CONFIDENTIAL

ROTTERDAM SITE DEVELOPMENT – DEFINITION PHASE
NESTE

GENERAL DESIGN RULES

FOR STEEL STRUCTURES AND

CIVIL WORKS

			Signed By Matteo Esposto 2020.10.12 09:59:28 +02'00'	Signed By Antonio Bindi 2020.10.12 10:24:52 +02'00'	Valerio Colone Olimpia Loiacono Valerio Colone (Oct 12, 2020 16:53 GMT+2) Olimpia Loiacono (Oct 12, 2020 19:47 GMT+2)
D	12/10/2020	RE-ISSUED FOR FEED	M.ESPOSTO	A.BINDI	V.COLONE/O.LOIACONO
C	24/09/2020	ISSUED FOR FEED	M.ESPOSTO	A.BINDI	V.COLONE/O.LOIACONO
B	08/04/2020	IBD	A.BINDI	A.BINDI	V.COLONE/O.LOIACONO
A	31/01/2020	ISSUED FOR REVIEW	A.BINDI	A.BINDI	V.COLONE/O.LOIACONO
REV.	**DATE**	**STATUS**	**WRITTEN BY** (name & visa)	**CHECKED BY** (name & visa)	**APPROV./AUTHOR. BY** (name & visa)

DOCUMENT REVISIONS

INDEX

1. SCOPE

This specification covers materials and general design criteria for foundations, concrete structures and steel structures to be built for the *NESTE Rotterdam Site Development*.

2. REFERENCE DOCUMENTS

2.1. Codes

For material selection and design criteria European Codes shall be applied.

Reference has been made to Eurocodes introduced into the Building Decree of the Netherlands from July 2008 as equivalent replacement to National Netherlands Codes (NEN).
Requirements of Eurocode have been compared with requirements of applicable National Codes and the most stringent has been applied.

2.1.1. General Design Codes

EN 1990	Eurocode Basis of structural design
EN 1991	Eurocode1 Actions on structures
NEN EN 1991-1-4	Eurocode1 – part 1-4 Actions on Structures-Wind Load
NEN EN 1991-1-3	Eurocode1 – part 1-3 Actions on Structures-Snow Load
EN 1998	Eurocode8 Design of structure for earthquake resistance
EN 1090	Execution of steel structures and aluminium structures

2.1.2. Foundations and Concrete Structures

For foundations and concrete structures, in addition, the following codes shall be applied:

EN 196-1	Methods of testing cement – strength
EN 196-2	Methods of testing cement – chemical analysis
EN 196-3	Methods of testing cement – setting time
EN 196-5	Methods of testing cement – pozzolanicity
EN 196-6	Methods of testing cement – fineness
EN 196-7	Methods of testing cement – samples of cement
EN 196-21	Methods of testing cement–chloride carbon and alkali content
EN 197-1	Composition, specification and conformity criteria for common cements
EN 206	Concrete - specification, performance, production and conformity
EN 12350	Testing fresh concrete
EN 13791	Testing concrete – in situ compressive strength
EN 10080	Steel for the reinforcement of concrete
EN 10138	Prestressing steel
EN 13670	Execution of concrete structure

EN 1992-1-1	Eurocode2 part 1-1 General rules and rules for buildings
EN 1992-1-2	Eurocode2 part 1-2 Structural fire design
EN 1992-2	Eurocode2 part 2 Concrete bridges - Design and detailing rules
EN 1992-3	Eurocode2 part 3 Liquid retaining and containing structure

2.1.3. Steel Structures

For steel structures, in addition, the following codes shall be applied:

EN 1993-1	Eurocode 3	part 1-1	General design rules and rules for building
EN 1993-2	Eurocode 3	part 2	Steel Bridges
EN 1993-3	Eurocode 3	part 3	Tower, Masts and chimneys
EN 1993-4	Eurocode 3	part 4	Silos, Tanks and pipelines;
EN 1993-5	Eurocode 3	part 5	Piling;
EN 1993-6	Eurocode 3	part 6	Crane supporting structures;

EN 10021	General technical delivery conditions for steel products
EN 10020	Definition and classification of grades of steel
EN 10079	Definitions of steel products
EN 10025	Hot rolled products of structural steel
EN 10113-1	Hot rolled products in weldable fine grain structural steels
EN 10137-3	Plate and wide flats made of high yield strength structural steels
EN ISO 898-1	Mechanical properties of fasteners made of carbon steel-alloy
EN 15048	Non-preloaded structural bolting assemblies

2.1.4. Vibrating Machineries

For the design of vibrating machinery, in addition, the following codes shall be considered:

DIN 4024 Part 1	Machines foundations – 1988 ed.
VDI 2056	Criteria for assessing mechanical vibrations of machines
ISO 1940/1	Mechanical vibration – Balance quality requirements of rigid rotors

2.1.5. Geotechnical Design

For geotechnical design, concrete crack control and foundation settlements check, the following codes have been considered:

EN 1997-1	Part 1 General Rules for Geotechnical Design

2.2. Project Standard Drawings and Documents

Soil report and Piles:

080871C-000-JSD-1410-001 JSD for Geotechnical Recommendations – area 1
080871C-000-JSD-1410-002 JSD for Geotechnical Recommendations – area 2
080871C-000-JSD-1410-003 JSD for Geotechnical Recommendations – area 3
080871C-000-JSD-1410-004 JSD for Geotechnical Recommendations – area 4

080871C-000-JSD-1422-001 JSD for Soil Improvement

080871C-000-JSD-1430-001 JSD for Piles – area 1
080871C-000-JSD-1430-003 JSD for Piles – area 3
080871C-000-JSD-1430-004 JSD for Piles – area 4

Civil & Structural and UG Construction Standards:

080871C-000-STC-1790 Reinforced Concrete Works
080871C-000-STC-1890 Steel Structures
080871C-000-STC-1490 Underground systems, Site finishing and Miscellaneous

Civil & Structural and UG General Notes:

080871C-000-DW-1702-001 Reinforced Concrete Works
080871C-000-DW-1802-001 Steel Structures
080871C-000-DW-1403-001 Piles
080871C-000-DW-1402-001 Underground systems, Site finishing and Miscellaneous

3. SITE GENERAL DATA

3.1. Site Data

Design of foundations, concrete works and steel structures shall be carried out on the base of the site general data applicable to the project such as:

- Basic wind speed is 30,0 m/s adopted for design according to NEN EN 1991-1-4 (see section 4.6 for relevant EN/NEN approach and comparison of results);
- Peak ground acceleration 0. Hence, seismic load is not applicable;
- Design thermal loads due to temperature variation between + 36 °C & -20 °C (see section 4.5);
- Snow load at mean sea level **0.7 kPa** (see section 4.14);
- Ground Water table elevation is according to Geotechnical Recommendations.
- Frost depth level -800 mm from finished grade level .
- Exposure classes:

	XC	XD	XS	XF	XA
Sewer ditches	XC4	XD3	XS1	XF4	XA2
Roads and paving	XC4	XD3	XS1	XF4	-
Pits	XC4	XD3	XS1	XF4	XA2
Basins -	XC3	XD1	XS1	-	XA2
Basins (external)	XC3	XD1	XS1	XF1	-
Pedestal on concrete foundations	XC3	XD1	XS1	-	-
Concrete above ground	XC4	XD1	XS1	XF3	-
Retaining walls	XC3	XD1	XS1	XF1	XA2
Precast concrete structures	XC3	XD1	XS1	XF3	-
Shallow foundations	XC3	-	-	-	XA2
Tank foundations	XC3	-	-	-	XA2
Reinforced concrete piles-caps for deep foundations	XC3	-	-	-	XA2
Duct banks	XC3	-	-	-	XA2
Piles	XC2	-	XS2	-	XA2

3.2. Soil Data

Design of foundations, structures, earthworks and other civil works shall be carried out in accordance with the prescriptions included in the final soil report related to:

- Foundations level;
- Allowable bearing capacity of soil related to settlements, dimensions and depth of foundations;
- Piles vertical and horizontal bearing capacity;
- Expected settlements (short term and long term);
- Specific weight of soil (dry and wet);
- Cohesion and friction angle (φ) ;
- Elastic modulus E;
- Dynamic modulus G;
- Westergaard modulus;
- Poisson coefficient;
- Water table elevation (min. and max);
- Permeability;
- Soil chemical characteristics.
- Cone Penetration tests.

4. LOADING CONDITIONS

The following loads shall be considered in the design of plant structures:

Dead Load	**(DL)**
Live Load	**(LL)**
Equipment/piping Erection Load	**(EE)**
Equipment/piping Test Load	**(ET)**
Equipment/piping Operating Load	**(EO)**
Thermal Load	**(TL)**
Wind Load	**(WL)**
Maintenance Load	**(ML)**
Exchanger bundle pulling	**(BP)**
Impact Load	**(IL)**
Vibration Load	**(VL)**
Construction Load	**(CL)**
Earth Load	**(HL)**
Snow Load	**(SL)**
Earthquake Load	**(EL)**

4.1. Dead Load (DL)

Dead load is the total weight of material forming the permanent part of the structures and the weight of all materials permanently fastened there to or supported thereby, such as fireproofing, pipes, insulation, walkways, equipment, empty vessels, valves, electrical/instrument cable trays, etc.

Symbols	Category	UNIFORM LOAD	
DL1	*Structure Self weight*	gravity	
DL2	*Self weight of grating and checkered plate*	0.5	kN/m^2
DL3	*Self weight of handrail*	0.3	kN/m
DL4	*Self weight of stairs and vertical ladders:*		
	• *Ladder with cage*	0.42	kN/m
	• *Ladder without cage*	0.22	kN/m
	• *UPN 180 stair without steps*	0.76	kN/m
	• *UPN 220 stair without steps*	1.14	kN/m
	• *UPN 280 stair without steps*	1.52	kN/m
	• *Sloped railing*	0.23	kN/m
	• *Embossed plate step 750x280x(6 + 2) 1 pcs.*	0.16	kN
	• *Grating 30x50-30x3 step 750x280 1 pcs.*	0.12	kN

4.1.1. Density of Materials

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

Material		Density (kN/m^3)
• a)	Reinforced Concrete	25
• b)	Cement screed finishes	23
• c)	Glass	27
• d)	Well-compacted soil	19
• e)	Structural Steel	78.5
• f)	Water	10

4.2. Live Load (LL)

Live load shall be defined according to EN1991 and relevant National Annex and consists of the following movable loads:

a. Persons, portable machinery, tools and, for buildings, furniture, business machines and archive materials;
b. Materials temporarily stored during maintenance such as exchanger parts, pipes and fittings, valves;
c. Materials normally stored during operation such as tools, maintenance equipment, catalysts and chemicals;
d. Passing or staying vehicles, trucks and operating machines, cranes;
e. Maintenance or construction crane loads. Crane loads shall be assumed at their max value, including lifting capacity and the max horizontal loads caused by braking.

Live loads shall be considered as uniformly distributed over the horizontal projection of the specified areas or as concentrated load, and have the following minimum values:

Category	Uniform load	Concentrated Load (3)
Light manufacturing and storage areas (loads to be determined from proposed use, but never less than noted).	7.5 kN/m^2	10.0 kN
Heavy manufacturing and storage areas (loads to be determined from proposed use, but never less than noted).	12.5 kN/m^2	10.0 kN
Operating floor areas and maintenance platforms in process structures and pipe-racks or piping operating platforms	5.0 kN/m^2	10.0 kN
Personnel access platforms, walkways and vertical ladders landings	2.5 kN/m^2	3.0 kN
Stairs and ramps	5.0 kN/m^2	7.0 kN
Roof accessible for maintenance, inspection and repair	2.0 kN/m^2	2.5 kN (roof members)
Office (1)	2.5 kN/m^2	3.0 kN

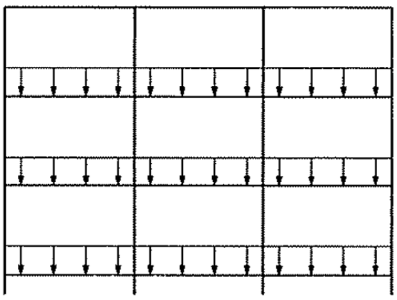
Substation (2)	10.0 kN/m^2	10.0 kN
Laboratory	5.0 kN/m^2	10.0 kN
Control room	6.0 kN/m^2	5.0 kN

(1) In case of multi storey buildings/structures above figure may be reduced subject to engineer's judgment and according to applicable design code.

(2) These live loads shall be checked against Manufacturer's documents.

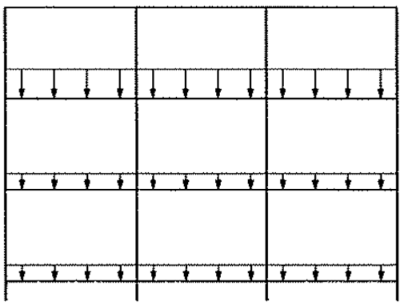
(3) Concentrated load to be adopted for main structural elements local checks only.

According to EN 1990 and National Annex, for buildings, or areas in buildings were people might gather, the extreme value of loads on floors must be calculated on each level of the building (see Figure 2 herein reported);



Figuur 2 — De extreme waarde van de veranderlijke vloerbelasting kan op alle verdiepingen gelijktijdig aanwezig zijn

for most other structures the extreme value may be calculated on only one level while on other levels the extreme load, multiplied by the combination value, may be used (see Figure 3 herein reported);



Figuur 3 — De extreme waarde van de veranderlijke vloerbelasting kan op elke verdieping aanwezig zijn; op de overige vloeren is de momentane vloerbelasting aanwezig

4.3. Equipment Loads

4.3.1. Equipment erection load (EE)

This load includes the weight of equipment and pipe. It shall be considered as a permanent load.

4.3.2. Equipment test load (ET)

Equipment and pipe test load is the weight of the equipment (ET_EQ) and pipes (ET_P) plus the weight of water necessary to perform the hydraulic test. In static calculation the weight of water shall be considered as a variable load; according to EN1991 it is to be considered permanent load. If one or more equipment act on the structure, the testing weight is taken on only one equipment/pipe at a time.

4.3.3. Equipment operation load (EO)

This load includes the weight of equipment/pipe (including platforms and ladders attached to the equipment), solids and/or liquids normally inside the equipment, connected pipes. In static calculation this load shall be considered as a permanent load.

