Structural Design
Philosophy and Acceptance Criteria

CO_2 Capture Facility

Kårstø, Norway

Bechtel Proprietary and Confidential

Rev.	Date	Reason for Revision	By	Check	App	App	Client
1	26 Nov 08	Incorporated Comments from Fichtner per Review Sheet No.10112936-S-PBFI-N-0146	MZ	RWAS	BTR	WRE	
0	10 Nov 08	Issued for Approval	MZ	RWAS	BTR	WRE	

Bechtel Power Corporation	Job No. 25474	
	Document No. 25474 - 000 - 30Y -S01G - 00001	Rev. 1
	PAGE 1 of 19	

GASSNOVA	Project No. - Originator - Disc Code - Doc Type - Serial No. 10112936 - PB - N - TED - 0001

Contents

Structural Design Philosophy and Acceptance Criteria

1.0 INTRODUCTION

The criteria set forth in this document govern structural (steel) designs for the FEED study CO_2 Capture and Compression (CCC) Plant at Kårstø. These criteria were written after the review of Exhibit E6.1 [Ref 2.3.2] of the contract was performed and concluded that no comments needed to be made with regards to that document.

2.0 GOVERNING CODES, REGULATIONS, AND REFERENCE DOCUMENTS

Unless specifically stated otherwise, the design of steel structures shall be based on the applicable portions of the following codes, regulations, project specifications, and reference documents. The editions of the codes and standards referred to in the design criteria are those in effect at the time of contract award, unless noted otherwise. In accordance to the requirements of Exhibit Appendix E1.2 [Ref 2.3.13] the following precedence is established:

1. Norwegian Law and statutory requirements
2. EC-directives referred to in the Norwegian regulations
3. Project Design Basis and Exhibit E
4. Client Standard and Documents for Kårstø and Interfaces
5. NORSOK Standards
6. Norwegian and European harmonized standards

2.1 CODES

2.1.1 IBC 2006 – International Building Code

2.1.2 NS-EN 1990 – Eurocode – Basis of structural design

2.1.3 NS-EN 1991 – Eurocode 1 – Actions on structures

- * Part 1-1: General Actions – Densities, self-weight, and imposed loads for buildings
- * Part 1-2: Actions on structures exposed to fire
- * Part 1-3: General Actions – Snow loads
- * Part 1-4: General Actions – Wind actions
- * Part 1-5: General Actions – Thermal actions
- * Part 1-7: General Actions – Accidental actions
- * Part 3: Actions induced by cranes and other machinery

2.1.4 NS-EN 1993 – Eurocode 3 – Design of steel structures

- Part 1-1: General Rules and rules for buildings
- Part 1-2: General Rules – Structural fire design

2.1.5 NS-EN 1998 – Eurocode 8 – Design of structures for earthquake resistance

- Part 1-1: General Rules – Seismic actions and general requirements for structures
- Part 3: Towers, masts, and chimneys

2.1.6 NS 3420 – Specification texts for building, construction, installations

2.1.7 NS 3464 – Execution of steel structures. General rules and rules for buildings

2.2 REGULATIONS

2.2.1 H-2036-KD – Internal Control Regulation, 22 March 1991 (Ministry of Municipal Affairs and Labor) – Regulations relating to systematic health, environmental, and safety activities in enterprises

