CSA BASIS OF DESIGN

DESIGN AND ENGINEERING SPECIFICATION

Site	HTDC
Shin-Etsu Doc. No.	4.111.250

Please destroy any previous issues

Rev	Description	Date	Made	Checked	Approved
A	Issued for Client Review	05Feb21	2E	2E	2E
B	Issued for Estimate	19Mar21	2E		2E
C	Issued for Design	21July21	2E		2E

2E

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Revision Description

Revision	Description
A	ICR – Issued for Client Review
B	IFE – Issued for Estimate
C	IFD- Issued for Design

Note: Rev. C General update – No track changes indicated

1. Scope

The scope of this specification is to provide Civil and Structural Data and Criteria for the HTDC - Line 7 project – HTDC part, Shin-Etsu PVC B.V. Rotterdam, The Netherlands. This document covers the minimum requirements for Civil and Structural design, engineering and materials.

2. Codes, specifications and standards

Applicable parts of the following Codes, Specifications and Standards shall be an integral part of this Specification and shall apply to the execution of this project.

The project shall be based on reference documents in the following order of precedence:

- Environmental and Safety Standards and Laws.
- Local site directives and regulations.
- European Directives (and national annexes).
- Owner documents
- Project Specifications & Standards.
- Other codes and standards.

In case of conflict between the listed standards, the Owner shall be consulted.

2.1. European codes

Table 2-1 European codes

Reference	Title
EN 206-1	Concrete - Part 1: specification, performance, production and conformity
EN 1990	Eurocode – Basis of structural design
EN 1991	Eurocode 1: Actions on structures
EN 1992	Eurocode 2: Design of concrete structures
EN 1993	Eurocode 3: Design of steel structures
EN 1997	Eurocode 7: Geotechnical design
EN 10080	Steel for the reinforcement of concrete – Weldable reinforcing steel – General
EN 12063	Execution of special geotechnical work – Sheet pile walls
EN 12504	Testing concrete in structures
EN 13670	Execution of concrete structures
EN 1090	Execution of steel structures and aluminium structures Part 1 and Part 2
EN 10025	Hot rolled products of structural steels
EN 1536	Execution of special geotechnical work –Bored piles
EN 12699	Execution of special geotechnical work – Displacement piles
EN ISO 1461	Hot dip galvanized coatings on fabricated iron and steel articles - Specifications and test methods
ISO 8501-3	Preparation of steel substrates before application of paints and related products; Visual assessment of surface cleanliness; Part 3: Preparation of grades of welds, edges and other areas with surface imperfections
ISO 12944-3	Paints and varnishes; Corrosion protection of steel structures by protective paint systems; Part 3: Design considerations

2.2. Dutch codes

Design codes EN 1990 through 1997 shall be applied in combination with their relevant Dutch national annexes (NB) listed below.

Table 2-2 Dutch codes

Reference	Title
NEN EN 1990 NB	Basis of structural design
NEN EN 1991 NB	Eurocode 1: Actions on structures
NEN EN 1992 NB	Eurocode 2: Design of concrete structures
NEN EN 1993 NB	Eurocode 3: Design of steel structures
NEN EN 1997 NB	Eurocode 7: Geotechnical design
NEN 8700	Beoordeling van de constructieve veiligheid van een bestaand bouwwerk bij verbouw en afkeuren – Grondslagen *Assessment of the structural safety of a structure in renovation and rejection.*

2.3. Shin-Etsu Specifications and Standards

Table 2-3 Shin-Etsu Specifications and Standards

Reference	Title
1.586.689	Technical conditions for the design and working details of steel constructions
1.583.441	Coördinaten-stelsels
1.583.498	Rioleringssystemen ten behoeve van fabrieksterreinen
1.583.499	Terreinverhardingen
1.583.502	Tankputten
1.583.507	Paalfunderingen
1.583.590	Drafting of basic specifications and technical specifications for package units
1.586.689	Technical conditions for the design and working details of steel constructions

Reference	Title
1.586.705	Execution of painting systems on iron and steel
1.714.048	Package Units (Englisch version)
1.761.916	Loadings and deformations for the calculations of building structures
1.761.926	Pre-commission cleaning of steam generating equipment and plant piping systems
1.770.954	Compression cooling units
1.770.959	Technical conditions relating to concrete constructions
1.778.879	Technical conditions for design and working details of pipe bridges
1.801.099	Plot lay-out tankparken; inrichting en HSE maatregelen
1.801.102	Plot lay-out verladingen
1.801.105	"Site lay-out" for chemical plants
1.801.109	Tank pits
1.801.113	Bouwkundige maatregelen ter voorkoming van bodemverontreiniging
1.862.847	Functie coderingen voor gebouwen en ruimten (ID-code L)
1.895.602	General data for coding systems
1.906.226	Explosieveiligheid van gebouwen in de procesindustrie
1.917.786	Technical requirements for the delivery of Heating, Ventilation and Air Conditioning (HVAC) installations
1.973.108	Stamping project documents
1.973.131	Drafting Project Specifications
2.176.096	Safety distances for "Site lay-outs"
2.176.109	Technical requirements for designing concrete structures
2.176.110	Execution of painting systems on wood, concrete, walls, plaster, metal elements, etc.
2.180.771	Guidelines for calculating of structural and civil engineering load-bearing structures
2.263.141	Guideline design of tank farms for hazardous liquids and also the development of measures to be taken in regard to HSE
2.263.142	Plot layout for cargo handling facilities
2.263.143	Site Surfacing
2.263.144	Aandachtspunten Bouwkundig toezichthouden
2.263.150	Piled foundations
2.263.156	Protective finishing's for concrete
2.265.385	Edge beams (frost edges) of reinforced concrete
2.265.395	Selection diagrams for painting systems for wood, concrete and stony substrates
2.265.406	Selection diagrams for painting systems for steel, galvanized steel and stainless steel

Reference	Title
2.265.406	Selection diagrams for painting systems for steel, galvanized steel and stainless steel
2.265.406	Selection diagrams for painting systems for steel, galvanized steel and stainless steel
2.424.755	Structural measures for the prevention of soil contamination
2.424.757	Coordinate systems
2.424.781	Asbestos remediation
2.462.423	Areas of attention for supervising civil construction works
2.462.425	Sprinkler systems
2.462.426	Fire, fire prevention and firefighting
2.462.433	Asbestsanering
2.462.434	Abbreviation list of engineering documents
2.462.435	Safety showers
2.462.437	Fill instructions of P&E and Base Autocad title blocks
2.462.441	CE Markering elementen of constructies van staal en aluminium
2.462.442	CE marking steel and aluminium on elements or structures
3.522.769	Control room layout & design
3.522.770	Concrete slabs, Typical details
386.1	Trappen, trapbordessen en leuningen, bordesvloeren
386.102	Staircases, landings and railings, platform floors
386.112	Kooiladders

2.4. Other

Table 2-4 Other

Reference	Title
None	

2.5. Units of Measurement

Table 2-5 Other

Reference	Units	Title
Mass	kilogram metric ton (1000 kg)	kg T or *t
Length	millimetre meter	mm m
Area	square meter	m^2
Volume	cubic meter	m^3
Velocity	meter per second	m/s
Force	Newton kiloNewton	N kN
Pressure	kiloPascal megaPascal	kPa MPa
Density	kilogram per cubic meter	kg/m^3
Specific weight	kiloNewton per cubic meter	kN/m^3
Temperature	degree Celsius	°C

For engineering calculations, the gravitational pull may be simplified to 10 m/s2. This converts weights (mass) to loads according to the following conversion:

1 kg = 10 N and 1000 kg = 10 kN

2.6. Abbreviations

Table 2-6 Other

Reference	Title
N.A.P.	Normaal Amsterdams Peil (Amsterdam Ordnance Datum, this is the Dutch national vertical datum)
NB/NA	Nationale Bijlage / National Annex to the Eurocodes
H.P.P.	High Point of Paving
B.O.B	Bottom of Baseplate
T.O.S	Top of Steel
T.O.G.	Top of Grating
T.O.C	Top of Concrete
B.O.C.	Bottom of Concrete

2.7. Language

All documents shall be in the English language, except for permit documentation when required.