4.4. Pipe-rack design loads

Loads on pipe racks shall be estimated as follows, unless other load information from stress/piping department is available.

4.4.1. Vertical loads

- Pipe bundle

EO = 1.8 kN/m^2	Operating dead load for pipe size < 12''
EE = 1.0 kN/m^2	Empty (estimated) dead load for pipe size < 12''
FL = 0.8 kN/m^2	Fluid Load (static) for average pipe size <12" in operation

- For larger pipe size (from 12'') concentrated load by piping department is required.

- Cable Tray loads on pipe rack shall be estimated as follows:

EO = 1.0 kN/ml	Operating dead load for single level,
EO = 1.9 kN/ml	Operating dead load for double level
EE = 1.0 kN/ml	Empty (estimated) dead load for single level.

Loads on pipe racks can be refined, based on detailed load calculation by piping and stress departments.

4.5. Thermal Load (TL)

Thermal loads are those forces caused by temperature variations.
Three different types of thermal loads shall be considered in design of structures and foundations:

a) TL_T : Load caused by the variation of ambient temperature.
In static calculation TL_T shall be considered as variable load, and shall not be combined with wind and other instantaneous actions.

A uniform temperature component ΔT shall be considered. This load shall be based on design atmospheric temperature according to EN 1991-1-5 as follows:

$$\Delta T = T - T_0$$

Where T is an average temperature of a structural element in winter or summer.
The values of temperatures are:

- Reference temperature for erection/construction: T_0 = 10 °C
- Maximum summer temperature: T_{max} = 36 °C
- Minimum winter temperature: T_{min} = -20 °C

The effect of direct sun radiation is taken in account by an additional 5 °C uniform increased temperature. Therefore the temperature loads are:

- Summer: ΔT = 36 + 5 - 10 = +31 ˚C
- Winter: ΔT = -20 - 10 = -30 ˚C

Hence ±31 °C is used in design.

According to National Annex the following rules should be observed, depending on the type of structure:

1. *Buildings (closed structure with external facade)*

In buildings the temperature of inner environment T_{in} and outer environment T_{out} are limited according to EN 1991-1-5 Table 5.1. and Table 5.2 respectively.

Table 5.1: Indicative temperatures of inner environment T_{in}

Season	Temperature T_{in}
Summer	T_1
Winter	T_2
NOTE: Values for T_1 and T_2 may be specified in the National Annex. When no data are available the values T_1 = 20 °C and T_2 = 25 °C are recommended.	

Table 5.2: Indicative temperatures T_{out} for buildings above the ground level

Season	Significant factor		Temperature T_{out} in ^{0}C
Summer	Relative absorptivity depending on surface colour	0,5 bright light surface	$T_{max} + T_3$
		0,7 light coloured surface	$T_{max} + T_4$
		0,9 dark surface	$T_{max} + T_5$
Winter			T_{min}
NOTE: Values of the maximum shade air temperature T_{max}, minimum shade air shade temperature T_{min}, and solar radiation effects T_3, T_4, and T_5 may be specified in the National Annex. If no data are available for regions between latitudes 45°N and 55°N the values T_3 = 0°C, T_4 = 2°C, and T_5 = 4°C are recommended, , for North-East facing elements and T_3 = 18°C, T_4 = 30°C, and T_5 = 42°C for South-West or horizontal facing elements.			

Therefore the temperature loads are:

- Summer: ΔT_u = 0.5* (+20 + 36) + 4 - 10 = +22˚C
- Winter: ΔT_u = 0.5* (+25 - 20) - 10 = -7.5 ˚C

<u>Hence ±22 °C is used in design.</u>

b) TL_S : Loads on structures and foundations caused by the expansion/contraction of equipment or pipes. These forces will be defined by piping stress department and shall be considered permanent and combined with other instantaneous loads such as wind.

In pipe racks design, each main supporting girder (girder which supports all diameter pipes) shall be calculated to withstand horizontally, in the direction of the pipes, an arbitrary anchor force minimum 10 kN located at the more unfavorable position, and resisted by the total section. During refinement of the design, when location of anchor is defined the proper loads shall be considered (for local girder design only).

Pipe rack frames shall be calculated taking into account the following horizontal thermal loads (TL_S), at right angle with pipes, as a minimum:

- 5% of the operating pipe loads at each concerned level, or 7.5 kN whichever is greater.
- For braced bays anchor forces transferred by longitudinal girders to structural anchors (bracing), an arbitrary force of 5% of the total pipe load per layer shall be taken into account. The above horizontal loads shall be distributed to the foundations.

Longitudinal tie girders for pipe rack shall be calculated for the following:

- Vertical loads 15 kN at mid span

- Compression load equal to 15% of load on adjacent column
- An arbitrary horizontal anchor force of 7.5 kN located at mid span and resisted by the total section.

These loads on longitudinal tie girders shall not be distributed to the foundations.

c) TL_F : In order to take into account friction forces due to thermal expansion of equipment and piping, the following static friction coefficient f, shall be used:

Teflon to teflon	0.10
Teflon to stainless steel	0.10
Steel to steel	0.35
Steel to concrete	0.45

In static calculation the friction forces caused by the thermal expansion/contraction of pipes or equipment shall be considered as variable actions, and shall not be combined with wind and other instantaneous actions.

In the design of each pipe supporting girder, the horizontal slip forces exerted by expanding or contracting pipes in steel pipe racks can be assumed to be 10% of the operating weight on the beam. These “slip” forces shall not be distributed to the foundations.

4.6. **Wind Loads (WL)**

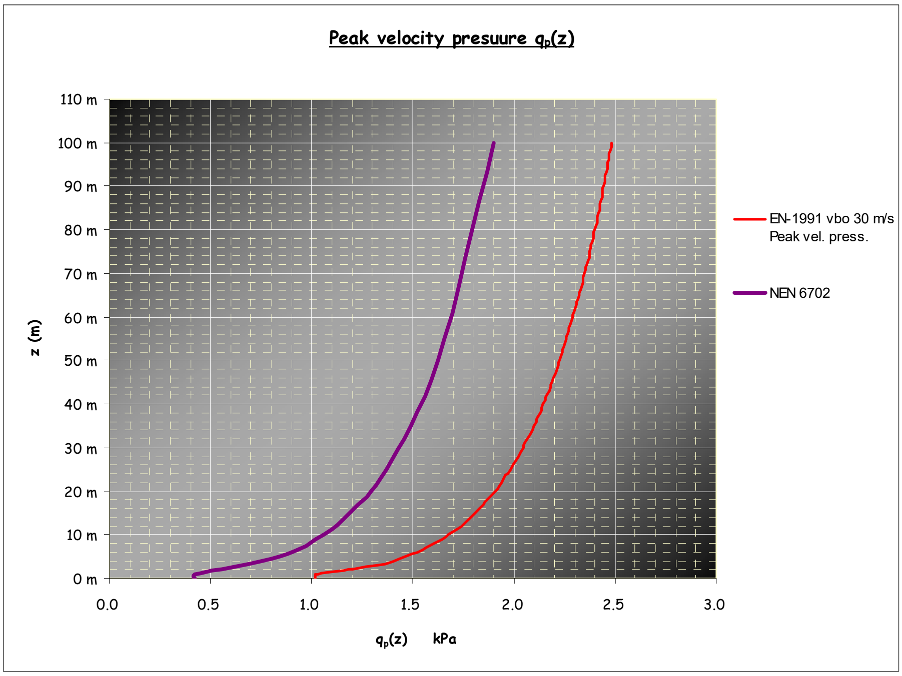
4.6.1. Design Wind Loads

Wind loads on piping or equipment supported on steel or concrete frames shall be added to the wind loads on the frames.
Wind pressure shall be calculated according to EN 1991, based on the value of **basic wind speed v_{bo}** stated in EN 1991-1-4.
The ***peak velocity pressure*** has been given by (EN 1991-1-4 sect.4.5 eq 4.8):

$$q_p(z) = [1 + 7 \cdot I_v(z)] \cdot \tfrac{1}{2} \cdot \rho \cdot v_m^2(z) = c_e(z) \cdot q_b$$

