent (5%) of the total mass and up to 95% of cumulative mass participation of the model shall be out of the range of 0.8 to 1.2 times the operating speed.

14.3.4 Permissible Amplitude Limits

a) Dynamic single amplitudes (positive or negative) of any part of the foundation shall not exceed the lower of the following values:

1) The maximum allowable values stated by the MANUFACTURER/SUPPLIER of the equipment;

2) 25 µm displacement;

3) 2 mm/s effective velocity at the location of the machine-bearing housings;

4) 2.5 mm/s effective velocity at any location of the foundation/structure.

The effective velocity is defined as the square root of the average of the square of the velocity, velocity being a function of time. In the case of a pure sinusoidal function the effective velocity is 0.71 times the peak value of the velocity.

b) Any proposal to exceed a dynamic amplitude value of 25 µm shall include written acceptance by the equipment MANUFACTURER/SUPPLIER.

c) It shall be demonstrated that the vibration amplitudes between 0.35 and 1.5 times the operating frequency are within the allowable values in order to account for the differences between the actual structure and the mathematical model and to ensure no resonance occurs.

14.3.5 Machine/Equipment Foundation Construction Requirements

a) All parts of machine support shall be isolated from adjacent foundations, subgrade and structures to prevent vibration transmission. The machine foundations shall have a minimum isolation gap of 25mm. The gap shall be filled with a flexible joint filler and sealer.

b) Auxiliary structures such as access platforms and crane supporting structures shall be supported independently of the machine foundation.

c) Multiple machines shall only be installed on a common foundation where the MANUFACTURER's approval for this has been obtained.

d) When several similar types of machines are mounted on a common rigid mat, the interconnecting piping shall be supported from the same mat to avoid high stress in the piping.

e) The height of foundation above grade shall be the minimum required to accommodate suction and discharge piping configuration and shall be at least 150mm above the finished grade.

f) Foundation design shall minimize the re-entrant type corners and other details causing stress concentrations.

g) All faces of the foundation shall be reinforced bi-axially to prevent cracking due to shrinkage and thermal expansion. Such reinforcement shall be as a minimum of 16mm dia. reinforcement at a maximum of 200mm spacing, both vertically and horizontally, and on all faces of the foundation.

h) An intermediate horizontal layer of two-way reinforcing with vertical re-bars is required when the thickness of foundation exceeds 0.75m. This shall be of 12mm dia. reinforcement spaced at 200mm. Spacing between horizontal layers shall not exceed 0.6m and vertical bars spaced no more than 1.0m between bars. Also, a horizontal layer of temperature steel shall be provided at the top of pedestals or slabs.

15 DYNAMIC BLAST ANALYSIS

15.1 General

a) Blast resistant buildings and their structural components shall be designed in accordance with the requirements of this Specification and ASCE "Design of Blast Resistant Buildings in Petrochemical Facilities". Alternative design methods may be used subject to COMPANY approval.

b) Concrete structures shall be designed in accordance with ACI 318M, special provision of seismic design, and steel structures shall be designed in accordance with AISC 360.

c) The building structural frame, roof, walls, bracing, and connections, shall be designed in such a manner that large plastic deformations of the major frame members and external wall panels will be allowed to take place without causing partial or total building collapse.

d) Buildings subjected to the dynamic blast loading shall be analysed and designed to meet the ductility demand limits defined in the PROJECT Building Design Criteria or Philosophy.

e) Load factor shall be taken equal to 1.0 in all blast load combinations. Blast load shall be combined with dead load, and with & without live load.

f) Wind and Seismic loads shall not be combined with Blast loading.

15.2 Blast Design Loading

For blast loads on the buildings refer to section 10.17.

15.3 Blast Analysis Methods

a) Dynamic analysis shall be carried out in accordance with methods described in ASCE Report 'Design of Blast Resistant Buildings in Petrochemical Facilities'. The CONTRACTOR shall use analysis methods appropriate for the specific blast design with prior approval from COMPANY. The selected methods shall adequately model the dynamic response of the structure to the applied blast loads and the structural component interaction. The following requirements shall apply:

1) Single Degree of Freedom (SDOF) analysis method can be used where the connected component differs in natural period by a factor of 2 or more.

2) For Multi Degree of Freedom (MDOF) analysis, a finite element analysis method can be carried out using a special/general-purpose structural analysis computer software with nonlinear transient dynamic analysis capability. Use of such software is subject to COMPANY approval.

b) Equivalent Static Method is not recommended for general use; however Equivalent Static method can be used subject to COMPANY approval. In such cases, the empirical equation provided in ASCE Manual 42 as specified in ASCE report shall be used for computing the required resistance or equivalent static load.

15.4 Blast Load - Building Performance & Deformation

a) The degree of structural permitted damage (low, medium, or high) for blast resistant buildings, known as "building response range," shall be as specified in the Table 15-1 below unless otherwise stated in PROJECT Blast Design Requirements (BDR) data sheet.

Table 15-1- Building Performance Requirements

Building type and Typical Performance Requirements	**Building Response Range**	**Description**
Instrument Equipment Shelters (IES), Field Auxiliary Rooms (FARs), Control Rooms and Occupied buildings *Continued use; reusable with cosmetic repairs*	Low	Localized building/component damage. Building can be reused; however repairs may be required to restore integrity of structural envelope. If elastic limit is specified, then no repairs are necessary. Total cost of repairs is moderate.

Building type and Typical Performance Requirements	Building Response Range	Description
Substations, Analyzer houses *Damage-limited; not reusable without major repairs/replacement*	Medium	Widespread building/ component damage. Building cannot be used until repaired. Total cost of repairs is significant.
Compressor houses *Collapse-limited; not repairable; abandon/replace*	High	Building/component has lost structural integrity and may collapse from additional environmental loads (i.e., wind, rain etc). Total cost of repairs approaches replacement cost of building.
For building types not shown in the above table, COMPANY shall be consulted.		

b) Structural members shall be designed based on maximum response consistent with the performance requirements as per the table above. Deformation limits shall be expressed as ductility ratio, support rotation or frame side-sway as appropriate.

c) Dynamic material strength shall be as specified in Appendix 5.A of ASCE Report - Design of Blast Resistant Buildings in Petrochemical Facilities.

d) Maximum response shall not exceed the limits specified in ASCE Report - Design of Blast Resistant Buildings in Petrochemical Facilities for low response range. The Response criteria to be applied for “medium” and “high” response range shall be subject to approval by the COMPANY.