2.8. Software

If required, structural analysis and design shall be performed by using SCIA Engineer version 20.0

3. Basic Engineering Data

3.1. General

3.1.1. Reference period, Consequence and Reliability Class

All permanent structures shall be designed for a design working life of 50 years.

All permanent structures shall be designed for Consequence Class CC3 and Reliability Class RC3

For revamp scope another approach can be chosen based on local code NEN 8700. For (parts of) an existing structure the original design level can be used, which would typically be lower than CC3. To apply NEN 8700 need to be in consultation with Owner and the applicable authorities.

3.2. Site Data

3.2.1. Site Coordinate System

The project site is in Botlek, Rotterdam, The Netherlands. Coordinates refer to final overall coordinate system. All elevations refer to an EL.100.000 level which equals to *4.750 m (+NAP)* and is unit H.P.P.

HOLD: Elevation link to NAP to be confirmed and updated in bridging before EPC.

Height reference *(HOLD benchmark verification is to be executed in bridging before EPC)*:

The height reference mark (bolt nr. 37.D.284) can be found at the south side of the office building near the entrance.

This reference point indicates a 4,974m + NAP (Normaal Amsterdams Peil), measured on top of the bolt.

In the plant multiple height references are available. However, these references must be checked in relation to (bolt nr. 37.D.284) before making use of them.

3.2.2. Elevations

The following elevation definitions shall be applied:

- Plinths for pipe supports and Structural steel baseplates: B.O.B. +150mm H.P.P.
- Equipment BOB. +300mm H.P.P. (minimum)
- Pumps BOB +500mm H.P.P. (minimum)
- Frost line depth is 0.8 m below grade
- For design, water table level shall be assumed to be at grade for FEED phase. *(HOLD To be updated in bridging / EPC when soil report is available)*

3.3. Meteorological Data

The following data shall be applied in the design:

3.3.1. Rainfall

Design rainfall shall be in accordance with the general project data book of 22 October 2020:

The average rainfall during the month is as follows:

- minimum 41 mm
- maximum 85 mm

To determine the minimum needed sewer system, the civil design should take the following values into account for the amount of rainfall:

- 25 mm/hr during 10 minutes
- Or for a long period 10 mm/hr

3.3.2. Barometric pressure

The barometric pressure is as follows:

- minimum 965 mbar
- maximum 1050 mbar

3.3.3. Wind

The fundamental value of 2E Velocity ($v_{b,0}$) based on NEN EN 1991-1-4 NB table NB.1 shall be 27m/s.

3.3.4. Snow

The characteristic value of snow load (s_k) shall be 0.70 kN/m^2 in accordance with NEN EN 1991-1-3.

3.3.5. Temperature

The temperature values listed are in accordance with NEN EN 1991-1-5:

Table 3-1 Temperature

Temperature	Daily avg. maximum	Daily avg. minimum	Avg. RH
Summer	21°C	11.4°C	≥ 70%
Winter	4.7°C	0.1°C	≤ 90 %

The minimum air temperature during the winter is -20 °C.

The maximum air temperature during the summer is 37 °C

3.4. Friction coefficients

Table 3-2 Friction coefficients

Material	Friction coefficient
Steel on Steel	0.40
Steel on Concrete	0.60
Steel on Grout	0.20[1)]
PTFE on PTFE	0.10 or to Manufactures instructions

Note 1. Friction coefficient used to determine the maximum shear force, transferred via the base plate and the grout layer to the concrete foundation acc. NEN-EN 1993-1-8, art.6.2

4. Load cases and Load Combinations

4.1. Load Cases

Loads on structures shall be in accordance with EN1990 and EN1991 and their relevant Dutch national annexes.

4.2. Permanent Basic Load Cases

4.2.1. Dead Load (DL)

Dead Loads shall be the total weight of materials forming the permanent part of a building or structure, empty vessels and equipment, built-in partitions, fireproofing, insulation, piping and electrical conduit and other permanent fixtures.

4.2.1.1 Self-Weight (G_{SW})

Self-weight of building materials and structures shall be in accordance with NBN EN 1991-1-1

Table 4-1 Temperature

Description	Unit Weight kN/m³
Reinforced concrete (in-situ)	25
Structural Steel	78.5
Soil, dry weight	18
Soil, wet weight	20
Water	10

4.2.1.2 Permanently attached appurtenances (G_{DL})

Table 4-2 Permanently attached appurtenances

Item	Description	Self- weight	Unit
Steel work	Plain steel	78.5	kN/m^3
	Grating, incl. support beams	1.0	kN/m^2
Roof cladding	Corrugated steel plate	0.15	kN/m^2
Small piping	Self-weight and content weight under platforms	See 4.2.1.5	

4.2.1.3 Ground water Load / Buoyancy and hydrostatic pressures (G_{GW})

Where the bottom of a structure or equipment extends below water level, either temporary or long term, buoyancy and hydrostatic pressures shall be accounted for in the design. A structure or vessel shall be considered as empty when evaluating impact of buoyancy.

4.2.1.4 Soil and paving load / earth pressure (G_{SL})

Earth pressure shall be calculated for each loading condition and in accordance with the geotechnical report which includes soil properties such as bulk density, cohesion and active and passive pressure coefficients

4.2.1.5 Empty Loads (G_{EM})

Empty weight of process equipment shall derive from certified vendor drawings/ data.

Empty piping load shall be stated by piping engineer. For piping with a diameter equal to or less than 8” a minimum blanket load of 1.2 kN/m^2 is assumed.

For piping with a diameter larger than 8’’ the actual loads are considered.

4.2.2. Operating Loads (G_{OP})

Operating Load shall be defined as the weight of any liquids or solids present within the vessels, equipment or piping as well as other applicable loads present during the normal operation.

The piping Operating loads shall be stated by piping engineer. For piping with a diameter equal to or less than 8” a minimum blanket load of 0.8 kN/m^2 is assumed for the contents of the pipes.

For piping with a diameter larger than 8’’ the actual loads are considered.

Unequal distribution factor of 1.25 shall be applied for Pipe Racks (Empty + Operating loads).

4.2.3. Test Load (G_{TL})

Test loads are defined as the weight of the liquid to pressure test vessels, equipment or piping. The supporting structure for equipment requiring onsite hydro-testing shall be checked for the weight of the equipment completely filled with water.

In accordance with 1.761.916, if the operating weight exceeds, or equal to, 0.8 times the testing weight, the testing weight does not have to be taken into account.

If the operating weight is lower than 0.8 times weight, the testing weight shall be taken into account.

4.2.4. Electrical cable tray load (G_{EC})

A minimum loading of 2.5 kN/m^2 per cable tray must be used, together with a minimum cable tray width of 300 mm in accordance with specification 1.778.879.

4.2.5. Thermal loads: Anchor and Guide loads (G_A)

Detailed anchor loads and their locations shall be provided by the pipe stress engineer.

4.3. Accidental Load Case: Crash and Liquid Overfill (A)

Crash load is an accidental load case that is unlikely to occur. If the liquid overfill scenario is possible, it shall be included in the load combinations.