In the following table EN 1991-1-4 wind load is compared versus NEN 6702 as given for wind area II, applicable for *Europoort* area; it is shown that the EN approach is more conservative and hence it is selected for design (the logarithmic variation of wind pressure is discretized using the max value of each interval of z).

Height above ground (m)	EN 1991-1-4	NEN 6702
	Design Velocity pressure (kPa)	Design Velocity pressure (kPa) p_{rep}
0 - 5	**1.465**	**0.680**
5 – 15	**1.810**	**1.010**
15 – 25	**1.982**	**1.180**
25 – 50	**2.226**	**1.430**
above 50	**2.484**	**1.500**



For detailed calculation of peak velocity pressure according to EN 1991-1-4, refer to attachment 2. The ***design wind force*** shall be given by:

$$F_w = q_p(z_e) \times c_s \times c_d \times c_f \times A_{ref} = [KN]$$

Where:

$q_p(z_e)$ = peak velocity pressure
cs = size factor = 1
cd = dynamic factor = 1
cf = force coefficient
A = effective wind area (for which F is calculated) [m^2]

Pressure values along height are reported in the table below.

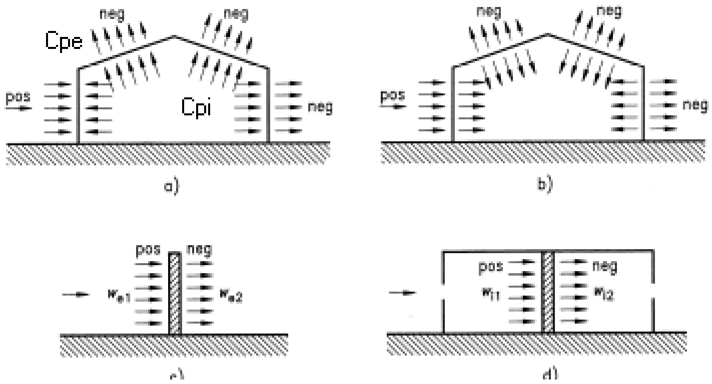
z (variabile)	$c_r(z)$	$v_m(z)$	$I_v(z)$	$q_p(z)$
= 0,10 m	0,91	= 27,19 m/s	= 0,172	= 1,02 kN/sqm
= 0,25 m	0,91	= 27,19 m/s	= 0,172	= 1,02 kN/sqm
= 0,50 m	0,91	= 27,19 m/s	= 0,172	= 1,02 kN/sqm
= 0,75 m	0,91	= 27,19 m/s	= 0,172	= 1,02 kN/sqm
= 1,00 m	0,91	= 27,19 m/s	= 0,172	= 1,02 kN/sqm
= 2,00 m	1,01	= 30,44 m/s	= 0,154	= 1,20 kN/sqm
= 3,00 m	1,08	= 32,34 m/s	= 0,145	= 1,32 kN/sqm
= 4,00 m	1,12	= 33,68 m/s	= 0,139	= 1,40 kN/sqm
= 5,00 m	1,16	= 34,73 m/s	= 0,135	= 1,46 kN/sqm
= 6,00 m	1,19	= 35,58 m/s	= 0,132	= 1,52 kN/sqm
= 7,00 m	1,21	= 36,30 m/s	= 0,129	= 1,57 kN/sqm
= 8,00 m	1,23	= 36,93 m/s	= 0,127	= 1,61 kN/sqm
= 9,00 m	1,25	= 37,48 m/s	= 0,125	= 1,65 kN/sqm
= 10,00 m	1,27	= 37,97 m/s	= 0,123	= 1,68 kN/sqm
= 11,00 m	1,28	= 38,42 m/s	= 0,122	= 1,71 kN/sqm
= 12,00 m	1,29	= 38,83 m/s	= 0,121	= 1,74 kN/sqm
= 13,00 m	1,31	= 39,20 m/s	= 0,119	= 1,76 kN/sqm
= 14,00 m	1,32	= 39,55 m/s	= 0,118	= 1,79 kN/sqm
= 15,00 m	1,33	= 39,87 m/s	= 0,117	= 1,81 kN/sqm
= 16,00 m	1,34	= 40,17 m/s	= 0,117	= 1,83 kN/sqm
= 17,00 m	1,35	= 40,46 m/s	= 0,116	= 1,85 kN/sqm
= 18,00 m	1,36	= 40,72 m/s	= 0,115	= 1,87 kN/sqm
= 19,00 m	1,37	= 40,98 m/s	= 0,114	= 1,89 kN/sqm
= 20,00 m	1,37	= 41,22 m/s	= 0,114	= 1,91 kN/sqm
= 21,00 m	1,38	= 41,44 m/s	= 0,113	= 1,92 kN/sqm
= 22,00 m	1,39	= 41,66 m/s	= 0,112	= 1,94 kN/sqm
= 23,00 m	1,40	= 41,87 m/s	= 0,112	= 1,95 kN/sqm
= 24,00 m	1,40	= 42,07 m/s	= 0,111	= 1,97 kN/sqm
= 25,00 m	1,41	= 42,26 m/s	= 0,111	= 1,98 kN/sqm
= 26,00 m	1,41	= 42,44 m/s	= 0,110	= 2,00 kN/sqm
= 27,00 m	1,42	= 42,62 m/s	= 0,110	= 2,01 kN/sqm
= 28,00 m	1,43	= 42,79 m/s	= 0,109	= 2,02 kN/sqm
= 29,00 m	1,43	= 42,96 m/s	= 0,109	= 2,03 kN/sqm
= 30,00 m	1,44	= 43,11 m/s	= 0,109	= 2,04 kN/sqm
= 31,00 m	1,44	= 43,27 m/s	= 0,108	= 2,06 kN/sqm
= 32,00 m	1,45	= 43,42 m/s	= 0,108	= 2,07 kN/sqm
= 33,00 m	1,45	= 43,56 m/s	= 0,107	= 2,08 kN/sqm
= 34,00 m	1,46	= 43,70 m/s	= 0,107	= 2,09 kN/sqm
= 35,00 m	1,46	= 43,84 m/s	= 0,107	= 2,10 kN/sqm
= 36,00 m	1,47	= 43,97 m/s	= 0,106	= 2,11 kN/sqm
= 37,00 m	1,47	= 44,10 m/s	= 0,106	= 2,12 kN/sqm
= 38,00 m	1,47	= 44,22 m/s	= 0,106	= 2,13 kN/sqm
= 39,00 m	1,48	= 44,34 m/s	= 0,106	= 2,14 kN/sqm
= 40,00 m	1,48	= 44,46 m/s	= 0,105	= 2,15 kN/sqm
= 41,00 m	1,49	= 44,58 m/s	= 0,105	= 2,15 kN/sqm
= 42,00 m	1,49	= 44,69 m/s	= 0,105	= 2,16 kN/sqm
= 43,00 m	1,49	= 44,80 m/s	= 0,104	= 2,17 kN/sqm
= 44,00 m	1,50	= 44,91 m/s	= 0,104	= 2,18 kN/sqm
= 45,00 m	1,50	= 45,01 m/s	= 0,104	= 2,19 kN/sqm
= 46,00 m	1,50	= 45,12 m/s	= 0,104	= 2,20 kN/sqm
= 47,00 m	1,51	= 45,22 m/s	= 0,104	= 2,20 kN/sqm
= 48,00 m	1,51	= 45,31 m/s	= 0,103	= 2,21 kN/sqm
= 49,00 m	1,51	= 45,41 m/s	= 0,103	= 2,22 kN/sqm
= 50,00 m	1,52	= 45,51 m/s	= 0,103	= 2,23 kN/sqm
= 51,00 m	1,52	= 45,60 m/s	= 0,103	= 2,23 kN/sqm
= 52,00 m	1,52	= 45,69 m/s	= 0,102	= 2,24 kN/sqm
= 53,00 m	1,53	= 45,78 m/s	= 0,102	= 2,25 kN/sqm
= 54,00 m	1,53	= 45,87 m/s	= 0,102	= 2,25 kN/sqm
= 55,00 m	1,53	= 45,95 m/s	= 0,102	= 2,26 kN/sqm
= 56,00 m	1,53	= 46,04 m/s	= 0,102	= 2,27 kN/sqm
= 57,00 m	1,54	= 46,12 m/s	= 0,102	= 2,27 kN/sqm
= 58,00 m	1,54	= 46,20 m/s	= 0,101	= 2,28 kN/sqm
= 59,00 m	1,54	= 46,28 m/s	= 0,101	= 2,29 kN/sqm
= 60,00 m	1,55	= 46,36 m/s	= 0,101	= 2,29 kN/sqm