2.2.2 The Planning and Building Act No. 77 of 14th June 1985, with amendments in force 1st April 2005

2.3 STANDARDS AND SPECIFICATIONS

2.3.1 Exhibit E0 – Design Basis (Doc. No.10112936-FI-B-CON-0051)

2.3.2 Exhibit E6.1 – General Requirements Civil, Structural & Architectural (Doc. No. 10112936-FI-B-CON-0120)

2.3.3 Exhibit E9 – Battery Limits (Doc. No. 10112936-FI-B-CON-0150)

2.3.4 TR1303 – Kårstø Design Data Document

2.3.5 TR1319 – Structural Steel and Aluminium Requirements for Kårstø Process Plant

2.3.6 TR1329 – Civil Specification for Kårstø Plant

2.3.7 TR 2080 – Metocean Design Basis

2.3.8 NORSOK Standard C-002 Edition 3, June 2006, Norwegian Architectural components and equipment

2.3.9 Exhibit E8.1 – HSE Requirements (Doc. No. 10112936-FI-B-CON-0140)

2.3.10 NORSOK Standard N-003 Edition 2, Sept 2007, Norwegian Oil Industry Association

2.3.11 TR1635 Active Fire Protection at Kårstø

2.3.12 TR1636 Specification for passive fire protection at Kårstø

2.3.13 Exhibit Appendix E1.2 – Design Codes and Standards (Doc. No. 10112936-FI-B-CON-0242)

2.3.14 Materials Technology Materials Selection Report (25474-000-G65-GEN-00001) [LATER]

2.3.15 Fire and Explosion Strategy (25474-000-30Y-U01G-00001) [LATER]

2.3.16 Design Philosophy and Acceptance Criteria for Civil Works (25474-000-30Y-C01G-00001)

2.4 MATERIALS

2.4.1 NS-EN 10025 – Hot rolled products of structural steels

2.4.2 EN 10210 – Hot Finished Structural Hollow Sections of Non-alloy and Fine Grain Structural Steels

2.4.3 EN ISO 1461 – Hot-dip galvanized coatings on fabricated iron and steel articles

2.4.4 EN ISO 4032 – Hexagon nuts, style 1: Product grades A and B

2.4.5 EN ISO 4014 – Hexagon head bolts: Product grades A and B

2.4.6 EN 1011 - Welding – Recommendations for Welding of Metallic Materials

3.0 STEEL STRUCTURES WITHIN THE CCC BATTERY LIMIT

3.1 PRE-ENGINEERED STRUCTURES

3.1.1 General

The CEMS Building, Storage Sheds, and Equipment Skids are miscellaneous unmanned steel structures and frames provided for housing or supporting equipment and instrumentation, and storing non-chemical items.

3.1.2 Design Methodology

All buildings and structures shall be designed with regard to the need for inspection, maintenance, cleaning and repair [Exhibit E6.1 Ref. 2.3.2].

3.2 SUPPORT STRUCTURE FOR MODIFIED HRSG STACK

3.2.1 General

The Site's support structure for modified HRSG stack is an unmanned steel structure. This structure provides strength and stability for the existing HRSG stack as the stack is modified to introduce a new alternative flue gas duct path. The steel structure also provides support of the new ductwork plenum that is attached to the modified HRSG stack.

3.2.2 Design Methodology

The support structure design shall be based on methods prescribed in EN 1990 and EN 1993-1. A 3-dimensional frame structure shall be employed to support a large ductwork plenum and the upper portion of the HRSG steel stack. Moment-resisting trusses shall transfer gravity loads and overturning moments from the stack to the frame's columns. Along with these trusses, a single braced bay on the southern side of the frame shall transfer all lateral and longitudinal horizontal loads (from wind, temperature, etc.) into the existing foundation as well as additional footings for columns bearing outside the HRSG stack foundation mat. Extra capacity shall be provided by fixed supports, thus keeping a reserve for unforeseen (accidental)/future longitudinal horizontal loads. For the structural steel design, an analytical model shall be constructed using "beam" elements to represent beams and columns, and "truss" elements to represent vertical and horizontal bracing (members with axial load only). In order to ensure a ductile behavior (and extra capacity) for accidental horizontal loads, the model shall have fixed supports. A code check is performed in accordance with NS-EN 1993 to provide a general design of the overall structure. Joint displacements are determined to ensure compliance with deflection criteria, and support reactions are determined for foundation design purposes.

3.3 DUCTWORK

3.3.1 General

The Site's ductwork is supported by an unmanned steel structure that shall be designed to support the flue gas ductwork extending from the modified HRSG stack to the blowers/flue gas absorbers. The steel structure shall also support ancillary dampers, a fogger injection system, plus small piping and instrumentation for the flue gas system, and electrical cable tray for multiple project purposes. Access shall be provided to the dampers and fogger system by ladders, platforms, and walkways. Duct supports shall consist of long-span prefabricated bridges and support towers that allow for the duct to span across existing buildings and roads while maintaining clearances.