4.4. Variable Basic Load Cases

4.4.1. Live Loads (Q_{LL} and Q_{RL})

Minimum values for uniformly distributed and concentrated live loads shall be according to following table:

Table 4-3 Live Loads

Design Component	Loaded Area	Minimum Live Load
Concrete slab at grade	Operation and Maintenance areas	10 kN/m^2
Concrete floor or Grating	Walkways and access platforms	2 kN/m^2 or a point load of 5 kN
Concrete floor or Grating	Operation and Maintenance areas	5 kN/m^2
Concrete floor or Grating	Buildings	3 kN/m^2
Roof	Buildings	1 kN/m^2
Stairs	Tread / Stringer	1.5 kN / 5 kN/m^2
Substation ground floor	-	10 kN/m^2
Platforms around compressor	-	10 kN/m^2

Other live loads:

- Dynamic loads shall be as specified by the equipment supplier
- Existing live loads shall be taken from existing documentation. If not available assumptions shall be defined in consultation with Owner.

4.4.2. Snow Load (Q_S)

Snow load on structures shall be calculated according to NEN EN 1991-1-3 in combination with its relevant Dutch national annex.

$s_k = 0.7$ kN/m^2

$C_e = 1$

$C_t = 1$

$\mu = 0.8$ (for flat roofs)

$Q_s = 0.8 \cdot 1 \cdot 1 \cdot 0.7 = 0.56$ kN/m^2

4.4.3. Wind Load (WL)

Wind load shall be calculated according to NEN EN 1991-1-4 & NEN EN 1991-1-6 in combination with its relevant Dutch national annex.

The following parameter values shall be adopted:

$v_{b,0}$ = 27 m/s

c_{dir} = 1

c_{seas} = 1

duration > 1 year

Therefore v_b = 27 m/s.

The variation of the mean wind velocity along the height z above the terrain is given by:

$v_m(z) = c_r(z) \cdot c_0(z) \cdot v_b$, where the coefficients are calculated considering z_0 = 0.2 m and z_{min} = 4 m applicable to terrain category II (onbebouwd gebied). (NEN EN1991-4,Tabel NB.3 – 4.1).

Finally, the peak velocity pressure $q_p(z)$ shall be as per NB.5 of NEN EN 1991-1-4 & NB.

Table 4-4 Peak velocity pressure Wind Loads $q_p(z)$ (kN/m^2)

Height z_e(m)	q_p (kPa)
5	0.66
10	0.85
15	0.98
20	1.07
25	1.14
30	1.20
35	1.25
40	1.30
45	1.34
50	1.38
55	1.42

Wind load shall be determined in accordance with EN 1991-1-4 & NEN-EN 1991-1-4:

- Wind force acting on buildings – according section 5.3(3) EN1991-4
- Wind force acting on a structure or structural component– according section 5.3(2) EN1991-4

The height of buildings and enclosed structures shall be increased with the following value for determining the wind load:

- 0.5 m for steel roofs
- 1.0 m for non-steel roofs
- 1.5 m for the top layer of the PR or entirely cable trays height.

Open structures shall be considered as entirely closed for determining the wind loads. Pipe Racks shall be considered as closed from bottom till top layer.

The height of the open structure shall be increased with 1.5 m for determining the wind load. (in accordance with 1.761.916)

Wind loads shall be applied in the nodes of the structural model.

Force coefficients (c_f) for typical petrochemical facilities not specifically covered by Euro-code, such as multiple-bay open-frame structures containing equipment, pipe racks, vessel with appurtenances etc., shall be determined based on guidelines provided in ASCE ''Wind Loads on Petrochemical Facilities.''

Parameter of wind load as shown in the table below:

Table 4-5 Overview wind parameters

Description	Notation	Value	Remarks
Fundamental value wind velocity	$V_{b,0}$	See 4.4.3	At 10m above ground
Orography factor	C_o	1	
Directional Factor	C_{dir}	See 4.4.3	
Seasonal Factor	C_{season}	See 4.4.3	
Structural(Bouwwerk)factor	C_d C_s	1	
Terrain roughness		Category II	Table 4.1 NEN-EN1991-4
Probability Factor (Return period 50 years)	C_{prob}	1	Buildings, structures & fabricated equipment
Probability Factor (Return period 10 years)	C_{prob}	0.9	Temporary construction & erection phases
Probability Factor (Return period 2 years)	C_{prob}	0.75	Test (t ≤ 3 days)
Force coefficient	C_f	2	Structural Element with sharp edged section e.g. I section
		0.7	Cylinders and pipes supported by structure
		1.2	For ladders & scaffolding
		1.4	For platform & walkways
		1.5	For equipment with insulation or with parallel running pipes (ctc ≤ 1.2ø)
		1.3 – 1.5 depending on h/d in wind direction	Combined pressure and suction coefficient on a closed box h/d = 5; c_f = 1.5 h/d =1; c_f = 1.3 for intermediate values use interpolation
Air Density	ρ	1.25 kg/m^3	
Turbulence Factor	K_l	1	

4.4.4. Seismic Load

Not Applicable

4.4.5. Exchanger Bundle Pull Load (Q_{BP})

Bundle Pull load shall be considered for structures and foundations supporting heat exchangers subjected to bundle pulling during maintenance.

Structures and foundations supporting heat exchangers subject to bundle pulling shall be designed for a horizontal load equal 100% the weight of the removable tube bundle but not less than 9 kN.

Where two or more heat exchangers are supported by one structure, this structure will be designed on the base that one heat exchanger bundle, which gives the most critical condition to the structure, is pulled out and the others are either empty or in operation.

4.4.6. Impact Load (Q_{IL})

Vertical, lateral and longitudinal impact loads on the supports for moving bridge cranes, trolleys, davits and monorail cranes shall be as per NEN EN 1991-3 NB. The design of crane supporting steel shall be as per NEN EN 1993-6 NB.

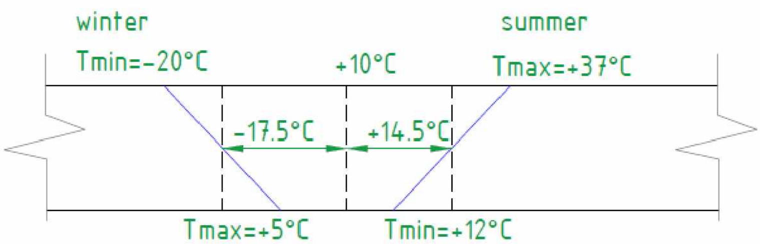
4.4.7. Temperature Load (Q_T)

Thermal loads shall be considered for support structures, foundation slabs and elements thereof based on the effects of differential temperature as per NEN EN 1991-1-5 NB and specification 1.778.879. Thermal effects shall be based on the difference between ambient or equipment design temperature and the installed temperature, whichever is more severe.

Steel: The maximum temperature difference to be considered depends on the colour of the steel structure: 60°C for a light colour, to 80°C for a dark colour. With the ΔT = +/- 30°C is the width of the deformation joint/ length of the slotted hole:

$1.2*10^{-6}*30°C *20m = 7.2$ mm in both direction, 14.5 mm total (for 20m length of beam)

Aboveground concrete: In concrete slabs a uniform thermal expansion effect due to ΔT has to be taken into account. The temperatures for these effects are indicated in image below, only the uniform part has to be accounted for. The temperature values are given in art.3.3.5. The initial temperature T_0 is taken as 10°C.



Difference in temperature due to low thermal conductivity of the concrete between exposed and bottom surfaces is -17.5°C in the winter and +14.5°C in the summer.

4.5. Load Combinations

4.5.1. General

Following generalized load combinations shall be considered and used as applicable. Engineering Judgment shall be used in establishing all appropriate load combinations and shall be as per NEN EN 1990 NB.

4.5.2. Ultimate Limit State CC3

All structures shall in general be checked with the following load factors according to NEN EN 1990 NB and consequence class CC3.

Structural calculations shall be made with the load combinations in accordance with eq. 6.10a and 6.10b of NEN-EN 1990, National Annex Table NB.5 and Table NB.10.