15.5 Component Design

a) Ultimate strength (Limit State) design methods shall be used for designing structural components for blast resistance. The ultimate strength capacity shall be determined in accordance with the applicable codes and standards as specified in this Specification for conventional design.

b) Brittle constructions, such as un-reinforced concrete, pre-stressed concrete, un-reinforced masonry (bricks or blocks) and cement based corrugated panels, shall not be used for load carrying components of blast resistant buildings.

c) Following requirements shall be considered in addition to the requirements given in Chapter 7 of ASCE Report ‘Design of Blast Resistant Buildings in Petrochemical Facilities’.

15.5.1 Reinforced Concrete

a) Structures shall be detailed in accordance to ACI 318, Chapter 21 ‘Special Provisions for Seismic Design’.

b) Minimum thickness of concrete walls and slab shall be 200mm unless a higher thickness is required to ensure sufficient space between the two layers of reinforcement.

c) Concrete walls and slabs shall be reinforced in the main direction with minimum 0.6% of the cross section on each side. In the other direction on each side, a distribution reinforcement of at least 20% of that in the main direction shall be applied. Maximum spacing of bars shall be 150mm centre to centre.

d) Pre-stressed or post tensioned concrete shall not be used due to its non-ductile behaviour and potential loss of strength in fires.

15.5.2 Structural Steel

a) Structures shall be detailed in accordance to AISC 341 'Seismic Provisions for Structural Steel Buildings'.

b) Connections for the main structural frame and roof beams shall be designed to develop the full plastic strength (ultimate moment and/or shear capacities) of the structural members. Connections shall be designed assuming reversible loads are possible.

c) Columns shall have a fixed base with anchorage designed to be ductile.

d) Roof members shall have the bottom flange braced to resist the same vertical load if reversed.

16 PIPERACK ADEQUACY CHECK

During the lifespan of plant there will be modifications and upgradation of facilities. This might result in adding a number of new pipes or equipment to the existing pipe racks/process structures. Structural adequacy check shall be performed for these existing pipe racks/process structures including foundations, prior to implementation.

However, the existing data required for adequacy check may not be always available with the COMPANY. In such scenarios, CONTRACTOR shall collect the data of the existing pipe rack from site surveys as per COMPANY's requirements and standard guidelines and shall propose reasonable technically acceptable solutions/methods to COMPANY for carrying out the adequacy check.

17 PREFABRICATED SKID AND FRAMES

a) The prefabricated skid and frame shall be designed in accordance with AISC 360 or BS EN 1993-1-1.

b) External forces acting on the pre-assembly and its components due to transportation, shipping, load acceleration and lifting shall be provided by the Transportation/Lifting CONTRACTOR. The final design shall take into account all stresses in the pre-assembly frame due to these forces.

c) The skid base shall comprise of at least 3 equally spaced primary beams adequately cross-braced to prevent flexing or distortion of the skid during transport and installation. The spacing between the primary beams shall not exceed 1.5m. Each skid shall be capable of being winched onto a flat transporter without skid distortion or damage to the equipment.

d) The skid beams shall be fully welded and designed as being simply supported at the extreme ends. The bracing shall be designed to resist lateral forces equal to a minimum of 20 percent of the total lifted load applied to any corner of the skid from any lateral direction.

e) Equipment mounted on skid/pre-assemblies shall not be considered as bracing or contributing to its structural strength. Equipment shall be arranged such that the center of gravity of the assembly and the physical center of the skid coincides, as closely as practicable. Floor grating or chequered plates shall not be used as a mounting for equipment or supports.

f) The maximum vertical deflection shall be not more than L/360 for the full skid length (L) with all equipment mounted on it and supported at the extreme ends.

g) Suitably designed pad type lifting lugs or other approved lifting arrangements shall be provided to facilitate the lifting operation during loading and unloading. If required by the method of lifting, one spreader bar shall be provided for each size of skid, to allow single point pick-up. Lifting lugs shall be designed for twice the anticipated loads.

18 TANK RING BEAM FOUNDATION

a) A concrete ring beam shall be considered as a foundation for cylindrical storage tanks.

b) The ring beam shall be designed to take circumferential bending due to vertical loads applied eccentrically to the ring wall centerline plus the maximum allowable differential settlement along the circumference as specified in the soil report.

c) The bearing capacity of the soil below the ring beam shall be calculated using a strip foundation analysis by considering the vertical load from the tank shell plus the weight of the liquid column on the beam wall, roof live load and load from the wind and earthquake.

d) Ring beam shall be founded in the firm stratum. The embedment depth shall be minimum 300mm inside the firm stratum or as per soil investigation report.

19 ENGINEERING MAINTENANCE MANUAL

The CONTRACTOR shall prepare a detailed maintenance manual for use by the operators. The manual shall contain the following information:

a) Design Basis

A brief description of the basis of design of all foundations, structures and buildings, including reference to the detailed calculations for each to enable them to be retrieved if necessary.

b) Inspection

1) Recommendations for the routine inspection of works to enable the early detection of potentially dangerous deterioration, including guidelines regarding the symptoms to be looked for, such as locations and types of cracking which could be found in reinforced concrete structures, etc.

2) Recommendations for special inspection requirements for structures such as dynamic equipment foundations, blast resistant buildings, cooling water structures, etc.

3) Routine forms for all types of inspection shall be established by the CONTRACTOR as part of the manual.

c) Materials

A detailed listing of all materials used (both generic types, and MANUFACTURERS' details) in the works, including concrete mix constituents, concrete surface coatings, steel grades, painting details, etc., to enable the COMPANY to obtain compatible materials for future maintenance.

d) Maintenance and Repair Procedures

Details of recommended repair procedures for common types of failure, such as breakdown or mechanical damage to concrete surface coatings, cracking of small foundations plinths due to reinforcement corrosion, etc.

e) Finishing Material Manual

Additional list of all finishing materials used in the PROJECT buildings including material catalogues and sources to enable the COMPANY to obtain such material or equal for future maintenance.

20 OPERATIONAL REQUIREMENTS

20.1 Computer Maintenance Management System (CMMS)

CONTRACTOR shall provide all input required for carrying out periodic inspection and maintenance of Civil / Structural assets through CMMS. As a minimum CONTRACTOR shall provide the following minimum input for CMMS.

a) Civil/Structural items Tagging Map for each Unit.

b) Asset Register in Excel file containing following:

1) Description
2) Building/Structure/Foundation Tag
3) Unit No.
4) HSECES/Critical/Non-Critical item
5) Other information like blast/Non-blast, etc.