In particular for enclosed buildings, wind pressure shall be evaluated as follows:

$$w = w_e - w_I = q_p\,(C_{pe} - C_{pi}) = [kPa]$$

$$w_e = C_{pe} * q_p \qquad\qquad w_i = C_{pi} * q_p$$

where:
w = wind pressure applied to structures or building;
w_e = wind external pressure;
w_i = wind internal pressure;
q_p = wind pressure;
C_{pe} = external pressure coefficient;
C_{pi} = internal pressure coefficient.



4.6.2. Wind Loads on Open Structures

The design wind load on an open type structure shall be the sum of the design wind loads on its parts (structural elements, equipment, pipes, etc.) taking into account the effects of both shielding and group action of the parts.

4.6.3. Wind Loads on Rack type pipe supports

If not provided by piping stress analysis, wind loads on pipes shall be calculated according to EN 1991-1-4

4.7. Maintenance load (ML)

Maintenance loads are temporary forces due to dismantling, repair or painting of equipment.
For the horizontal load is used as minimum the value F_h = 0.5*weight of the tube group.
The particular maintenance load due to the exchanger bundle pulling shall be determined in accordance to the following paragraph 4.8.
In static calculations it shall be considered as a variable load.

4.8. Exchangers bundle pulling (BP)

Structures and foundations supporting heat exchangers shall be designed to withstand a longitudinal force applied at centre of tube bundle. Fixed end support only shall be designed to resist such force, which shall be equal to weight of the bundle or to 10 kN whichever is greater.
In case of stacked equipment it shall be assumed that the bundle pulling of equipment shall not be simultaneous.
In static calculations it shall be considered as a variable load.

4.9. Impact load (IL)

Impact loads are forces caused by moving objects, such as bridge-cranes and monorails, on supporting structures, on their runways or where lifted loads are placed.
For structures supporting live load which induce impact, the design live loads shall be increased for the impact effect, as shown on the following table, if not otherwise specified:

STRUCTURE	LOAD DIRECTION	DYNAMIC INCREASE
Bridge-cranes runway (electrically operated)	a) Vertical	25% of lifted load
	b) Longitudinal to runway	10% of the sum of the lifted load and the weight of the crane trolley applied at top of runway, one half on each side. This force shall be considered acting in either directions parallel to runway rail.
	c) Transversal to runway	20% of the sum of the lifted load and the weight of the crane trolley applied at top of runway, one half on each side. This force shall be considered acting in either directions normal to runway rail.
Monorails runway	a) Vertical	25% of lifted load
	b) Longitudinal	10% of lifted load
	c) Transversal	20% of lifted load
Davits (davits for manhole are excluded)	a) Vertical	25% of lifted load
	b) Horizontal	20% of equipment weight

4.10. Vibration Load (VL)

Vibration loads are those forces and moments caused by rotating or reciprocating machinery such as compressors, turbines, fan, blowers, and pumps.
Vibration loads have one, or more than one, frequency and application point.
The evaluation of such loads shall be done on the basis of Manufacturer's documents and as indicated in the following chapter "Foundations and Structures for Vibrating Machinery".
For Eurocode combinations, VL is considered as permanent load.

4.11. Construction load (CL)

Construction loads are temporary forces due to installation or erection of structures or equipment. In static calculations it shall be considered as variable load.
This load and loading conditions shall be considered in static calculation with an appropriate safety factor.

4.12. Earth Load (HL)

Earth load is due to soil and/or ground water pressure against structures and foundations. It shall be considered as a permanent load.
Earth load shall be assumed in design in accordance to relevant EN 1997-1.

4.13. Snow load (SL)

Snow load has been computed according to the requirements of NEN **EN 1991-1-3;**
as per mentioned standard, exceptional snow load is not considered in the Netherlands.

According to EN 1991-1-3 snow load on roofs is determined as follows:

$$s = \mu_i C_e C_t s_k$$

According to requirements of **NEN-EN 1991-1-3**, the characteristic value of snow load at mean sea level for every site in the Netherlands has to be assumed as **s_k=0.7 kN/m^2**.

The exposure coefficient for every site in the Netherlands is C_e = 1.0.

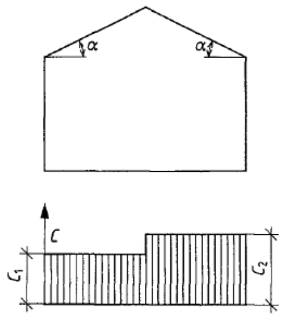
The thermal coefficient for every building in the Netherlands is C_t = 1.0.

Load shape coefficient μ_i shall be selected according to NEN EN 1991-1-3 sect. 5.3 based on roof shape. In the following pictures C_1 & C_2 coefficients correspond to μ_i.