Table 4-6 Ultimate Limit State CC3

						Operating load cases						Empty load cases		Test load cases
			ψ0	ψ1	ψ2	A	B	C	D	E	F	G	H	I
G_{SW}	Self-weight	1.5				1.5	1.3	1.3	1.3	1.3	1.3	0.9	0.9	1.3
G_{DL}	Dead Load	1.5				1.5	1.3	1.3	1.3	1.3	1.3	0.9	0.9	1.3
G_{SL}	Soil & paving	1.5				1.5	1.3	1.3	1.3	1.3	1.3	0.9	0.9	1.3
G_{GW}	Ground water	1.5										1.35	1.2	
G_{EM}	Empty Dead load	1.5				1.5	1.3	1.3	1.3	1.3	1.3	0.9	0.9	1.3
G_{OP}	Operating Dead load	1.5				1.5	1.3	1.3	1.3	1.3	1.3			
G_{TL}	Test Dead load[1)]	1.5												1.3
G_{EC}	Cable Load	1.5				1.5	1.3	1.3	1.3	1.3	1.3	0.9	0.9	1.3
G_{A}	Anchor load[2,3)]	1.5				1.5	0.39	1.3	1.3	1.3	1.3			
Q_{W}	Wind[3,4)]	1.65	0	0.2	0		1.65						1.65	1.0
Q_{S}	Snow	1.65	0	0.2	0			1.65						
Q_{T}	Temperature	1.65	0	0.5	0				1.65					
Q_{LL}	LL on floor, platform, PR etc.	1.65	1	0.9	0.8	1.65	1.65	1.65	1.65	1.65				1.65
Q_{RL}	LL on the roof	1.65	0	0	0					1.65				
	Bundle, impact and other loads	1.65	X	X	X						1.65			

1) *Test load is not considered, if Empty + Operating Loads are more, that 0.8 Test Load (acc.1.761.916).*
2) *Anchor load and wind direction shall be aligned for every combination (the same direction)*
3) *Only 30% Anchor load (thermal component) shall be combined with Friction or Wind*
4) *Wind +x and Wind +y, for directions -x and -y use negative partial factor*
5) *See c_{prob} - Test duration: t ≤ 3 days, Erection: 3 months < t ≤ 1 year*
6) *Bundle pull shall not be combined with wind.*
7) *Where applicable, wind load shall include wind forces acting on temporary scaffolding during empty and test condition.*
8) *X = By engineer judgement*

Table 4-7 Accidental Combinations

			ψ0	ψ1	ψ2	Accidental load cases J	K
G_{SW}	Self-weight	1.0				1.0	1.0
G_{DL}	Dead Load	1.0				1.0	1.0
G_{SL}	Soil & paving	0.4				1.0	1.0
G_{EM}	Empty Dead load	1.0				1.0	1.0
G_{OP}	Operating Dead load	1.0				1.0	1.0
G_{EC}	Cable Load	1.0				1.0	1.0
Q_W	Wind[3,4)]	1.0	0	0.2	0	0.2	
Q_S	Snow	1.0	0	0.2	0		
Q_T	Temperature	1.0	0	0.5	0		
Q_{LL}	LL on floor, platform, PR etc.	1.0	1	0.9	0.8	0.8	0.9
A	Accidental load	1.0				1.0	1.0

4.5.3. Service Limit State

Table 4-8 Service Limit State, Characteristic load combinations

Irreversible limit states: plastic deformations and displacements

			ψ0	ψ1	ψ2	Operating load cases L	M	N	O	Empty load cases P	Test load cases Q
G_{SW}	Self-weight	1				1	1	1	1	1	1
G_{DL}	Dead Load	1				1	1	1	1	1	1
G_{SL}	Soil & paving	1				1	1	1	1	1	1
G_{GW}	Ground water	1								1	
G_{EM}	Empty Dead load	1				1	1	1	1	1	1
G_{OP}	Operating Dead load	1				1	1	1	1		
G_{TL}	Test Dead load[1)]	1									1
G_{EC}	Cable Load	1				1	1	1	1	1	1
G_A	Anchor load[2,3)]	1				0.3	1	1	1		
Q_W	Wind[3,4)]	1	0	0.2	0	1				1	0.6
Q_S	Snow	1	0	0.2	0		1				
Q_T	Temperature	1	0	0.5	0			1			
Q_{LL}	LL on floor, platform, PR etc.	1	1	0.9	0.8	1	1	1	1		1
Q_{RL}	LL on the roof	1	0	0	0				1		

Table 4-9 Service Limit State, Frequent load combinations

Reversible limit states: cracking control

						Operating load cases				Empty load case	Test load cases		
			ψ0	ψ1	ψ2	R	S	T	U	V	W	X	Y
G_{SW}	Self-weight	1				1	1	1	1	1	1	1	1
G_{DL}	Dead Load	1				1	1	1	1	1	1	1	1
G_{SL}	Soil & paving	1				1	1	1	1	1	1	1	1
G_{GW}	Ground water	1								1			
G_{EM}	Empty Dead load	1				1	1	1	1	1	1	1	1
G_{OP}	Operating Dead load	1				1	1	1	1				
G_{TL}	Test Dead load[1)]	1									1	1	1
G_{EC}	Cable Load	1				1	1	1	1	1	1	1	1
G_{A}	Anchor load[2,3)]	1				0.3	1	1	1				
Q_{W}	Wind[3,4)]	1	0	0.2	0	0.2				0.2	0.12		
Q_{S}	Snow	1	0	0.2	0		0.2						
Q_{T}	Temperature	1	0	0.5	0			0.5				0.5	
Q_{LL}	LL on floor, platform, PR etc.	1	1	0.9	0.8	0.8	0.8	0.8	0.9		0.8	0.8	0.9
Q_{RL}	LL on the roof	1	0	0	0								

Table 4-10 Service Limit State, Quasi-permanent load combinations

Long-term effects: shrinkage, relaxation, creep; prestressed anchors

			ψ0	ψ1	ψ2	Operating load case Z	Empty load case AA
G_{SW}	Self-weight	1				1	1
G_{DL}	Dead Load	1				1	1
G_{SL}	Soil & paving	1				1	1
G_{GW}	Ground water	1					
G_{EM}	Empty Dead load	1				1	1
G_{OP}	Operating Dead load	1				1	1
G_{TL}	Test Dead load[1)]	1					
G_{EC}	Cable Load	1				1	1
G_{A}	Anchor load[2,3)]	1				1	
Q_{W}	Wind[3,4)]	1	0	0.2	0	1	
Q_{S}	Snow	1	0	0.2	0		
Q_{T}	Temperature	1	0	0.5	0		
Q_{LL}	LL on floor, platform, PR etc.	1	1	0.9	0.8	0.8	
Q_{RL}	LL on the roof	1	0	0	0		

4.6. Allowable Deflections and Displacements

4.6.1. Vertical

Table 4-11 Vertical Deflection

Elements	Deflection
Floor beams	L/300
Pipe support beams & equipment support beams	L/400, max 25mm
Overhead crane	L/600, max 25mm
Monorails	L/500

Where L = the span of the beam or twice the length of the cantilever.

4.6.2. Horizontal

Table 4-12 Horizontal Deflection

Elements	Deflection
Pipe racks & process structures Piperack Complete structure	 H/200 H/200
Overhead crane Column	 H/400
Change of spacing between the centres of crane rails, including effect of thermal changes	10 mm

4.7. Material Factors

EC2+NB

Concrete Accidental $\gamma_c = 1.20$
Concrete Persistent and Transient $\gamma_c = 1.50$

Reinforcing steel Accidental $\gamma_s = 1.00$
Reinforcing steel Persistent and Transient $\gamma_s = 1.15$

EC3+NB

Structural steel $\gamma_{M0} = 1.0$; $\gamma_{M1} = 1.0$; $\gamma_{M2} = 1.25$
Structural steel Accidental $\gamma_{M0} = 1.0$; $\gamma_{M1} = 1.0$; $\gamma_{M2} = 1.15$

NEN EN 1997 NB

Foundation Piles $\gamma_t = 1.2$

5. Design Requirements

5.1. Foundation Design

Foundation design and sizing of foundations shall conform to NEN EN 1992 and NEN EN 1997. Soil parameters, soil bearing capacity, pile capacities etc shall be in accordance with the factual reports and recommendations *(HOLD pending Soil investigations still to be obtained when this document was issued IFD)*

Concrete Design for liquid retaining structure shall conform to requirements of NEN EN 1992-3.