20.2 Monitoring Existing Foundation Settlements

A computerized monitoring system for tank foundations and other critical foundations carrying large loads, rotating equipment, etc. has been developed by the COMPANY. Therefore, relevant data for any new tank foundation or other critical foundations (as mentioned above) are required to be provided by the CONTRACTOR to monitor the evaluation for future maintenance. The CONTRACTOR is required to provide the following:

a) Permanent benchmarks to allow for future check surveys.

b) List of tanks and critical foundations/structures proposed for monitoring.

c) Monitoring devices/Settlement Monitoring Plates (non-corrosive material) embedded/fixed in the critical foundations such as foundations of major equipment, tank, main pipe rack, etc.

d) Plot plans showing locations of the monitoring points and the permanent benchmarks.

e) A computerized form filled with the first readings of the monitoring points surveyed at the completion of the PROJECT.

20.3 Corrosion Monitoring of Critical Concrete Structures

a) CONTRACTOR shall submit for COMPANY approval a corrosion monitoring system to be used for monitoring corrosion risk to reinforcement as and when required, along with the list of critical structures requiring such system.

b) In concrete structures which cannot be shut down for inspection due to operational requirements, a monitoring system involving sensors attached to the structure shall be used. The following are examples of structures requiring monitoring schemes through utilization of sensors:

1) Cooling water structures

2) Below ground tanks such as sulphur pits

3) Reinforced concrete or pre-stressed pipes

4) Tank ring beams

c) CONTRACTOR shall be responsible for the installation of all approved monitoring systems on all identified structures.

21 UNITS OF MEASUREMENTS

All dimensions, quantities and units of measurement used in Specification addendums, data sheets, calculations and drawings shall be in SI units except the pipe size which shall be in the English units of inches.

22 SOFTWARE

a) List of COMPANY approved software packages for structural analysis and design of plant structures (pipe racks, process structure, plant buildings, etc.) is as follows:

1) STAAD PRO by Research Engineers, Inc.

2) Foundation 3D & Mat 3D by Dimensional Solutions, Inc. for foundation element design.

b) For infrastructure related concrete buildings, other software (such as ETABS & SAFE) may be used with COMPANY approval.

c) All software listed above shall be compatible with the latest edition/revision of relevant design codes/standards unless otherwise as per the revision specified in the Contract.

d) In case it is proposed to use any in-house developed software, the same shall be accompanied by a comprehensive validation and quality manual, listing the theories and design codes forming the software. All computation steps for such proprietary programs shall be structured with sufficient clarity to allow direct review and design concurrently by the COMPANY.

SECTION D

APPENDIX 1 : BUILDING BLAST DESIGN REQUIREMENTS DATA SHEET

BUILDING BLAST DESIGN REQUIREMENTS (BDR) DATA SHEET

Project : ________________________________

Project Number : ________________________________

Location : ________________________________

Building Name & ID : ________________________________

A. Blast Resistant Building Requirements

1.1 Building Response Range:

Low ☐ Medium ☐ High ☐

1.2 Building Structural System:

Frame	Wall	Roof
◻ Cast-in-Place Concrete	◻ Cast-In-Pace Concrete	◻ Cast-In-Pace Concrete
◻ Hot-Rolled Steel	◻ Pre-Cast Concrete	◻ Pre-Cast Concrete
◻ Pre-Engineered Metal	◻ Reinforced Masonry /CMU	◻ Single Sheet Metal Panel
◻ Load Bearing Wall	◻ Single Sheet Metal Panel	◻ Insulated Metal Sandwich Panel
◻ Other: ___________	◻ Insulated Metal Sandwich Panel	◻ Composite Concrete Deck
	◻ Other: ___________	◻ Other: ___________

B. Blast Load Design Requirements

Peak side-on pressures and durations for the following table shall be taken from the Project Risk Assessment Report. (See Figure on following page.)

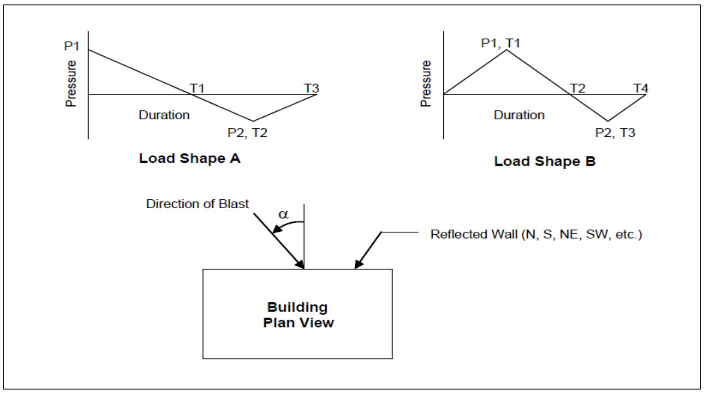
Reference for Project Risk Assessment Report: ________________________________

Blast Scenario as per above Report	Reflected Wall (N, S, NE SW etc.)	Load Shape and angle		Peak side-on pressure (kPa)		Duration (msec)			
		A, B	α (deg)	P1	P2	T1	T2	T3	T4

Notes:

1. Side-on pressure shall be computed at the wall nearest to the blast center.
2. The reflected wall(s) may be different for each scenario. Indicate the reflected wall(s) (N, S, NE, SW, etc.) facing the blast center.
3. Indicate angle of blast center (in degrees) measured from a line normal to reflected wall. See Figure below.
4. If rise time is a small percentage of the positive phase duration then use load shape A. Negative phase pressure is typically not considered, however, if the explosion modelling software predicts a significant negative phase pressure it shall be tabulated.

Load Shapes and Building Orientation



C. Blast Door Performance Requirements

Summarizes the design requirements for each blast door located on the exterior walls of blast resistant building, as per COMPANY Specification for Doors and Windows.

Blast Door ID	Door Location (N, S, NE, SW etc.)	Performance Category

D. Foundation Design Requirements

Geotechnical Report: ____________________

Type of Foundation:

- □ Isolated / Strip Footing
- □ Raft Foundation
- □ Pile Foundation

E. Other Special Requirements

____

____

____

APPENDIX 2: LOAD COMBINATIONS MATRIX

Table A2-1: LRFD - Strength Design Load Factors for Structural and Foundation Design as per ASCE 7-16.