3.3.2 Design Methodology

The ductwork support structural steel design shall be based on methods prescribed in EN 1990 and EN 1993-1. For the structural steel design, an analytical model shall be constructed using "beam" elements to represent beams/truss chords and columns, and "truss" elements to represent vertical and horizontal bracing (members with axial load only). The duct support structure shall be designed to withstand associated dead, live, operating, and environmental loads. Manufactured expansion joints shall be installed periodically to provide thermal isolation of modular duct sections, and ducts shall be supported in such a way to allow thermal movements without over-constrained loads. The use of low-friction support bearings may be considered to reduce friction loads [Section 4.6]. In order to ensure a ductile behavior (and extra capacity) for accidental horizontal loads, the model shall have fixed supports at the base of the superstructure. A code check is performed in accordance with NS-EN 1993 to provide a general design of the overall structure. Joint displacements are determined to ensure compliance with deflection criteria, and support reactions are determined for foundation design purposes. Subsequent hand calculations are performed to determine the effects of contingency live loads on the critical pipe support and catwalk beams.

3.4 PIPE RACK

3.4.1 General

The Site's pipe rack is an unmanned steel structure, and shall be designed to support multiple levels of piping along with electrical cable tray extending from the battery limit and servicing the test facility. The structure shall be prefabricated and delivered in modular sections. The pipe rack shall be designed to withstand associated dead, live, and environmental loads. In addition, access and egress for a catwalk located on the uppermost level will be designed for personnel to access equipment, piping, and instrumentation.

3.4.2 Design Methodology

The following design loads and requirements are extracted from Section 4.3.1 of TR 1319 [Ref. 2.3.5]:

Future piping shall be considered in design of pipe rack columns.

If no information is available, pipe rack supporting pipe of up to 300 mm diameter shall be designed for a vertical uniformly distributed dead load of 2.5 kN/m^2 (operating load) over full width of the rack, per level. For larger pipe sizes, the loads shall be calculated. This loading allows for pipe deadweight, contents (normal operating or hydro test), and insulation.

A contingency live load of 20 kN shall be applied to the top of all main columns unless a more defined loading is available.

Unless more defined loading is available, pipe racks shall be designed for a thermal load of 15% of the piping load (i.e., 0.375 kN/m^2) applied in the longitudinal direction for each pipe-carrying support beam. This load shall not be considered to transfer to the foundations. In addition, a lateral thermal load of 10 kN shall be applied at mid-span of the side steel for each bay and at each level. The structure shall also be checked for anchor loads. Unless more defined loading is available, anchor loads shall be taken as 5% of the total piping load between anchor bays. This load shall be transferred to the foundations.

Longitudinal piping thermal loads and anchor loads shall not be considered concurrently.

Longitudinal wind loads may be neglected. The following transverse wind load shall be taken for the projected area of pipes [Ref. 2.3.5]:

Width of pipe rack	<4 m	>4m <6 m	>6m
Height of area subject to wind loading	1.5 m	2.0 m	2.5 m

Except at fixed points, all piping shall be considered as being supported by sliding supports at each tier or transverse beam. The following friction coefficients shall be used [Ref. 2.3.5]:

Surface	Friction Coefficient
Steel/Steel	0.33
Stainless Steel/Stainless Steel	0.15
Teflon/Teflon	0.08

Anchor bays shall be designed for loads from supports between pipe expansion joints. Structural arrangement including location of expansion joints and anchor bays in Superstructure shall suit their locations in piping.

Braced bays shall transfer all longitudinal horizontal loads from wind, temperature, pipe anchors, etc., to the foundations. Extra capacity shall be provided by fixed supports, thus keeping a reserve for unforeseen (accidental)/future longitudinal horizontal loads. For the structural steel design, an analytical model shall be constructed using "beam" elements to represent beams and columns, and "truss" elements to represent vertical and horizontal bracing (members with axial load only). In order to ensure a ductile behavior (and extra capacity) for accidental horizontal loads, the model shall have fixed supports. A code check is performed in accordance with NS-EN 1993 to provide a general design of the overall structure. Joint displacements are determined to ensure compliance with deflection criteria, and support reactions are determined for foundation design purposes. Subsequent hand calculations are performed to determine the effects of contingency live loads on the critical pipe support and catwalk beams.