5.1.1. Piled foundations, Pile stiffness

[HOLD pending soil report]

Drilled full displacement piles (Tubex or approved equal) shall be used.

- A uniform pile tip elevation per structure should be aimed for. When a variable pile tip elevation is required this shall be aligned with the lead engineer.
- The minimum center-to-center spacing of piles in a pile group for new structures shall be 3 times the pile tip diameter unless otherwise specified in the geotechnical report.
- New piles shall be positioned such, that existing (out-of-use) piles will not adversely affect the bearing capacity of the new pile.
- Generally all pile heads shall be designed as moment restraint connections (connected to the foundations by means of anchoring reinforcement), except for specific cases (e.g. single pile with cap without tie-beams).
- The piling contactor is responsible for the detailed pile design, including pile rebar design.

5.1.2. Shallow foundations

[HOLD pending soil report]

- The minimum foundation depth shall be 0.80 m below finished grade. [HOLD for soil report]
- For operating condition with full wind, overburden soil pressure on footings and passive soil resistance shall be taken into account.
- For maintenance/erection condition with partial wind, overburden soil pressure on footings and passive soil resistance shall not be taken into account.
- Stability check shall be performed in accordance with NEN-EN 1997-1 + NA.
    - Stability check Overturning (loss overall stability) ULS

      $E_{stb;d}$ (kNm) > $E_{dst;d}$ (kNm)

      $\gamma_{stb} \cdot E_{std}$ (kNm) > $\gamma_{dst} \cdot E_{dst}$ (kNm)

      - E_{std} is the stabilizing action (un-factored service value)
      - E_{dst} is the destabilizing action (un-factored service value)
      - $E_{stb;d}$ is the design value of the effect of stabilizing actions (factored)
      - $E_{dst;d}$ is the design value of the effect of destabilizing actions (factored)

In accordance with the TableA.1 NEN EN 1997-1 Annex A:

Table 5-1

Partial factor on actions(γ_F)			
permanent	unfavorable	$\gamma_{G,dis}$	1.1
	favorable	$\gamma_{G,stb}$	0.9
variable	unfavorable	$\gamma_{Q,dis}$	1.5
	favorable	$\gamma_{G,stb}$	0

- <u>Stability check Sliding</u>

  $R_d + R_{P;d} – R_{A;d}$ (kN) > H_d (kN) (eq.6.2 EN 1997-1)

  $\gamma_{R;h} \cdot (R+R_P)$ (kN) > $\gamma_E \cdot H$ (kN)

- R is the resistance to sliding by friction at the underside. (un-factored service value)
- H is the sliding action. (un-factored service value)
- R_P is the resisting force by earth pressure on the side of a foundation. (un-factored service value)
- R_d is the design value of the effect of resistance to sliding. (factored)
- H_d is the design value of the effect of sliding actions. (factored)
- $R_{p;d}$ is the design value of the resisting force caused by earth pressure on the side of a foundation. (factored)
- $R_{A;d}$ is the design value of the active force caused by earth pressure on the side of a foundation. (factored) NEN EN 1997-1, sec.6.5.3

In accordance with the TableA.3 and A.5 NEN EN 1997-1 Annex A:

Table 5-2

Partial factor on actions(γ_F)				Partial factor on resistance(γ_R)		
			A1			
permanent	unfavorable	γ_G	1.5(1.2 for water)$^{1)}$	Bearing capacity	$\gamma_{R,v}$	1.0
	favarable	γ_G	0.9	Sliding	$\gamma_{R,h}$	1.0
variable	unfavorable	γ_Q	1.65			
	favorable	γ_Q	0			

Note 1: for water γ_G = 1.20, as for fluid pressure with physically limited value (NEN EN 1997-1, table A.3(c).

- <u>Uplift (UPL)</u>

  $G_{stb;d} + R_d > V_{dst;d}$ (EN1997, (eq.2.8))

  $\gamma_{G;std} \cdot (G_{std} + R) > \gamma_{G;dst} \cdot G_{dst} + \gamma_{Q;dst} \cdot Q_{dst}$

- G_{std} is the stabilizing permanent vertical actions. (un-factored service value)
- R is value of any additional resistance to uplift. (un-factored service value)
- $G_{stb;d}$ is the design value of the stabilizing permanent vertical actions. (factored)
- R_d is the design value of any additional resistance to uplift. (factored)
- $V_{dst;d}$ is the design value of the combination of destabilizing permanent and variable vertical actions. ($V_{dst;d} = G_{dst;d} + Q_{dst;d}$) (factored)

In accordance with the TableA.15 NEN EN 1997-1 Annex A:

Table 5-3

Partial factor on actions(γ_F)			
permanent	unfavorable	$\gamma_{G,dis}$	1.0
	favorable	$\gamma_{G,stb}$	0.9
variable	unfavorable	$\gamma_{Q,dis}$	1.5

5.2. Concrete Design

5.2.1. General

- Soil parameters, soil bearing capacity etc. shall be in accordance with geotechnical reports and recommendations. *(HOLD see under 5.1)*
- Concrete shall be as per EN 206-1.
- Max allowed water cement ratio is 0.5 and for marine environment 0.40
- Reinforcement shall be of grade B500B according to EN 10080. The following concrete characteristics shall apply:

Table 5-4 General Concrete

Concrete use	Exposure class	Minimum Strength class	Crack width (mm)
Lean concrete (blinding)	X0	C12/15	NA
Piles	XC2, XD2, XA2*	C30/37	0.3
Foundations	XC2, XD2, XA2*	C30/37	0.3
Foundations and plinths (above grade)	XC4, XD2, XS1, XF1*	C30/37	0.2
Base slabs	XC4, XD2, XS1, XF2, XA2*	C30/37	0.2
Beams and columns	XC4, XD2, XS1, XF1	C30/37	0.2
Liquid tight	XC4, XD2, XS1, XF2, XA2*	C30/37	0.07
Paving	XC4, XD2, XS1, XF2, XA2*	C30/37	0.2
Prefab Concrete	XC4, XD2, XS1, XF1	C45/55	0.2

* Minimum environmental class needs to be verified / confirmed on completion of soil investigation. (HOLD)

5.2.2. Liquid tight and liquid tight retaining constructions

Where required, the soil shall be protected against pollution by means of liquid tight or liquid retaining provisions. Concrete constructions shall meet the requirements by using a sealing and protective layer and not by tightness of the concrete itself.

5.2.3. Minimum concrete cover

The minimum cover shall be calculated according to Eurocode 2 + NA §4.4.1.2.

Depending on actual situation this would result in the following situation:

Table 5-5 Minimum concrete cover

Concrete cover (reinforcement d<25mm)	Nominal Cover (mm)
Foundations (poured against blinding)	50
Elevated beams/slabs	50
Piles (concrete against soil)	80
Concrete above ground (inside)	50
Concrete above ground (outside)	50

5.2.4. Blinding

All reinforced concrete poured on soil shall have a blinding layer (50mm thick). The blinding concrete layer shall be integral with the subsoil and have a wooden trowel finish. Lean concrete is sufficient for this purpose.