Primary Loads **(Table 11-1)**	Empty		Operation				Test			Erection[16]		Earthquake/ Seismic Note -14		Blast	
			without Wind		with Wind		without Wind	with Wind		with Wind					
Basic Load Combinations as pe Cl. 2.3 of ASCE 7-16	1.4D	0.9D + W	1.2D + 1.6L + $0.5L_R$	1.2D + $1.6L_R$ + L	1.2D + $1.6L_R$ + 0.5W	1.2D + L + W + $0.5L_R$	1.4D	1.2D + W	1.2D + L + W	1.2D + L + W	0.9D +W	1.2D + (E_V+Eh) + L	0.9D + (-E_V+Eh)	1.2D + BL + 0.5L	0.9D + BL
DL	1.4	0.9	1.2	1.2	1.2	1.2	1.4	1.2	1.2	1.2	0.9	1.2	0.9	1.2	0.9
DL_{empty}	1.4	0.9	1.2	1.2	1.2	1.2	1.4	1.2	1.2	-	-	1.2	0.9	-	-
DL_{Test}	-	-	-	-	-	-	1.4[7]	1.2[7]	1.2[7]	-	-	-	-	-	-
LL	-	-	1.6	1.0	-	1.0	-	-	1.0	1.0[9]	-	1.0	-	0.5	-
LL_{move}	-	-	1.6	1.0	-	1.0	-	-	1.0	-	-	-	-	-	-
L_R	-	-	0.5	1.6	1.6	0.5	-	-	-	-	-	-	-	-	-
LL_{op}	-	-	1.6[5]	1.2[5]		1.2[5]	-	-	-	-	-	1.2[5]	-	-	-
WL[12]	-	1.0	-	-	0.5	1.0	-	0.5[8]	0.5[8]	0.5[8]	0.5[8]		-	-	-
EQ[13] (Both E_V & E_H[14])	-	-	-	-	-	-	-	-	-	-	-	1.0	1.0	-	-
DY	-	-	1.2[3]	1.2[3]	-	1.2[3]	-	-	-	-	-		-	-	-
TL_{AG}[5]	-	-	1.6[5]	1.2[5]	-	1.2[5]	-	-	-	-	-	1.2[5]	-	-	-
TL_F[5]	-	-	1.6[5]	1.2[5]	-	-	-	-	-	-	-	-	-	-	-
TL_{SS}[6]	1.2[2]	-	1.2[2]	1.2[2]	-	-	-	-	-	-	-	-	-	-	-
DS	1.2[4]	1.2[4]	1.2[4]	1.2[4]	1.2[4]	1.2[4]	1.4[4]	1.2[4]	1.2[4]	-	-	1.0[4]	1.0[4]	-	-
CR	-		1.6	1.0		1.0			1.0	1.0	-	-	-	-	-
HY[11]	-	1.6 or 0.0	1.6 or 0.0	1.6 or 0.0	1.6 or 0.0	1.6 or 0.0	1.6 or 0.0	1.6 or 0.0	1.6 or 0.0	1.6 or 0.0	1.6 or 0.0	1.6 or 0.0	1.6 or 0.0	1.6 or 0.0	1.6 or 0.0
ER	-	-	-	-	-	-	-	-	-	1.2[10]	0.9[10]	-	-	-	-
BL	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0	1.0

NOTES

1- LLop is operating load of Equipment and Piping and is attributed imposed Load factors.
2- Load Factors for Self-Straining Loads are based on ASCE 7-16 Commentary C.2.3.4.
3- Dynamic load is function of DL and therefore DL factors are assigned.
4- Differential Settlement attributed same factors as Dead Load.
5- Operating (content), Pipe Friction and Anchor Forces attributed same factors as live Loads. However, the load factor for operating and anchor forces has been adjusted to suit the nature of load (non-occupancy).
6- As per ASCE 7 - 2016 Clause 2.3.4, the combination of self-straining loads with other load conditions is discretionary. Based on the experience in the region, the adverse effects on the structure due to variation in temperature has not been established and the probability of extreme loading conditions act unlikely. Therefore, the self-straining load is not included in extreme conditions like seismic and wind load combinations.
7- Test Load considered mainly for local member design as generally one equipment or pipe section shall be tested at a time.
8- Reduced wind Load is considered for Erection / Test Condition.
9- Live Load corresponding to Erection condition shall be considered.
10- Erection dead Loads are weight of equipment corresponding to erection condition.
11- Depending on stabilizing or destabilizing effect, appropriate Load Factors shall be considered for HY load case.
12- The strength design wind speed shall be used in the load combinations in Table C-1.
13- When using ASCE 7-05/ADIBC 2013 for seismic load calculations, the related factors shall be suitably updated in accordance with the respective codal provisions.
14- The earthquake horizontal load Eh is the orthogonal combination of horizontal seismic load effect; i.e. Eh = ± Ex ± 0.3Ey or Eh = ± Ey ± 0.3Ex.
15- The load combinations should be expanded to include the lateral loads in both '+' and '-' directions.
16- The erection load combinations are applicable for vessel supports and foundation.

Table A2-2: ASD Load Factors for Structure & Foundation design and Serviceability Load Factors for Deflection / drift, Crack width, Foundation Bearing Pressure, Overturning, Sliding & Uplift as per ASCE 7-16.