3.5 COMPRESSOR BUILDING

3.5.1 General

The Compressor Building shall be a pre-engineered building capable of housing equipment such as the compressor, storage drums, and pumps. Acoustical walls , roof insulation and acoustical louvers shall be provided for noise reduction. Lay down areas must be accounted for to enable easy handling/transportation during maintenance and repair. Overhead cranes or hoists must be provided as required for maintenance.

3.5.2 Design Methodology

Requirements stated in the general requirements for civil, structural and architectural shall be met [Ref. 2.3.2]. Following that basis, the support structure design shall be based on methods prescribed in EN 1990 and EN 1993-1. Internal and external explosions shall be taken into account.

3.6 FLUE-GAS BLOWER ENCLOSURES

3.6.1 General

The flue-gas blower enclosures shall be buildings with flat roofs capable of housing the blowers and ancillary equipment. The enclosures are intended for noise reduction.

3.6.2 Design Methodology

Requirements stated in the general requirements for civil, structural and architectural shall be met [Ref. 2.3.2]. The support structure design shall be based on methods prescribed in EN 1990 and EN 1993-1.

3.7 CONTROL/STORAGE/WORKSHOP BUILDING

3.7.1 General

The control/storage/workshop building shall be a multi-story structure with a flat roof with the dual purpose of housing control equipment, offices, meeting room, consumable and spare part (non-chemical) storage items, document storage room, and mechanical and other workshop areas. The building shall house the Central Control Room (CCR) and rest room, including the kitchen/canteen facilities. The CCR and other rooms for installation of electrical/instrumentation cabinets shall be designed with false floor.

3.7.2 Design Methodology

Requirements stated in the general requirements for civil, structural and architectural shall be met [Ref. 2.3.2]. The structural steel design shall be based on methods prescribed in EN 1990 and EN 1993-1. The CCR shall be designed to withstand accidental loads from explosions and earthquakes.

3.8 ELECTRICAL BUILDING

3.8.1 General

The electrical building shall be a structure with a flat roof and an elevated concrete floor with the purpose of housing the electrical switchgear room. Switchgear and other electrical equipment will be located on the elevated floor while a cable spreading room will occupy the ground floor.

Oil-filled transformers shall be supported on reinforced concrete foundations located outside the building, and shall be separated by a fire wall. The foundation supporting the transformers shall incorporate transformer rails (when applicable) for ease of transportation and placement. Transformers shall be fixed to the foundations with anchor bolts. Each transformer foundation shall be provided with slope and raised borders, enclosing an oil pit in which the oil content of the transformer can be carried in the event of an oil leak. Above the oil pit a minimum 20 cm thick gravel layer on a steel grating shall be provided. The oil pits shall drain into a central oil collecting pit with integrated oil separator. The oil collecting pit shall be sized to hold the oil capacity of the largest transformer [Ref 2.3.6].

3.8.2 Design Methodology

Requirements stated in the general requirements for civil, structural and architectural shall be met [Ref. 2.3.2]. The structural steel design shall be based on methods prescribed in EN 1990 and EN 1993-1. The reinforced concrete transformer foundation shall be designed in accordance with the requirements of the Design Philosophy and Acceptance Criteria for Civil Works [Ref. 2.3.16].

3.9 TANK BUND AREA

3.9.1 General

The bund area shall be a reinforced concrete structure providing a diked area for chemical storage. The area shall be capable of collecting the larger of 110% of the inventory of the largest tank within the bund or 25% of the volumes of all the tanks within the bund [Ref. 2.3.16].

3.9.2 Design Methodology

The reinforced concrete structure shall be designed in accordance with the requirements of the Design Philosophy and Acceptance Criteria for Civil Works [Ref. 2.3.16].

4.0 DESIGN LOADS

4.1 PERMANENT LOADS (D)

Permanent loads are also called dead loads. They shall consist of the weight of all materials of construction incorporated into each structure, including, but not limited to, floors, stairways, finishes, and other similarly incorporated architectural and structural items, plus piping and fixed equipment loads as per preliminary information.