5.2.5. Expansion joints and water stops

Design of expansion joints and water stops shall be confirm to Manual 3.522.770

5.3. Steel Design

Design of steel shall conform to NEN EN 1993 and the requirements listed in section 2 of this BOD.

5.3.1. General

- All connections for steel shall be bolted. Welded connections require Fluor approval.
- A flat washer (or tapered washer if appropriate) shall be placed under each bolt head or nut.
- Slip resistant connections shall be applied for vertical bracings in pre-assembled racks.
- Members and connections that collect water shall be avoided or designed so water can drain away.
- Grating shall be hot-dip galvanized steel and shall be in accordance with the following requirements:
    - Galvanized conform NEN-EN-ISO 1461;
    - Mesh size: 33,33 mm x33,33 mm;
    - Bearing bars: 30 x 3 mm;
    - Filling rods : 10 x 3 mm;
    - Single anti-slip.
- Floor grating assembly shall be in accordance with the following requirements:
    - On the full width of the structure flange a self-adhesive neoprene strip must be applied where the floor grating is resting on;
    - The floor grating must have tight fit in the steel structure that sliding of the floor grating is not possible even without clips;
    - The floor grating must be fixed with clips to prevent sliding.

- Staircases: Only 45° staircases are allowed due to safety reasons and better accessibility. The only exception is made for escape routes then cage ladders can be applied.
- Cage ladders: “Double Bar Gate” and self-closing must be used.
- Closed structural shapes, such as pipes, tubes, and box members are not permitted. Use of built-up sections consisting of back to back members shall be avoided where possible
- All strength welds shall be continuous fillet welds. For fillet welds, the minimum weld size "a" shall be 5 mm, where "a" is the dimension of the throat.
- Sections applied shall not have a material thickness < 5 mm;
- The sections of girders in platforms in all constructions shall not be less than UNP120, IPE120 or L 100x65x8 or equivalent.
- Load transmitting members shall be connected with at least two rivets or bolts with a diameter of at least 16 mm.

- Steel floor plates in the open air shall have a minimum thickness of 6 mm. Inside buildings a minimum thickness shall be 5 mm.
- Checker plate shall have a minimum thickness of 6/8 mm.
- The span shall not be more than 1 m due to floor loading requirements and grating panels shall not be square.
- Structural steel shall be painted in accordance with GSS 1.586.705, GSS 2.265.406 and not in accordance with HTDC – Project Data Book subject Civil. COSC-004 shall be applied for structural steel.
- During painting in the shop a certified specialist of paint manufacturer shall be present to observe the application of the paint system in relation to manufacturer application requirements and Client requirements in relation to the specified RAL colors.

5.3.2. Steel grade

The following steel grade shall be used for all steelwork in accordance with EN 10025, NEN-EN 1993-1 art. 3.2.3 and NEN-EN 1993-10:

- S355 JR for all Main structural steel in structures, columns equipment support beams and the attached base plates
- S235 JR for all other structural steel for example small structures, supporting.
- S235 JR for ladders, stairs, handrails, checkered plate and grating
- All bolts shall be grade minimum 8.8 as per NEN 1993-1-8.

5.3.3. Minimum connection capacity

- Pinned connections shall be based on the actual calculated shear value with a minimum of 50% of the ultimate shear capacity of the web of the member.
- Moment connections shall be designed to the calculated moment with a minimum transfer capacity of 50% of the potential ultimate moment capacity of the smallest member of the connection elements. Ultimate moment connection design shall also simultaneously take in to account 5% of the axial potential capacity and 30% of potential shear capacity.
  Additional the following shall be applied:
  A joint that has to transmit a moment shall, in addition to the calculated expected moment, be also able to transmit a moment that is equal to the lesser from the following two values:
  - 50% of the plastic moment of the strongest connected member;
  - 100% of the plastic moment of the weakest connected member.
- Moment connections shall be designed as rigid joints as per Eurocode 3. Pinned connections are to be designed as pinned joints.
- Bracing connection shall be designed on the actual calculated tension or compression force with a minimum of 50% of the potential gross ultimate tension or compression capacity of member in consideration.
- Beam-to-column connections shall be designed in accordance with the assumptions made in the global analysis of the structure. A beam-to-column connection may be classified as rigid when its stiffness satisfies the conditions specified in the applicable code.

- Connection design shall be assessed during detailed engineering together with Fluor. In specific cases, for disproportionate connections, adjusted design values shall be used, only after approval of Fluor.
- The transverse force capacity of a joint shall be at least 70% of the transverse force capacity of the unweakened body of the beam.
- The normal force capacity of a connection must be at least to 70% of the normal force bearing capacity of the full beam cross-section. Typical application: compression bars.
- Welded joints where bending forces or shearing forces are found shall be designed for full strength. A design that is based on actual bending or shear force is not permitted.

5.4. Other Design Requirements

5.4.1. Roads

Not applicable

5.4.2. Grouting

Cementatious grout shall be utilized, to the extent possible.

Non-shrink grout shall be per the manufacturer's specification. Non shrink grout shall be used for tall vessels and towers.

Grout shall not extend less than 50 mm or more than 100 mm beyond base plate edges. Grout shall not extend above the bottom face of base plates, soleplates, rails, skirt base rings and lugs.

The grout thickness can be in accordance with the table below:

Table 5-6 Grouting

Structure	Anchor diameter	Grout thickness [mm]
Main Structure	Anchor diameter ≤ M24	40
Main Structure	Anchor diameter > M24	50
Minor structure/ equipment		30
Handrails on concrete		25
Minimum grout thickness		25

5.4.3. Paving

All paving inside the process units curbed areas shall be reinforced concrete as part of the piled foundation plate. All paving outside the curbed areas within the process unit shall be Stelcon type plates 2x2 meters, industrial type. Except for maintenance area's the liquid sealed Stelcon types shall be applied.

Paving slopes should be directed away from equipment to reduce the risk of escalation of fire Minimum slope shall be 1.0%.

5.4.4. Drainage and Sewage

The areas within the curbed areas shall be drained to the CRWS system which consist of a trench with partitions connected to a manhole at the outside of the curbed area. Trench to be located along the curb.

Equipment shall be drained to a closed piped system which is located in a covered with heavy duty grating. In the trench also the low pressure condensate will be installed.

See attachment 6.1

5.4.5. Fireproofing

Fireproofing shall be according PDB Civil and document 2.462.426. Location and extend is defined by the applicable HSE documentation. Steel structures which need fireproofing will be made of Vermiculity or Chartek. The latter is mandatory in constructions where vibrations can occur. (e.g. exchange of reboilers).

5.4.6. Corrosion protection

Structural steel shall in general be protected by a paint system in accordance with COSC-004 and in accordance with 2.265.406. An “international third party” inspector is required to monitor the painting application in the shop during the EPC phase. The inspection requirement is also applicable for the application of Chartek.

5.4.7. Anchor Bolts

5.4.7.1 Cast-in anchor bolts

Anchor bolts shall be:

- Shall be galvanized and made of steel grade 5.6, in accordance with EN 898-1. Higher grade 8.8 or 10.9 shall only be used for post-tensioning or high – dynamic forces.
- Expansion type anchors shall not be used to attach rotating equipment to existing concrete and in any other application where the anchor bolts will be subjected to vibratory loads.
- The anchor bolt resistance shall be calculated according EN1992-4.
- Generally no shear load transfer shall be accounted for through the anchor bolts, but shear keys shall be provided. Only for small supports with small shear loads (smaller than approx. 10kN) for which shear keys are impractical shear transfer shall be considered.
- Shear loads shall be transferred from steel to concrete in accordance with the following table.

Table 5-7 Shear Load Transfer

Loading	Allowable load transfer to concrete
Shear load + compression load	Either by: • Shear key or • Friction[1),2)] or • Anchor bolts
Shear load + tension load (uplift)	Either by: • Shear key or • Anchor bolts

Note 1: For sand-cement mortar use a friction coefficient of $C_{f,d}$ = 0.2, according to art. 6.2 NEN-EN 1993-1-8.