Primary Loads (Table 11-1)	EMPTY			Operation				Test			Erection[20]		Earthquake/ Seismic Note-12			Blast [18]	
				without Wind		with Wind		without Wind	with Wind		with Wiind						
Basic Load Combinations as per Cl. 2.4 of ASCE 7-16	D	D + 0.6W[15] / 0.625W[16]	0.6D + 0.6W[15] / 0.625W[16]	D + L	D + 0.75L + $0.75L_R$	D + 0.6W[15] / 0.625W[16]	D + 0.75L + 0.75(0.6W)[15] / 0.75(0.625W)[16] + $0.75L_R$	D	D + 0.6W[15] / 0.625W[16]	D + 0.75L + 0.75(0.6W)[15] / 0.75(0.625W)[16]	D + 0.75L + 0.75(0.6W)[15] / 0.75(0.625W)[16]	0.6D + 0.6W[15] / 0.625W[16]	D + 0.7(Ev+Eh)	D + 0.525(Ev+Eh) + 0.75L	0.6D + 0.7(-E_v+Eh)	D + BL + 0.5L	0.9D + BL
DL	1.0	1.0	0.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.6	1.0	1.0	0.6	1.0	0.9
DL_{empty}	1.0	1.0	0.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-	-	1.0	1.0	0.6	-	-
DL_{Test}	-	-	-	-	-	-	-	1.0	1.0	1.0	-	-	-	-	-	-	-
LL	-	-	-	1.0	0.75	-	0.75	-	-	0.75	0.75[9]	-	-	0.75	-	0.5	-
LL_{move}	-	-	-	1.0	0.75	-	0.75	-	-	0.75	-	-	-	-	-	-	-
L_R	-	-	-		0.75	-	0.75	-	-	-	-	-	-	-	-	-	-
LL_{op}	-	-	-	1.0[5]	-	1.0[5]	1.0[5]	-	-	-	-	-	1.0[5]	1.0[5]	-	-	-
WL[15] (For ASD Design)	-	0.6[17]	0.6[17]	-	-	0.60[17]	0.45[17]	-	0.30[8]	0.23[8]	0.23[8]	0.30[8]	-	-	-	-	-
WL[16] (For Serviceability checks)	-	0.63	0.63	-	-	0.63	0.47	-	0.32[8]	0.24[8]	0.24[8]	0.32[8]	-	-	-	-	-
EQ[14] (Both E_V & E_H[12])	-	-	-	-	-			-	-	-	-	-	0.7	0.525	0.7	-	-
DY	-	1.0[3]	-	1.0[3]	1.0[3]	1.0[3]	1.0[3]	-	-	-	-	-	-	-	-	-	-
TL_{AG}[5]	-	-	-	1.0[5]	-	1.0[5]	1.0[5]	-	-	-	-	-	1.0[5]	1.0[5]	-	-	-
TL_F[5]	-	-	-	1.0[5]	-	-	-	-	-	-	-	-	-	-	-	-	-
TL_{SS}[6]	1.0[2]	-	-	1.0[2]	1.0[2]	-	-	-	-	-	-	-	-	-	-	-	-
DS	-	1.0[4]	1.0[4]	1.0[4]	1.0[4]	1.0[4]	1.0[4]	1.0[4]	1.0[4]	1.0[4]	-	-	1.0[4]	1.0[4]	0.6[4]	-	-
CR	-	-	-	1.0	0.75	-	0.75	-	-	0.75	0.75	-	-	-	-	-	-
HY[11]	-	1.0 or 0.0	1.0 or 0.0	1.0 or 0.0	1.0 or 0.0	1.0 or 0.0	1.0 or 0.0	1.0 or 0.0	1.0 or 0.0	1.0 or 0.0	1.0 or 0.0	1.0 or 0.0	1.0 or 0.0	1.0 or 0.0	1.0 or 0.0	1.0 or 0.0	1.0 or 0.0
ER	-	-	-	-	-		-	-	-	-	1.0[10]	0.6[10]	-	-	-	-	-
BL	-	-	-	-	-		-	-	-	-	-	-	-	-	-	1.0	1.0

NOTES

1- LLop is operating load of Equipment and Piping and is attributed imposed Load factors.
2- Load Factors for Self-Straining Loads are based on ASCE 7-16 Commentary C.2.4.4.
3- Dynamic load is function of DL and therefore DL factors are assigned.
4- Differential Settlement attributed same factors as Dead Load.
5- Operating (content), Pipe Friction and Anchor Forces attributed same factors as live Loads. However, the load factor for operating and anchor forces has been adjusted to suit the nature of load (non-occupancy).
6- As per ASCE 7 - 2016 Clause 2.3.4, the combination of self-straining loads with other load conditions is discretionary. Based on the past experience in the region, the adverse effects on the structure due to variation in temperature has not been established and also the probability of extreme loading conditions acting simultaneously is unlikely. Therefore, the self-straining load is not included in extreme conditions like seismic and wind load combinations.
7- Test Load considered mainly for local member design as generally one equipment or pipe section shall be tested at a time.
8- Reduced wind Load is considered for Erection / Test Condition.
9- Live Load corresponding to Erection condition shall be considered.
10- Erection dead Loads are weight of equipment corresponding to erection condition.
11- Depending on stabilizing or destabilizing effect, appropriate Load Factors shall be considered for HY load case.
12- The earthquake horizontal load Eh is the orthogonal combination of horizontal seismic load effect; i.e. Eh = ± Ex ± 0.3Ey or Eh = ± Ey ± 0.3Ex.
13- For Serviceability load combinations Table A2-2 shall be used with different load factors for wind as shown. Also see note 16 below.
14- When using ASCE 7-05/ADIBC 2013 for seismic load calculations, the related factors shall be suitably updated in accordance with the respective codal provisions.
15- For ASD load combinations 0.6 times Strength Design Wind shall be used.
16- For Serviceability load combinations 0.625 times Strength Design Wind shall be used.
17- Blast load combinations shall be applicable for the Foundation stability checks only i.e. Foundation Bearing Pressure, Overturning, Sliding & Uplift.
18- The load combinations should be expanded to include the lateral loads in both '+' and '-' directions.
19- The erection load combinations are applicable for vessel supports and foundation.

BS EN – Load Combinations

Notations:

G_{kj}	= Characteristic value of a permanent action j
Q_k	= Characteristic value of a single variable action
$Q_{k,1}$	= Characteristic value of the leading variable action 1
$Q_{k,i}$	= Characteristic value of the accompanying variable action i
γ_G	= Partial factor for permanent actions, also accounting for model uncertainties and dimensional variations
γ_Q	= Partial factor for variable actions, also accounting for model uncertainties and dimensional variations
γ_I	= Importance factor
$\Psi_{0,i}$	= Factor for combination value of a variable action
$\Psi_{1,i}$	= Factor for frequent value of a variable action
$\Psi_{2,i}$	= Factor for quasi-permanent value of a variable action
A_d	= Design value of an accidental action
A_{Ed}	= Design value of seismic action $A_{Ed} = \gamma_I A_{Ek}$
A_{Ek}	= Characteristic value of seismic action
G_{kj}	= Characteristic value of a permanent action j
Q_k	= Characteristic value of a single variable action

Ψ - Factors used above in variable Load Cases for Process Structures / Pipe racks BS EN 1990

Type of Load	Load Cases	Ψ Factors		
		Ψ_0	Ψ_1	Ψ_2
Variable Loads	Live Load (LL)	0.7		0.3
	Wind Load (WL)	0.6		0.0
	Operating Load of Vessel and Piping (LL_{OP})	0.7		0.3
	Thermal Structure Self Straining Load (TL_{SS})	0.6		0.0
	Moving/Truck Load (LL_{move})	0.7		0.3
	Crane / Impact load (CR)	1.0		0.8
	Thermal Pipe Anchor & Guide Load (TL_{AG})	0.7		0.3
	Thermal Pipe Friction Load (TL_F)	0.7		0.3