The design dead load criterion specific for steel structures in this facility is:

Main Steel (office areas)	2.5 kN/m^2 minimum [Ref. 2.1.3]
Main Steel (supporting piping/cable tray/raceway loading)	2.4 kN/m^2 minimum
Miscellaneous Steel (otherwise)	1.2 kN/m^2 minimum
Pipe Rack Steel	Section 3.4
Ductwork Loading (multiplied by surface area of liner plate)	1.75 kN/m^2 minimum (including liner plate, external and internal structure, insulation, and lagging)

4.2 LIVE LOADS (L AND L_o)

4.2.1 General

Live loads (L) are those loads produced by the use and occupancy of each structure and do not include construction or environmental loads such as wind loads, seismic loads, snow loads, rain loads, flood loads, or dead loads. In the absence of any load, EN 1991-1-1 may be referenced. No reductions in live load shall be considered. In loading combinations including wind or seismic, the live loads shall be limited to those occurring during the plant operation (L_o). The operating live loads shall be established in accordance with the layout and mechanical requirements, applied simultaneously with the wind loads. These loads may vary, depending on the function of the specific area and as per actual vendor/manufacturer drawings.

4.2.2 Minimum Live Loads for Design

In general, steel structure design shall be based on the given reactions transferred from the structure being supported. In the absence of those values, the design live load criterion specific for steel structures in this facility is:

Steel Grating Floors, Platforms and Walkways, Stairways and Landings	5 kN/m^2 minimum uniform load In addition a concentrated load of 13.3 kN applied concurrently to supporting beams to maximize moment and shear (not carried to columns)
Platforms and Walkways (General Access Only)	3 kN/m^2 minimum uniform load In addition a concentrated load of 4.5 kN applied concurrently to supporting beams to maximize moment and shear (not carried to columns)
Catwalks (Pipe Rack only)	3 kN/m^2 minimum uniform load In addition a concentrated load of 4.5 kN applied concurrently to supporting beams to maximize moment and shear (not carried to columns)
Handrails	1 kN/m^2 in horizontal direction [Ref. 2.3.4]

The following concentrated load shall also be used to account for unforeseen construction or operating conditions. This load is applied in the vertical direction, but need not be carried to columns:

Concentrated load at mid-span of beams and girders	13.3 kN minimum or as required for construction and plant operation

4.2.3 Impact on Live Loads for Design of Maintenance Facilities

Impact factors shall be applied as follows [Section 4.3.3, Ref. 2.3.5]:

Item Supported	Vertical	Lateral	Longitudinal
Traveling cranes and hoists	25%	10%	5%
Davits and beams as hitching points	25%	10%	-

General purpose davits shall be designed for twice the lift load or 5kN, whichever is greater. Trolley beams shall be of HEB or IPE sections.

Where several maintenance loads act, consideration shall be limited to two crane or trolley loads acting simultaneously and to one tube bundle pulling load.

4.3 WIND LOADS (W)

All structures and equipment mountings shall be designed for wind loading using the following parameters from EN 1991-1-4:

- Basic Wind Speed: V_b= 43 meters/second [Ref. 2.3.16]
- Terrain Category: Type 0 [Ref. 2.3.16]

The pipe rack and equipment supporting structure shall be designed for 20% extra wind forces to allow for future extensions. Fatigue loading shall be considered for equipment and structures subject to vortex-shedding excited vibrations [Ref. 2.3.4].

4.4 SEISMIC LOADS (E)

The design seismic load criteria are as follows [Ref. 2.3.16]:

- Design Code/Standard Reference — IBC 2006-Section 1613
- Occupancy Category — II
- Mapped maximum considered earthquake - spectral response acceleration at short period (475 years), Ss — 0.07g [Ref. 2.3.4]
- Site Class — B
- Seismic Design Category — A

4.5 SNOW LOADS (S)

Structures shall be designed for a snow load of 2.0 kN/m^2 [Section 2.10, Ref. 2.3.7].

4.6 THERMAL LOADS (T)

Thermal and friction loads are loads caused by the thermal movement of equipment or piping, or by temperature differentials or gradients across structural elements. Thermal loads shall be defined as forces acting due to the operation and natural temperature difference from an ambient temperature of 10°C, and temperature differences in parts of structural members [Section 5.7.8, Ref. 2.3.4]. See Section 3.4 for pipe rack thermal loads. Industry-accepted methods, such as the use of manufactured low-friction bearings, may be employed to reduce friction loads.