- *Anchor bolt diameter shall not be less than 16mm diameter for major structure and equipment, except where equipment requires smaller diameters as specified by the equipment supplier.*
- *Anchor bolts shall have a minimum distance of four times the bolt diameter from the centerline of bolts to edge of concrete, but not less than 100mm. The minimum distance between edge of anchor plate and edge of the concrete shall be 75mm.*

Note 2: For special cases and in agreement with the lead engineer, the friction capacity of the connection may be increased by using pre-stressed anchor bolts with Load Indicating Washers.

5.4.7.2 Chemical anchors

Minor steel supports and small equipment shall be fastened to new and existing foundations with chemical anchors in drilled holes, unless noted otherwise by vendor.

The chemical anchor system shall consist of:

- FIS A A4-70 (stainless steel A4-70) rod by Fischer or approved equal
- FIS SB chemical mortar by Fischer or approved equal

Application of the chemical anchors shall be according manufactures instructions

Minimum anchor size shall be M12.

5.4.7.3 Post-installed rebar

New concrete shall be connected to existing concrete with post-installed starter bars in drilled holes.

The post-installed rebar system shall consist of:

- Reinforcement grade B500B
- FIS SB chemical mortar by Fischer or approved equal
- Application of post installed rebar shall be according manufacturing instructions

5.4.8. Architectural scope

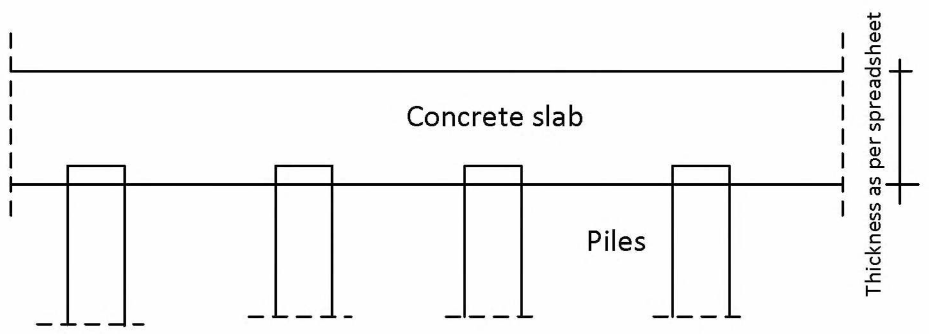
The Substation and Instrument room building will be stick build.

Other building is a sprinkler deluge insulated building.

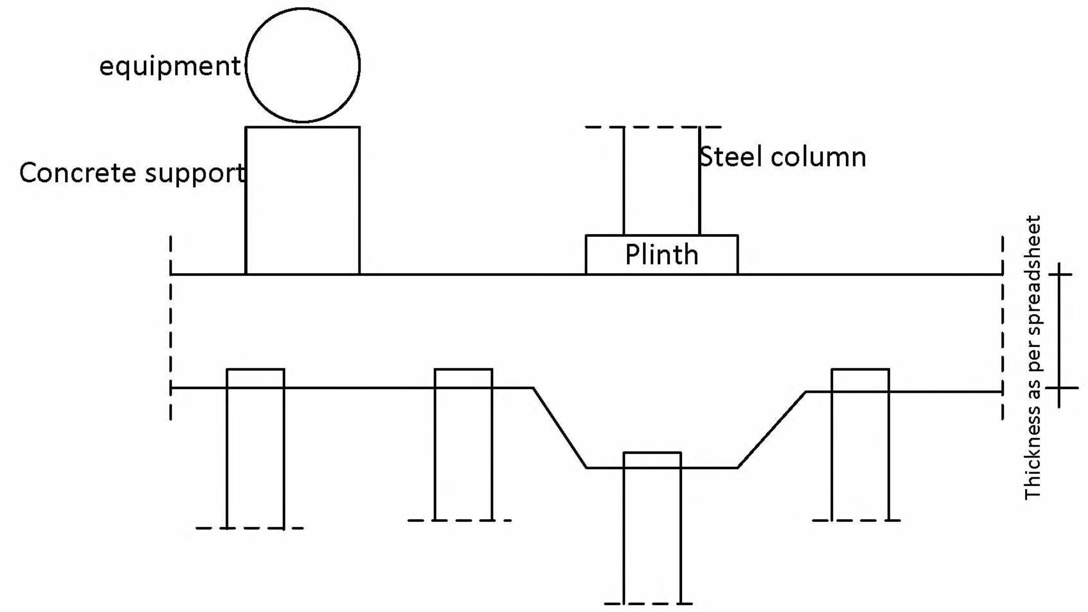
6. Attachments

6.1. Foundation and drainage principle HTDC unit

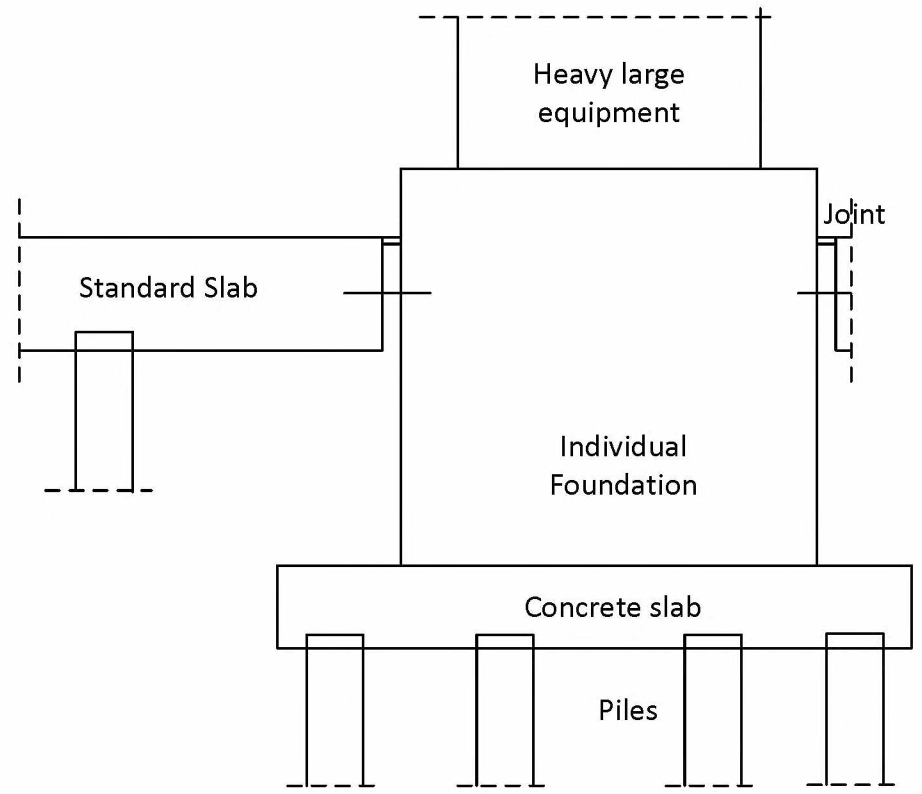
Design principles Foundation and Drainage - HTDC
not to scale