Ψ - Factors used above in variable Load Cases for Buildings BS EN 1990

Type of Load	Load Cases	Ψ Factors		
		Ψ_0	Ψ_1	Ψ_2
Variable Loads	Live Load (LL)	0.7	0.5	0.3
	Wind Load (WL)	0.6	0.2	0.0
	Roof Live Load (L_R)	0.0	0.0	0.0
	Crane / Impact load (CR)	1.0		0.8

Table A1.2(B) - Design values of actions for ultimate limit states in the persistent and transient design (STR/GEO) (Set B)

Persistent and transient design situations	Permanent actions		Leading variable action (*)	Accompanying variable actions (*)	
	Unfavorable	Favorable		Main (if any)	Others
(Eq. 6.10)	$1.35\ G_{k,j,sup}$	$1.00\ G_{k,j,inf}$	$1.5\ Q_{k,1}$		$1.5\ \psi_{0,i}Q_{k,i}$

Table A1.3 - Design values of actions for use in accidental and seismic combinations of actions

Persistent and transient design situations	Permanent actions		Leading variable action (*)	Accompanying variable actions (*)	
	Unfavorable	Favorable		Main (if any)	Others
Accidental (*) (Eq. 6.11a/b)	$G_{k,j,sup}$	$G_{k,j,inf}$	A_d	$\psi_{1,1}$ or $\psi_{2,1}Q_{k,1}$	$\psi_{2,i}\ Q_{k,i}$
Seismic (Eq. 6.12a/b)	$G_{k,j,sup}$	$G_{k,j,inf}$	$A_{Ed} = \gamma_I A_{Ek}$	$\psi_{2,i}\ Q_{k,i}$	

The partial factors for actions for the ultimate limit states in the accidental and seismic design situations (expressions 6.11a to 6.12b) should be 1,0. ψ values are given in Table A1.1.

Table A1.4 - Design values of actions for use in combinations of actions

Persistent and transient design situations	Permanent actions		Variable actions (*)	
	Unfavorable	Favorable	Leading	Others
Characteristic	$G_{k,j,sup}$	$G_{k,j,inf}$	$Q_{k,1}$	$\psi_{0,i}\ Q_{k,i}$

ADNOC

Table A2-3: Strength Design Load Factors (For Buildings) as per BS EN 1990.

Type of Load	Primary Loads	Persistent and transient design case							Seismic	Accidental Case	
		Without wind			With wind						
		EQ 6.10 LL Leading (Unfavorable)	EQ 6.10 LL_R Leading (Unfavorable)	EQ 6.10 LL Leading (Favorable)	EQ 6.10 LL Leading (Unfavorable)	EQ 6.10 WL Leading (Unfavorable)	EQ 6.10 WL Leading (Favorable)	EQ 6.10 WL Leading (Unfavorable)	Seismic EQ 6.12a/b	Accidental EQ 6.11a/b LL Frequent	Accidental EQ 6.11a/b LL quasi perm.
Basic Load Combination		DL+LL	DL+LL_R+LL	DL+LL	DL+LL+WL	DL+WL	DL+WL	DL+WL+LL		DL+BL+LL	DL+BL+LL
Permanent Loads	DL	1.35	1.35	1.0	1.35	1.35	1.0	1.35	As per ASCE 7-16	1.0	1.0
	HY	1.35	1.35	1.0	1.35	1.35	1.0	1.35		1.0	1.0
	DS	1.35	1.35	1.0	1.35	1.35	1.0	1.35		-	-
Variable Loads	LL	1.5	1.05	1.5	1.5	-	-	1.05		0.5	0.3
	WL	-	-	-	0.9	1.5	1.5	1.5		-	-
	L_R	0	1.5	0	-	-	-	0		-	-
	CR	1.5	1.5	1.5	1.5	-	-	1.5		-	-
	TLss	0.9	0.9	0.9	-	-	-	-		-	-
Accidental Loads	BL	-	-	-	-	-	-	-		1.0	1.0
	E_Q (Both E_V & E_H)	-	-	-	-	-	-	-		-	-
Notes	1- Ψ0, Ψ1, Ψ2 factors used in the above table are based on building category B: office areas and however for crane/impact load these are considered for storage areas and hence values corresponding to category E are used. 2- Load cases represented in the load combinations provide a generic representation of Permanent, Variable and Accidental loads. All the required load cases with appropriate load factors shall be included in the combinations as per this table. 3- The load combinations should be expanded to include the lateral loads in both '+' and '-' directions.										

Table A2-4: Serviceability Load Factors (For Buildings) as per BS EN 1990.

Type of Load	Primary Loads	Persistent and transient design case							Seismic	Accidental Case (Note 4)	
		Without wind			With wind						
		EQ 6.14b LL Leading (Unfavorable)	EQ 6.14b LL_R Leading (Unfavorable)	EQ 6.14b LL Leading (Favorable)	EQ 6.14b LL Leading (Unfavorable)	EQ 6.14b WL Leading (Unfavorable)	EQ 6.14b WL Leading (Favorable)	EQ 6.14b WL Leading (Unfavorable)	Seismic	Accidental EQ 6.11a/b LL Frequent	Accidental EQ 6.11a/b LL quasi perm.
Basic Load Combination		DL+LL	DL+LL_R+LL	DL+LL	DL+LL+WL	DL+WL	DL+WL	DL+WL+LL		DL+BL+LL	DL+BL+LL
Permanent Loads	DL	1.0	1.0	1.0	1.0	1.0	-	1.0	As per ASCE 7-16	1.0	1.0
	HY	1.0	1.0	1.0	1.0	1.0	-	1.0		1.0	1.0
	DS	1.0	1.0	1.0	1.0	1.0	-	1.0		-	-
Variable Loads	LL	1.0	0.7	1.0	1.0	-	-	0.7		0.5	0.3
	WL	-	-	-	0.6	1.0	-	1.0		-	-
	L_R	0	1.0	0	0	-	-	0		-	-
	CR	1.0	1.0	1.0	1.0	-	-	1.0		-	-
	TLss	0.6	0.6	0.6	-	-	-	-		-	-
Accidental Loads	BL	-	-	-	-	-	-	-		1.0	1.0
	E_Q (Both E_V & E_H)	-	-	-	-	-	-	-		-	-

Notes

1- Ψ0, Ψ1, Ψ2 used in the above table are based on building category B: office areas and however for crane/impact load these are considered for storage areas and hence values corresponding to category E are used.
2- Load cases represented in the load combinations provide a generic representation of Permanent, Variable and Accidental loads. All the required load cases with appropriate load factors shall be included in the combinations as per this table.
3- The load combinations should be expanded to include the lateral loads in both '+' and '-' directions.
4- Blast load combinations shall be applicable for the Foundation stability checks only i.e. Foundation Bearing Pressure, Overturning, Sliding & Uplift.