4.7 OPERATING AND EXCURSION PRESSURE LOADS (P)

Ductwork and supporting structures shall be designed for the effects of the governing positive and negative pressures, as determined by flow modeling analyses of the ductwork system for operating and transient conditions.

4.8 ACCIDENTAL LOADS

Accidental loads are loads caused by abnormal operation or technical failure [Section 5.7.13, Ref. 2.3.4]. They include fires, explosions and impacts due to vehicles or fragments . Structural steel work shall be designed to withstand explosion and fire loads specified as Design Accidental Loads (DAL).

Explosion reflective pressure shall be 10 kPa for a duration of 120 milliseconds [Ref. 2.3.1]. The following table demonstrates DAL scenarios to be used [Ref. 2.3.5]:

Scenario	DAL Combination of Effects
1	Explosion Pressure
2	Explosion Pressure + Thermal (Jet Fire)
3	Explosion Pressure + Fragment Impact + Thermal (Jet Fire)

4.9 TEMPORARY LOADS

The following temporary loads shall be considered during design:

- Test loads, such as hydrostatic pressure (liquid loads) in pipes and vessels, crane or hoist test lift. Under a temporary phase hydro test, superstructure may require shoring under beams, but hydro test load shall not decide sizes of sections [Section 4.3.2, Ref. 2.3.5].
- Transient loads such as those from stop valves and water hammer.
- Construction erection/installation loads such as those caused by lifting and jacking.
- Maintenance loads arising during maintenance work when the plant is not in operation [Section 5.7.11, Ref. 2.3.4].

- For heat exchangers a horizontal force shall be applied equal to 300% of the weight of bundle if loosening devices are to be used. If no loosening device is to be used, force shall be taken as 150% of the weight of bundle with minimum value = 10kN [Section 4.3.2, Ref. 2.3.5].

4.10 TRANSPORTATION LOADS

Transportation loads caused by transport, load off and installation operations shall be considered. Fatigue loads shall include loads caused by vibrating machinery, hoisting, equipment, fluid vibration in pipes and wind oscillations. Preassembled structures and units shall withstand the actual transportation loads on sea and road. Temporary bracings and internal sea fastening of pipes, valves and equipment may be required and shall be prepared for safe removal after final installation of the unit. Preassembled modular sections shall be handled, loaded, off-loaded, and erected as modules.

4.11 OTHER LOADS

4.11.1 Liquid Loads

Liquid loads shall include weight of contents in pipes and vessels during operation and testing.

4.11.2 Fabrication Loads

The effects of errors, e.g. geometric deviations or defects exceeding the tolerance limits, shall be considered in the design [Ref. 2.3.5].

4.11.3 Loads due to Settlement of Foundations

Loads on the structure as results of uneven settlement shall be considered. Local reaction forces on the structure during installation shall be considered.

5.0 DESIGN BASIS

5.1 GENERAL

Steel structures shall be designed in conjunction with methods described in EN 1990 and EN 1993-1-1. Furthermore, steel structures shall be designed and detailed in conjunction with the technical requirements of TR 1319 [Ref. 2.3.5].

5.2 LOAD COMBINATIONS AND LIMIT STATES

Steel structure designs shall be in accordance with the general rules given in EN 1990. EN 1993 deems these requirements satisfied when the following are applied together:

- Limit-state design in conjunction with partial factor method in accordance with EN 1990
- Loads in accordance with EN 1991
- Combination of loads in accordance with EN 1990
- Durability, and serviceability in accordance with EN 1993

5.3 STRUCTURAL RELIABILITY

The reliability class shall be associated with consequence of failure (loss of life, environmental damage, and loss of asset). The following reliability classes apply:

- RC3: High consequence of failure – Applies to steel structures supporting equipment/piping containing hydrocarbons, structures that can harm hydrocarbon piping/vessels by failure, and all substations and manned buildings. This includes pipe rack, compressor building, control/storage/workshop building, tank bund areas, absorber tower, stripper.
- RC2: Medium consequence of failure – Applies to remaining structures.