When computed according to NEN-EN 1991-1-3, snow load at mean sea level has to be multiplied for a factor C_i, which, in all applicable cases, is no more than 1.2 and 0.8 for near flat roofs.

b) Zadeldak

$0° < \alpha \leq 15°$	$C_1 = C_2 = 0{,}8$
$15° < \alpha < 30°$	$C_1 = 0{,}8$
	$C_2 = 0{,}8 + 0{,}4\left(\frac{\alpha - 15}{15}\right)$
$30° < \alpha < 60°$	$C_1 = 0{,}8\left(\frac{60 - \alpha}{30}\right)$
	$C_2 = 1{,}2\left(\frac{60 - \alpha}{30}\right)$
$\alpha \geq 60°$	$C_1 = C_2 = 0$



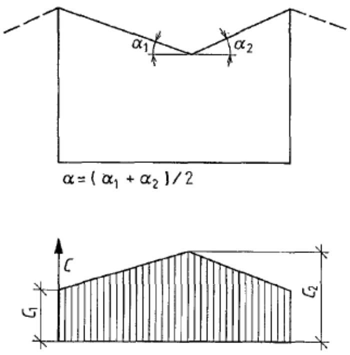
Design value of snow load when computed for NEN EN 1991-1-3 therefore is :

$s_{max} = \mu_i C_e C_t s_k = 1.2 \times 0.7$ kPa = 0.84 kPa   This value has been adopted in design.

Higher values of C_i must be assumed for closed roofs (see NEN-EN 1991-1-3) and due attention in design shall be paid to all particular situations and roof shapes which might lead to heaped snow.

c) Aaneengesloten daken

$0° < \alpha \leq 30°$	$C_1 = 0{,}8$
	$C_2 = 0{,}8\left(\frac{30 + \alpha}{30}\right)$
$30° < \alpha < 60°$	$C_1 = 0{,}8\left(\frac{60 - \alpha}{30}\right)$
	$C_2 = 1{,}6$
$\alpha \geq 60°$	$C_1 = 0$
	$C_2 = 1{,}6$



Effect of gliding snow from higher to lower roofs or for snow heaped by wind, etc… shall be considered in design whenever applicable.

4.14. Earthquake load (EL)

Earthquake calculations are not necessary in the Netherlands and Earthquake load is typically not applicable.

5. LOADING COMBINATIONS

Loading combinations definition for structural design shall be in accordance with EN1991-1 and EN 1990.

Elevated structures (concrete & steel) and foundations shall be designed for the Ultimate Limit State (ULS).

Maximum deflections in structures shall be checked for the Serviceability Limit State (SLS).

Geotechnical design shall be conducted according to Load Combinations for Ultimate Limit State defined in relevant code EN 1990-1 and checked versus EN 1991-1 and EN 1997-1 plus National Annex.
Stability checks of foundations shall be conducted for ULS load combinations.

Safety of persons and structures shall be assured during all transient phases of construction.

The following loading combinations, with the specified loading factors, shall be considered.

ULS: STR / GEO combinations - Design of structural members and foundations

ERECTION & CONSTRUCTION	
Vertical (permanent)	1,35DL+1,35EE+1,35HL
Therm Amb	1DL+1EE+1HL+1,5TLt
Wind (overturning)	1DL+1EE+1HL+1,5WL
Construction	1,35DL+1,35EE+1,35HL+1,50x0,6WL+1,5CL+1,50x0,5SL
Construction + no inst. actions	1,35DL+1,35EE+1,35HL+1,50x0,6TLt+1,5CL
Wind	1,35DL+1,35EE+1,35HL+1,5WL+1,50x0,7CL+1,50x0,5SL
Snow	1,35DL+1,35EE+1,35HL+1,50x0,6WL+1,50x0,7CL+1,5SL
OPERATING	
Vertical (permanent)	1,35DL+1,35EO+1,35HL+1,35VL
Therm Amb	1DL+1EO+1,35TLs+1HL+1VL+1,50x0,7LL+1,5TLt+1,50x0,6TLfr+1,50x0,5SL
Therm Pipes	1,35DL+1,35EO+1,35TLs+1,35HL+1,35VL+1,50x0,7LL+1,50x0,6TLt+1,5TLfr+1,50x0,5SL
Wind (overturning)	1DL+1EO+1TLs+1HL+1VL+1,5WL
Live	1,35DL+1,35EO+1,35TLs+1,35HL+1,35VL+1,5LL+1,50x0,6WL+1,50x0,6IL+1,50x0,5SL
Live + no inst. actions	1,35DL+1,35EO+1,35TLs+1,35HL+1,35VL+1,5LL+1,50x0,6TLt+1,50x0,6TLfr
Wind	1,35DL+1,35EO+1,35TLs+1,35HL+1,35VL+1,50x0,7LL+1,5WL+1,50x0,6IL+1,50x0,5SL
Snow	1,35DL+1,35EO+1,35TLs+1,35HL+1,35VL+1,50x0,7LL+1,50x0,6WL+1,50x0,6IL+1,5SL
Impact	1,35DL+1,35EO+1,35TLs+1,35HL+1,35VL+1,50x0,7LL+1,50x0,6WL+1,5IL+1,50x0,5SL
TEST	
Vertical (permanent)	1,35DL+1,35ET+1,35HL
Wind (overturning - reduced value)	1DL+1ET+1HL+1,5WL
Live	1,35DL+1,35ET+1,35HL+1,5LL+1,50x0,6WL+1,50x0,6IL+1,50x0,5SL
Wind (reduced value)	1,35DL+1,35ET+1,35HL+1,50x0,7LL+1,5WL+1,50x0,6IL+1,50x0,5SL
Snow	1,35DL+1,35ET+1,35HL+1,50x0,7LL+1,50x0,6WL+1,50x0,6IL+1,5SL
Impact	1,35DL+1,35ET+1,35HL+1,50x0,7LL+1,50x0,6WL+1,5IL+1,50x0,5SL
MAINTENANCE	
Maintenance (overturning)	1DL+1EE+1HL+1,50x0,7LL+1,50x0,6WL+1,5ML+1,5BL+1,50x0,6IL+1,50x0,5SL
Maintenance	1,35DL+1,35EE+1,35HL+1,50x0,7LL+1,50x0,6WL+1,5ML+1,5BL+1,50x0,6IL+1,50x0,5SL

ULS: EQU combinations - Static equilibrium (sliding and overturning)