Table A2-5: Strength Design Load Factors (For Process Structures/Pipe racks) as per BS EN 1990.

Type of Load	Primary Loads	Empty		Operating					Test			Erection[4]		Seismic
		With wind		Without wind			With wind		without Wind	with Wind		with Wind		
		EQ 6.10 WL Leading (Unfavorable)	EQ 6.10 WL Leading (Favorable)	EQ 6.10 LL_{op} Leading (Unfavorable)	EQ 6.10 LL Leading (Unfavorable)	EQ 6.10 LL_{op} Leading (Favorable)	EQ 6.10 LL_{op} Leading (Unfavorable)	EQ 6.10 WL Leading (Unfavorable)	EQ 6.10 Only dead (Unfavorable)	EQ 6.10 Dead (Unfavorable)	EQ 6.10 LL leading (Unfavorable)	EQ 6.10 (Unfavorable)	EQ 6.10 (Favorable)	Seismic
Basic Load Combination		DL+WL	DL+WL	DL+LL	DL+LL	DL+LL	DL+LL+WL	DL+WL+LL	DL	DL+WL	DL+LL+W	D+L+W	D+W	
Permanent Loads	DL	1.35	1.0	1.35	1.35	1.0	1.35	1.35	1.35	1.35	1.35	1.35	1.0	As per ASCE 7-16
	DL_{empty}	1.35	1.0	1.35	1.35	1.0	1.35	1.35	1.35	1.35	1.35	-	-	
	DL_{test}	-	-	-	-	-	-	-	1.35	1.35	1.35	-	-	
	DS	1.35	1.0	1.35	1.35	1.0	1.35	1.35	1.35	1.35	1.35	-	-	
	HY	1.35	1.0	1.35	1.35	1.0	1.35	1.35	1.35	1.35	1.35	1.35	1.0	
	ER	-	-	-	-	-	-	-	-	-	-	1.35	1.0	
	DY	1.35	1.0	1.35	1.35	1.0	1.35	1.35	-	-	-	-	-	
Variable Loads	LL	-	-	1.05	1.5	1.05	1.05	1.05	-	-	1.5	1.05	-	
	LL_{op}	-	-	1.5	1.05	1.5	1.5	1.05	-	-	-	-	-	
	TL_{AG}	-	-	1.5	1.05	1.5	1.5	1.05	-	-	-	-	-	
	TL_{F}	-	-	1.5	1.05	1.5	-	-	-	-	-	-	-	
	TL_{SS}	-	-	0.9	0.9	0.9	-	-	-	-	-	-	-	
	WL	1.5	1.5	-	-	-	0.9	1.5	-	0.9	0.9	0.9	0.9	
	CR	-	-	1.5	1.5	1.5	1.5	1.5	-	-	1.5	1.5	-	
Accidental Loads	E_Q (Both E_V & E_H)	-	-	-	-	-	-	-	-	-	-	-	-	

Notes

1- Ψ0, Ψ1, Ψ2 used in the above table are based on building category B: office areas and however for crane/impact load these are considered for storage areas and hence values corresponding to category E are used.
2- Load cases represented in the load combinations provide a generic representation of Permanent, Variable and Accidental loads. All the required load cases with appropriate load factors shall be included in the combinations as per this table.
3- The load combinations should be expanded to include the lateral loads in both '+' and '-' directions.
4- The erection load combinations are applicable for vessel supports and foundations.

Table A2-6: Serviceability Design Load Factors (For Process Structures/Pipe racks) as per BS EN 1990.

Type of Load	Primary Loads	Empty With wind	Operating					Test			Erection[4]		Seismic
			Without wind			With wind		without Wind	with Wind		with Wind		Seismic
		EQ 6.14b WL Leading	EQ 6.14b LL_{op} Leading (Unfavorable)	EQ 6.14b LL Leading (Unfavorable)	EQ 6.14b LL_{op} Leading (Favorable)	EQ 6.14b LL_{op} Leading (Unfavorable)	EQ 6.14b WL Leading (Unfavorable)	EQ 6.14b Only dead (Unfavorable)	EQ 6.14b Dead (Unfavorable)	EQ 6.14b LL leading (Unfavorable)	EQ 6.14b (Unfavorable)	EQ 6.14b (Favorable)	Seismic
Basic Load Combination			DL+LL	DL+LL	DL+LL	DL+LL+WL	DL+WL+LL	DL	DL+WL	DL+LL+W	D+L+W	D+W	
Permanent Loads	DL	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	As per ASCE 7-16
	DL_{empty}	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-	-	
	DL_{test}	-	-	-	-	-	-	1.0	1.0	1.0	-	-	
	DS	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-	-	
	HY	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	
	ER	-	-	-	-	-	-	-	-	-	1.0	1.0	
	DY	1.0	1.0	1.0	1.0	1.0	1.0	-	-	-	-	-	
Variable Loads	LL	-	0.7	1.0	0.7	0.7	0.7	-	-	1.0	0.7		
	LL_{op}	-	1.0	0.7	1.0	1.0	0.7	-	-	-	-	-	
	TL_{AG}	-	1.0	0.7	1.0	1.0	0.7	-	-	-	-	-	
	TL_{F}	-	1.0	0.7	1.0	-	-	-	-	-	-	-	
	TL_{SS}	-	0.6	0.6	0.6	-	-	-	-	-	-	-	
	WL	1.0	-	-	-	0.6	1.0	-	0.6	0.6	0.6	0.6	
	CR		1.0	1.0	1.0	1.0	1.0	-	-	1.0	1.0	-	
Accidental Loads	E_Q (Both E_V & E_H)	-	-	-	-	-	-	-	-	-	-	-	
Notes	1- Ψ0, Ψ1, Ψ2 used in the above table are based on building category B: office areas and however for crane/impact load these are considered for storage areas and hence values corresponding to category E are used. 2- Load cases represented in the load combinations provide a generic representation of Permanent, Variable and Accidental loads. All the required load cases with appropriate load factors shall be included in the combinations as per this table. 3- The load combinations should be expanded to include the lateral loads in both '+' and '-' directions. 4- The erection load combinations are applicable for vessel supports and foundations.												