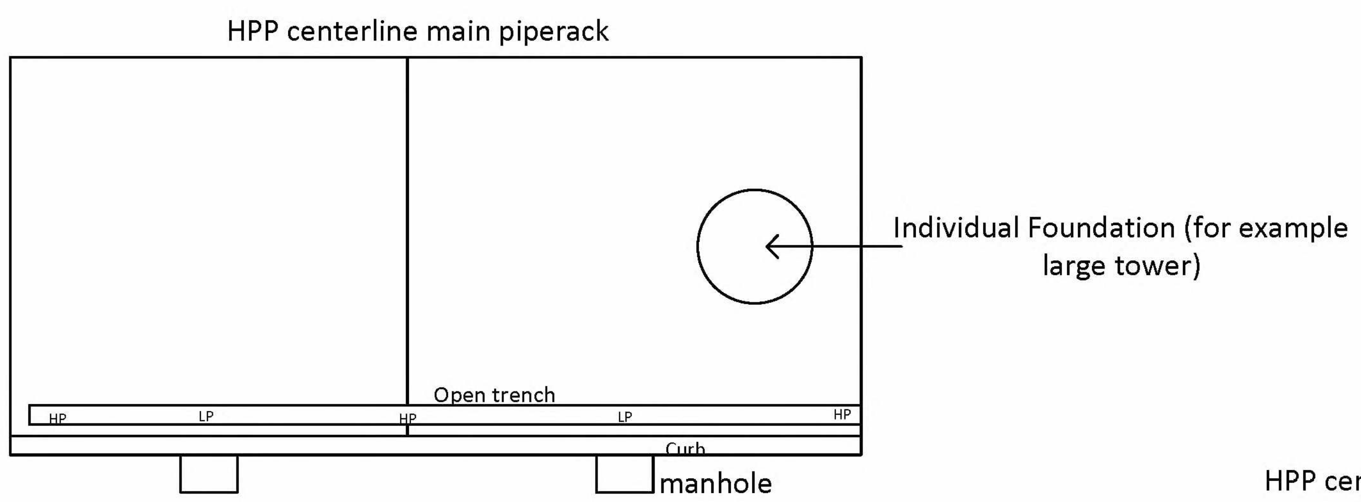


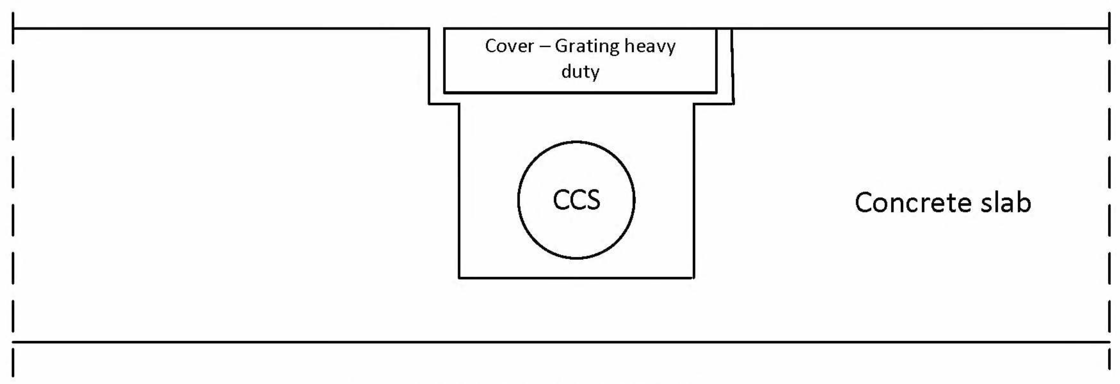
Principle detail piled slab – section standard



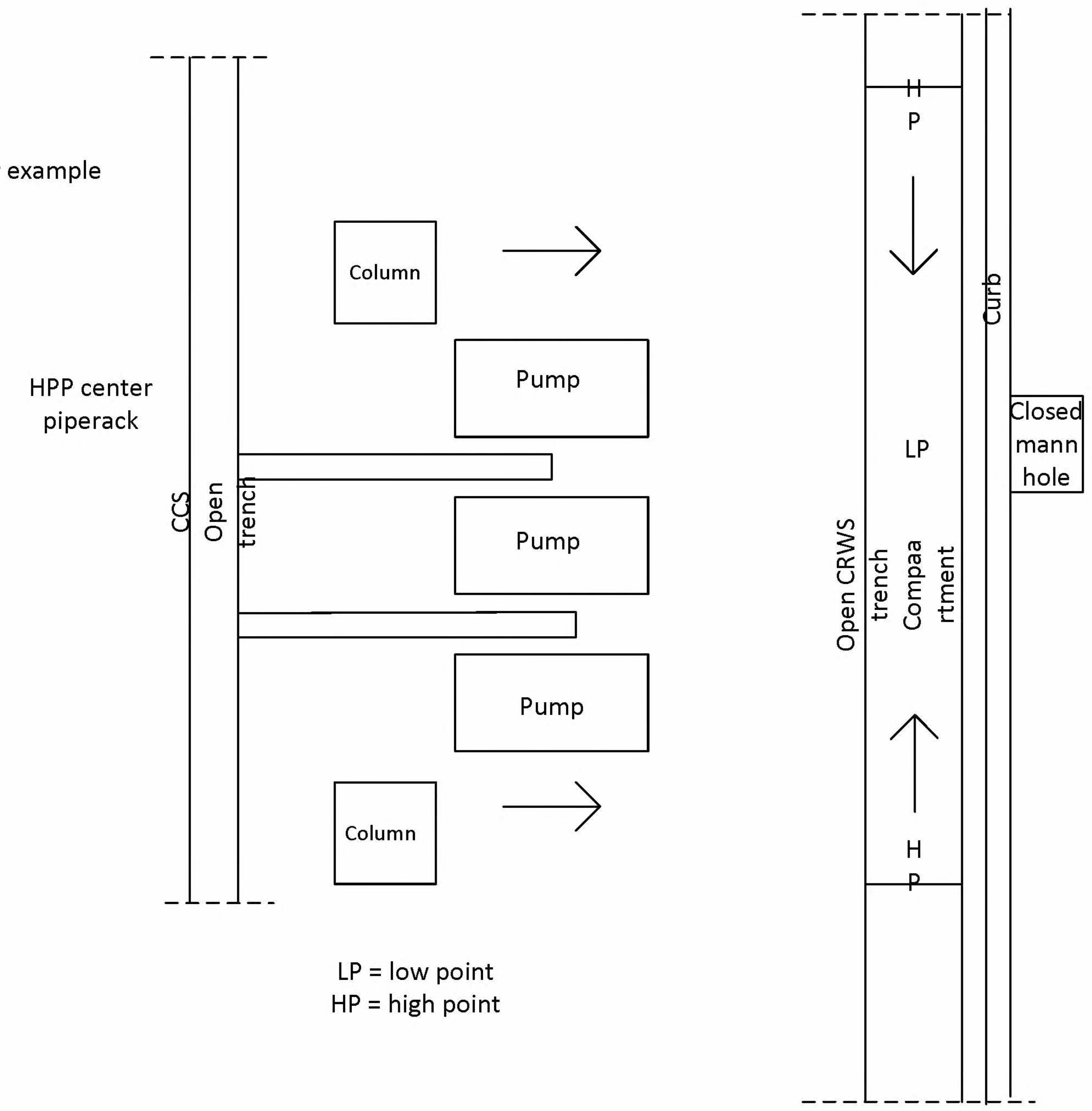
Principle detail piled slab with local thicker slab – section standard



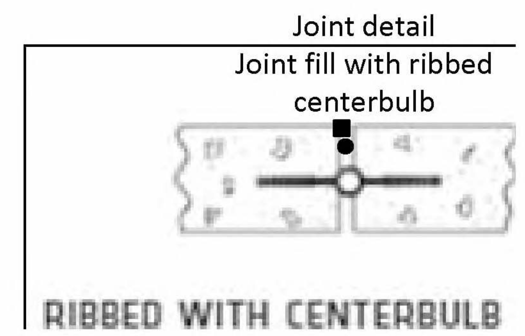




Section view principle CCS system



Principle drainage within curbed area



Foundation Typical's and Drainage Principle
Pka – Rev B

END OF DOCUMENT