ERECTION & CONSTRUCTION	
Vertical (permanent)	1,1DL+1,1EE+1,1HL
Therm Amb	0,9DL+0,9EE+0,9HL+1,5TLt
Wind (overturning)	0,9DL+0,9EE+0,9HL+1,5WL
Construction	1,1DL+1,1EE+1,1HL+1,50x0,6WL+1,5CL+1,50x0,5SL
Construction + no inst. actions	1,1DL+1,1EE+1,1HL+1,50x0,6TLt+1,5CL
Wind	1,1DL+1,1EE+1,1HL+1,5WL+1,50x0,7CL+1,50x0,5SL
Snow	1,1DL+1,1EE+1,1HL+1,50x0,6WL+1,50x0,7CL+1,5SL
OPERATING	
Vertical (permanent)	1,1DL+1,1EO+1,1HL+1,1VL
Therm Amb	0,9DL+0,9EO+1,1TLs+0,9HL+0,9VL+1,50x0,7LL+1,5TLt+1,50x0,6TLfr+1,50x0,5SL
Therm Pipes	1,1DL+1,1EO+1,1TLs+1,1HL+1,1VL+1,50x0,7LL+1,50x0,6TLt+1,5TLfr+1,50x0,5SL
Wind (overturning)	0,9DL+0,9EO+0,9TLs+0,9HL+0,9VL+1,5WL
Live	1,1DL+1,1EO+1,1TLs+1,1HL+1,1VL+1,5LL+1,50x0,6WL+1,50x0,6IL+1,50x0,5SL
Live + no inst. actions	1,1DL+1,1EO+1,1TLs+1,1HL+1,1VL+1,5LL+1,50x0,6TLt+1,50x0,6TLfr
Wind	1,1DL+1,1EO+1,1TLs+1,1HL+1,1VL+1,50x0,7LL+1,5WL+1,50x0,6IL+1,50x0,5SL
Snow	1,1DL+1,1EO+1,1TLs+1,1HL+1,1VL+1,50x0,7LL+1,50x0,6WL+1,50x0,6IL+1,5SL
Impact	1,1DL+1,1EO+1,1TLs+1,1HL+1,1VL+1,50x0,7LL+1,50x0,6WL+1,5IL+1,50x0,5SL
TEST	
Vertical (permanent)	1,1DL+1,1ET+1,1HL
Wind (overturning - reduced value)	0,9DL+0,9ET+0,9HL+1,5WL
Live	1,1DL+1,1ET+1,1HL+1,5LL+1,50x0,6WL+1,50x0,6IL+1,50x0,5SL
Wind (reduced value)	1,1DL+1,1ET+1,1HL+1,50x0,7LL+1,5WL+1,50x0,6IL+1,50x0,5SL
Snow	1,1DL+1,1ET+1,1HL+1,50x0,7LL+1,50x0,6WL+1,50x0,6IL+1,5SL
Impact	1,1DL+1,1ET+1,1HL+1,50x0,7LL+1,50x0,6WL+1,5IL+1,50x0,5SL
MAINTENANCE	
Maintenance (overturning)	0,9DL+0,9EE+0,9HL+1,50x0,7LL+1,50x0,6WL+1,5ML+1,5BL+1,50x0,6IL+1,50x0,5SL
Maintenance	1,1DL+1,1EE+1,1HL+1,50x0,7LL+1,50x0,6WL+1,5ML+1,5BL+1,50x0,6IL+1,50x0,5SL

SLS: Characteristic (rare) combinations - Vertical and horizontal displacements - Damage

ERECTION & CONSTRUCTION	
Vertical (permanent)	1DL+1EE+1HL
Therm Amb	1DL+1EE+1HL+1TLt
Wind (overturning)	1DL+1EE+1HL+1WL
Construction	1DL+1EE+1HL+0,6WL+1CL+0,5SL
Construction + no inst. actions	1DL+1EE+1HL+0,6TLt+1CL
Wind	1DL+1EE+1HL+1WL+0,7CL+0,5SL
Snow	1DL+1EE+1HL+0,6WL+0,7CL+1SL
OPERATING	
Vertical (permanent)	1DL+1EO+1HL+1VL
Therm Amb	1DL+1EO+1TLs+1HL+1VL+0,7LL+1TLt+0,6TLfr+0,5SL
Therm Pipes	1DL+1EO+1TLs+1HL+1VL+0,7LL+0,6TLt+1TLfr+0,5SL
Wind (overturning)	1DL+1EO+1TLs+1HL+1VL+1WL
Live	1DL+1EO+1TLs+1HL+1VL+1LL+0,6WL+0,6IL+0,5SL
Live + no inst. actions	1DL+1EO+1TLs+1HL+1VL+1LL+0,6TLt+0,6TLfr
Wind	1DL+1EO+1TLs+1HL+1VL+0,7LL+1WL+0,6IL+0,5SL
Snow	1DL+1EO+1TLs+1HL+1VL+0,7LL+0,6WL+0,6IL+1SL
Impact	1DL+1EO+1TLs+1HL+1VL+0,7LL+0,6WL+1IL+0,5SL
TEST	
Vertical (permanent)	1DL+1ET+1HL
Wind (overturning - reduced value)	1DL+1ET+1HL+1WL
Live	1DL+1ET+1HL+1LL+0,6WL+0,6IL+0,5SL
Wind (reduced value)	1DL+1ET+1HL+0,7LL+1WL+0,6IL+0,5SL
Snow	1DL+1ET+1HL+0,7LL+0,6WL+0,6IL+1SL
Impact	1DL+1ET+1HL+0,7LL+0,6WL+1IL+0,5SL
MAINTENANCE	
Maintenance (overturning)	1DL+1EE+1HL+0,7LL+0,6WL+1ML+1BL+0,6IL+0,5SL
Maintenance	1DL+1EE+1HL+0,7LL+0,6WL+1ML+1BL+0,6IL+0,5SL

Notes:

1) *In order to consider the increase of self-weight (DL) due to the presence of fireproofing, refer to construction standard drawings for concrete and fireproofing.*
2) *Test shall be carried out for one equipment at a time. This condition shall be considered for local checks only (i.e. equipment support beams).*
3) *50% of wind loads shall be considered on structures during hydraulic test and maintenance*
4) *Exceptional events are (they should be considered only when applicable):*
   - *fire*
   - *gas explosion*
   - *collision by vehicles*
   - *impulse on roofs or guardrails (only local effects)*
   - *very extreme groundwater tables*
   - *a broke stay wire (for instance of flare)*

6. CONCRETE WORKS

6.1. Materials

6.1.1. Concrete

Specified characteristic compressive strength at 28 days, measured on cylinder, shall be:

Concrete class	f_{ck} [N/mm^2]	
C16/20	16	fill and lean concrete
C25/30	25	dense concrete fireproofing, concrete duct banks, paving 100 and 150mm thk , sleepers and stair foundations
C30/37	30	Elevated cast in situ and precast structural members, slabs, foundations, foundation for vibrating machineries, cast in situ piles, basins, pits, ditches, retaining walls, paving 200mm thk.
C40/50	40	Precast piles

- Mean value of density — 25 kN/m^3
- Poisson ratio for uncracked concrete — $v = 0.2$
- Poisson ratio for cracked concrete — $v = 0.0$
- Coefficient of thermal expansion — $\alpha = 10\ 10^{-6}$ °C^{-1}
- Modulus of Elasticity [MPa] — $E_{cm} = 22.000\ [\ f_{cm} / 10\ ]^{0.3}$
- Mean cylinder compressive strength — $f_{cm} = f_{ck} + 8$ [MPa]
- Maximum aggregates size is 16 mm unless 31.5 mm is specified on construction drawings.

6.1.2. Reinforcing Steel

Deformed steel bars and steel welded wire fabric shall be grade B500B having minimum specified characteristic yield stress of 500 N/mm², according to EN 10080.

Plain steel bars, generally used for steel insert hooks and for paving joint bars shall be grade S235J0 having minimum yield strength of 235 N/mm².

Bar diameters in use for the whole project shall be:
Ø8, Ø10, Ø12, Ø16, Ø20, Ø25, Ø32.