The factor applicable to actions for reliability differentiation, K_{F1}, shall be used as 1.0 for reliability class RC2, and 1.1 for reliability class RC3.

5.4 DEFLECTIONS

5.4.1 Vertical

Limiting values for vertical live load deflections of structural elements are [Ref. 2.3.5}:

• Cantilevers	L/300
• Secondary Beams, Purlins	L/200
• Floor Beams	L/400
• Beams for Pipe Racks	L/400
• Vessel Support Beams	L/800
• Monorail and Hoist Beams (without impact)	L/600
• Grating, Floor Plate	L/200 or 6 mm

Where L is span length

5.4.2 Horizontal

Limiting values for horizontal deflections at the tops of columns are [Ref. 2.3.5]:

• Columns	H/300
• Frames	H/300
• Pipe Racks	H/150
• Steel Braced Building Frames	H/200
• Steel Moment-Resisting Building Frames	H/120
• Masonry Walls	H/400
• Siding Support Members, Girts	L/180

Where H is height, L is span length

6.0 CONSTRUCTION MATERIALS

6.1 STRUCTURAL AND MISCELLANEOUS STEEL

All structural and miscellaneous steel and accessories shall be in accordance with the requirements established in TR 1319 [Ref. 2.3.5]. Steel shall be used for the design and construction of structural members, connections, and "outfitting" structures (or miscellaneous members). Aluminum is not to be used for these items. All steel designed shall conform to EN 10025. In addition, square and round hollow structural tubing shall conform to EN 10210. Steel for structures shall meet the requirements in NS 3472 and NS 3464, and documented by material certification as in accordance with EN 10204. Preferred steel grades are shown in the table below:

Location	Grade
Main members in modules and lift beams	S355J2+N
Secondary steel, angle bracing Misc pipe supports and site erected steelwork Outfitting structures (ladders, handrail etc.)	S235JR
Square hollow sections	S355J2+N

Fabrication of steel structures shall comply with NS3464 and all relevant project specifications. All outdoor and indoor structural and miscellaneous steel shall be coated in accordance with the Materials Selection Report [Ref. 2.3.14]. Edges of plates and structural items, which are intended to be coated, shall be rounded to approximately 2 mm radius [Ref. 2.3.5].

In addition, the following considerations shall also be made [Ref. 2.3.5]:

- Members shall have a size not less than the following -
  - 120 mm deep for channels and I beams, 50 x 50 x 6 mm for angles, 8 mm thick for connecting plates.
  - Structures permanently exposed to the elements shall have a minimum flange thickness of 6 mm.
- Bracing shall be arranged so as to minimize torsion, and arranged symmetrically about the resultant line of force. Connections shall be arranged so that the centroid lies on the resultant of the forces they are intended to resist. Where the above condition cannot be achieved, members and connections shall be designed considering any local bending due to the eccentricity of these forces.
- Bolted connections shall be either slip-critical or direct bearing joints assembled with EN ISO 4014 high strength structural bolts, 22 mm diameter, with heavy semi-flushed hexagon nuts (EN ISO 4032). Hot-dip galvanized plain washers for high strength structural bolting and ordinary bolting shall conform to ISO 7415. Tapered washers shall conform to ISO 7416. Slip critical joints shall include two hardened flat washers, one direct tension indicator (DTI) washer and one 8 mm washer to prevent the grinding of the DTI against the head of the bolt. All bolts, nuts, and washers shall be hot-dip galvanized in accordance with EN ISO 1461. Two bolts shall be the minimum used for any one connection.

- Welded connections:
  - All welding shall utilize low hydrogen electrodes in accordance with EN 1011.
  - Weld dimensions and design for steel structures shall be in accordance with NS 3472.
  - The majority of welded connections are to be performed "off-site" or in a fabrication shop setting. Therefore, the preference for "on-site" connections made during the erection and installation of structures are bolted connections [Ref. 2.3.5].

- Floor Plate:
  - Type: Four-way safety tread (commercial grade)
  - Minimum Thickness: 8 mm
  - Finish: Hot-dip galvanized (EN ISO 1461) after fabrication, unless noted otherwise.