APPENDIX 3: TYPICAL WIND PRESSURE CALCULATION

This is a sample calculation for illustrative purpose only to show the basic steps involved in wind load calculations as per ASCE and BS EN codes. Appropriate values for the parameters shall be used based on actual conditions of each PROJECT.

1.0 References:

a) AGES-SP-01-003: ADNOC Structural Design Basis Onshore Specification

b) ASCE 7-16: Minimum Design Loads and Associated Criteria for Buildings and Other Structures.

c) BS EN 1991-1-4: Actions on Structures- Part 1-4: General Actions -Wind Actions.

2.0 Basic Assumptions:

a) The wind speed is a 3 sec gust wind of 44.5 m/sec at 10m height in open field with 50-year return period.

b) The ASCE exposure is C: (open terrain with scattered obstructions that have heights generally less than 9.1m. this category includes flat, open country and grasslands).

c) The BS-EN terrain category is type II: (areas with low vegetation such as grass and isolated obstacles (tree, buildings) with separations of at least 20 obstacle heights).

d) Example is for a typical building structure.

e) References to sections/equations of the above codes are shown inside parenthesis.

3.0 ASCE 7-16 Method:

3.1 Basic Wind Speed for Strength Design (load factor for this wind load is 1.0)

Basic wind speed corresponding to a 3-sec gust wind at 10m height for a Category III risk (return period 1700 years) is as given in the above ADNOC Specification (Table 10-2) as follows:
V_b = 60.2 m/sec.

3.2 Velocity Pressure

$q_Z = 0.613\ K_Z.K_{Z1}.K_d.K_e.V_b^2$ (Eq. 26.10-1)

V_b = basic wind speed = 60.2 m/sec

K_{Z1}= topography factor = 1.0 (Sec 26.8.2)

K_d = wind directionality factor for buildings =0.85 (Sec 26.6)

K_e = ground elevation factor, for 100m above sea level =1.0 (Sec 26.9)

K_Z = velocity pressure exposure coefficient for exposure C (Sec 26.10.1)
in accordance with Table 26.10-1 of ASCE 7-16.

Substituting for values of Vb, Kz1, Kd, and Ke in equation 26.10-1 above, a new equation can be reached for values of velocity pressures as a function of exposure coefficient KZ as follows:

q_Z = 0.613 x Kz x 1.0 x 0.85 x 1.0 x 60.2^2 x 1/1000 = $\underline{1.89\ K_Z}$ kN/m^2 Eq. AA

Inserting the appropriate values of Kz from Table 26.10-1 of ACSE into Eq. AA, gives values of velocity pressure, qZ, in a tabular format as follows:

Table A3-1: Values of Ultimate Wind Pressures, q_Z (kN/m^2) in accordance with ASCE 7-16

Height above Ground Level, z (m)	Kz	q_Z (kN/m^2)
0-4.6	0.85	1.61
6.1	0.90	1.70
7.6	0.94	1.78
9.1	0.98	1.85
12.2	1.04	1.97
15.2	1.09	2.06
18.0	1.13	2.14
21.3	1.17	2.21
24.4	1.21	2.29
27.4	1.24	2.34
30.5	1.26	2.38
36.6	1.31	2.48
42.7	1.36	2.57
48.8	1.39	2.63
54.9	1.43	2.70
61.0	1.46	2.75
76.2	1.53	2.89
91.4	1.59	3.00
106.7	1.64	3.10
Note: According to ASCE7-16, the wind load is determined in conjunction with a gust-effect factor shown as 'G' factor in Sec 26.11. This factor depending on the type of structure needs to be considered when calculating wind loads for each structure.		

4.0 BS EN 1991-1-4 Method:

4.1 Basic Wind Speed

Basic wind speed corresponding to a 10-min mean wind velocity at 10m height as given in the above ADNOC Specification (Table 10-2) is as follows:
V_{bo} = 31.2 m/sec.

4.2 Peak Velocity Pressure

$q_p\ (z) = Ce(z)\ q_b$ Eq. (4.8)

$q_b = ½\ \rho\ V_b^2$ Eq. (4.10)

$V_b = C_{dir}\ .\ C_{season}\ .\ V_{b0}$ Eq. (4.1)

Where Ce(z) is the exposure factor, ρ is the air density, and

ρ = 1.25 Kg/m^3

C_{dir} = 1.0 (values less that unity may be considered for the directional factor for various wind directions, reference shall be made to the above BS EN code).

C_{season} = 1.0

Therefore:
V_b = 1.0 x 1.0 x 31.2 = 31.2 m/s

and

$q_p\ (z) = Ce(z) \times ½ \times 1.25 \times 31.2^2 = Ce(z) \times 608.4\ N/m^2 = 0.61\ Ce(z)\ kN/m^2$ Eq. BB

Values of Ce(z) for flat terrains are illustrated in Fig (4.2) of BS EN 1991-1-4 as a function of height above the terrain and a function of terrain category. Using this figure, values of Ce(z) can be obtained for different heights/levels above the ground for terrain category II. Values of Ce(z) can then be substituted in Eq. BB to give values of peak velocity pressures. This is shown in a tabular format as follows:

Table A3-2: Values of Peak Velocity Pressure, q_z (kN/m^2) in accordance with BS-EN 1991-1-4

Height above Ground Level, z (m)	Ce(z)	q_p (z) (kN/m^2)
5.0	2.00	1.22
10.0	2.34	1.43
15.0	2.57	1.57
20.0	2.81	1.71
25.0	2.96	1.81
30.0	3.08	1.88
35.0	3.19	1.95
40.0	3.29	2.00
45.0	3.38	2.06
50.0	3.46	2.11
55.0	3.52	2.15
60.0	3.58	2.18
65.0	3.64	2.22
70.0	3.70	2.26
75.0	3.75	2.29
80.0	3.81	2.32
85.0	3.85	2.35
90.0	3.90	2.38
95.0	3.95	2.41
100.0	4.00	2.44

APPENDIX: 4 ADDITIONAL SPECIFIC REQUIREMENTS - SPECIFIC TO A PARTICULAR APPLICATION OR BUSINESS UNIT (LIKE OFFSHORE OR PETROCHEMICAL)

Not Applicable.

APPENDIX: 5 SPECIFIC LESSONS LEARNT

Not Applicable.