- Grating:
  - Grating shall be serrated having main bars 30mm (min) x 3mm with 33 mm spacing [TR 1319 Ref. 2.3.5] for outdoor use conforming to EN 10025 Grade S275JR.
  - Finish: Hot-galvanized (EN ISO 1461)

- Handrail and posts:
  - 40 mm nominal diameter standard weight, steel pipe conforming to EN 10210, Grade S235JR for handrail, and made of weldable material with minimum yield strength of 50 ksi for posts. Handrails and posts shall be hot-dip galvanized after fabrication.
  - Hand railing with toe plates shall enclose all platform areas and stairways and be provided around floor openings for permanent equipment when the clearance is 300 mm or more [Ref. 2.3.5]. When hand railing is prefabricated, welded connections shall be preferred.
  - Steel pipe used for handrail to be ventilated with holes indicated on shop drawings. Holes are to be seal with coating prior to installation.

- Platforms and handrailing (additional requirements from TR 1319, Ref. 2.3.5):
  - Platform floors shall be of either welded steel plate flooring or steel grating. Platform framing shall be arranged to support plate flooring on four sides and steel grating on two sides. The spacing of members shall be based on flooring designed to support live load as specified in TR1303 [Ref. 2.3.4]. The steel plates shall be adequately supported by stringers of angles or similar. Joints of platform floor plate and handrails shall be welded. All connections shall be welded.
  - Steel grating transverse bars shall be twisted square bars press welded to the top of main bars at maximum 100 mm spacing. All edges and perimeters of openings and cut-outs shall be fitted with a binding bar of the same size as the

main bars. The binding bar shall be substituted by a 100 mm high toe plate when the clearance at the grating edge is between 50 and 300 mm.
- Clearance of more than 300 mm requires handrail with toe plate.
- Grating shall be fitted with additional round bars between main bars sufficient to prevent a ball of 15 mm diameter to pass through, fastened with pinned screws from the upper side of the grating. The punched hole pattern shall give an antiskid surface. The holes shall have a size to prevent a ball of 15 mm diameter to pass through.

- Stairs [Section 4.4, Ref. 2.3.5]:
  - Stair treads shall be hot-dip galvanized, serrated welded bar grating with cast iron abrasive nosing, having a minimum width of 1000 mm, and conforming to EN 10025 Grade S235JR. Treads fasteners shall also be hot-dip galvanized. Stairway treads shall have a minimum depth of 230 mm and a preferred rise of approximately 190 mm. The angle with a horizontal line shall be between 36.5° and 38°.
  - The distance between two treads can also be calculated according to the following formula:

    $2h + s = 630$ mm, where
    h = the vertical rise of treads and
    s = the depth of treads
  - Minimum headroom clearance shall be 2300 mm and minimum perpendicular clearance shall be 1800mm.

- Ladders [Section 4.4, Ref. 2.3.5]:
  - Ladders shall conform to EN 10025 Grade S275JR.
  - The vertical distance between landings shall not exceed 6000 mm. The ladders shall preferably be arranged for side exit, and if the ladder height exceeds 6.0 m the ladder shall be staggered.
  - Safety cages shall be provided for ladders higher than 2500 mm. Where ladders starts from a level higher than ground level, and are positioned close to the perimeter of the structure, the safety cages shall be designed in such a way that the risk for falling to a lower level is minimized. Where the bottom of the ladder terminates at a platform with a handrail which is less than 2500 mm from the front of the ladder or from the centre of the ladder to either side, the area between the cage and the top of the handrail shall be secured/guarded.
  - A self closing gate shall be provided at the top of all ladders.

6.2 FIRE PROTECTION COATINGS

Application and material for passive fire protection on steel structures shall be based on the recommendations within the Fire and Explosion Strategy [Ref. 2.3.15].

7.0 CONSTRUCTION CONSIDERATIONS

Prior to issuing any design document for construction, verify that all required types of materials for the installation of the design have been specified on the particular drawing by listing associated reference specifications and/or drawing notes.

Temporary bracing shall be provided for the erection of pipe rack and duct support structure, with indication for removal. Structural and miscellaneous steel that must be temporarily left out of the erection process until equipment is installed shall be indicated as such.