- Mean value of density — 78.5 kN/m^3
- Poisson ratio — $v = 0.3$
- Coefficient of thermal expansion — $\alpha = 12\ 10^{-6}$ °C^{-1}
- Design value of Modulus of Elasticity — $E_s = 200.000$ MPa

6.2. Structure and Foundation components

6.2.1. Steel Inserts

Material for steel plates and steel shapes shall be S235J0 with minimum yield strength F_y= 235 N/mm^2, according to EN 10025, unless otherwise indicated on construction drawings. Sliding plates for horizontal equipment shall conform to Standard drawings.

6.2.2. Anchor Bolts

All major equipment and structures shall be anchored to concrete by means of cast-in-place bolts.
Anchor bolts, nuts and washers shall be hot-dip galvanized and shall conform to EN ISO 898: grade 8.8 anchor bolts may be used where large diameter bolts are required to resist high tensions and shears.
Design of anchor bolts shall be performed according to the following stress:

Diameter (mm)	**CLASS**	f_{yb} (N/mm^2) yield strength	f_{ub} (N/mm^2) ultimate tensile strength
Ø<42	Grade 5.6	300	500
Ø≥42	Grade 8.8	640	800

Material shall be according to EN 10025.
The minimum size of anchor bolts shall be 10 mm.

Use of prefabricated stock rebar anchor bolts (for example peikko type or equivalent) can be considered as an alternative, provided that their resistance (considering all resisting mechanisms of steel and concrete elements) is not lower than the one guaranteed by anchor bolts according to Standard Drawings.

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

- shear-keys shall be provided under columns which transfer important shear loads (such as braced frames, shelters with bridge-cranes and pipe-rack braced bays);

- Shear can be transferred to foundations by friction for minor structures (such as walkways, shelters without bridge-crane, pipe-racks, etc.). In these cases the effective reagent area shall be calculated on the base of actual vertical load, shear load and moment. If the effective shear load exceeds the maximum shear transferred by friction, shear-key shall be foreseen.

Shear-key shall be made of a steel profile inserted in pockets inside the pedestals.

Pockets shall be grouted in place and steel profile shall be supplied welded to base plate.
Where anchor bolts are to be installed in an existing foundation, consideration shall be given to a manufactured post installed (Hilti type or equivalent) mechanical or chemical anchor bolt (for minor structures or equipment only), or embedding the anchor bolts in the foundation with an epoxy resin.
Design and installation of post installed anchors shall be as per Manufacturer's instruction.
Where shear on anchor bolts is unavoidable, check will be carried out with following formulas:

$$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1{,}4\,F_{t,Rd}} \leq 1{,}0$$

Where:
N_{Ed} = Resultant design tension on bolt
V_{Ed} = Resultant design shear on bolt

N_{Rd} = Design resistance in tension of bolt
V_{Rd} = Design resistance in shear of bolt

6.2.3. Grout

Base plates for equipment, steel structures, vibrating machines, miscellaneous steel, etc., supported directly on a concrete foundation shall be set at the required level using non-shrink grout.
Type of grout and application shall be as defined in the following table (unless otherwise specified in design drawings) :

PROCESS AREA		
	Pockets for anchor bolts	**Base-case fill**
Reciprocating and centrifugal compressors	Non-shrink grout	Epoxy grout
Reciprocating and centrifugal pumps	Non-shrink grout	Non-shrink grout
Steel structure base plates	Non-shrink grout	N.A.
Packages on skid	Non-shrink grout	N.A.
Rotating machinery	Non-shrink grout	Non-shrink grout

6.3. Concrete Details

- Minimum concrete cover shall comply with EN-1992-1-1 (Eurocode 2) as follows:

  - concrete cast against earth (without formwork): 75 mm;
  - concrete for foundations (cast with formwork) exposed to earth: 50 mm;
  - walls and slabs 40 mm;
  - beams and columns 40 mm.

- Minimum anchor length shall be in accordance with EN 1992-1-1

  All lap splices in reinforcing bars shall be staggered (if practicable). Minimum overlap of steel reinforcement shall comply with EN 1992-1-1

- All exposed edges of concrete shall be chamfered 25 mm, unless otherwise noted on drawings.

7. FOUNDATION DESIGN

7.1. General

The following general design criteria shall be applied:

- Foundation base shall be below frost line, top of foundation pad shall be (except sleepers and pump foundations) at minimum 800 mm below finished grade level. Top of pedestal shall be at least 200 mm (including grout thickness) above the high point of paving or finished grade level.

- Anchor bolts shall be positioned within the reinforcing bar cage. As general rule anchor bolts shall be installed before concrete casting. If necessary, adequate, pockets shall be provided in the foundation when anchor bolts are installed later. Pockets shall be filled using non-shrinking grout.

- Foundations shall be cast on a 50mm thickness lean concrete layer.

- Reference elevation designated as elevation 100.000 mm, corresponds to reference elevation of site plant + 5,20 express in meters (m) NAP .(Dutch reference sea level).Generally High point of paving (HPP) in process area is +101.300; HPP outside process area is +100.000. For details refer to plot plans.

7.2. Soil check

Check of soil pressure or load on piles shall be carried out according to USL method for soil resistance and according to SLS for settlements check purpose, unless otherwise stated in final report for geotechnical recommendations.
Design stress/resistance on soil/piles shall be determined on the base of prescriptions of final soil report.

Shallow foundations shall be designed according to the following criteria:

- **Bearing capacity** and **sliding check** shall be carried out according to ULS Method (STR/GEO) combinations as indicated in EN 1997-1. It shall be verified that:

$E_d \leq R_d$

$$E_d = E\{\gamma_F F_{rep;} X_k / \gamma_M \} \qquad R_d = R\{\gamma_F F_{rep;} X_k / \gamma_M \} / \gamma_R$$

- E_d Design value of the effect of actions
- R_d Design value of the resistance to an action
- F_{rep} Value of an action

- γ_F Partial factor on actions (EN 1997-1 Annex A Table A.3)
- X_k Value of soil action
- γ_M Partial factor of soil (EN 1997-1 Annex A Table A.4)
- γ_R Partial resistance factor (EN 1997-1 Annex A Table A.5)

Maximum soil pressure due to soil resistance, determined considering dimensions and shape of foundation, shall be lower than the design value in all USL applicable loading combination (maximum vertical load, or maximum overturning moment or both) using the *Meyerhof Area reduction method*.

$$\frac{q_{Ed}}{q_{Rd}} \leq 1/\gamma_R$$

$$\frac{q_{Rd}}{q_{Ed}} \geq 1.0$$

Where:
q_{Ed} Acting bearing pressure
q_{Rd} Ultimate bearing capacity

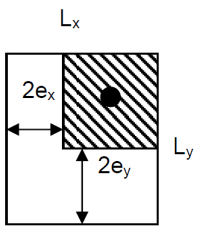
a) Maximum soil pressure calculation for isolated foundations, to be considered rigid, shall be carried out following the "***reduced area method****" of Meyerhof* as follows:

$\sigma = P/A_R \leq$ allowable bearing pressure

A_R is the area obtained reducing the soil contact area by shifting its edge(s), that is (are) opposite to the load application point of twice the eccentricity; hence the centroid of the reduced area is coincident with the load application point.

For a rectangular foundatio: $A_R = (L_x-2e_x)(L_y-2e_y)$, where:

- $e_x = |My/P|$
- $e_y = |Mx/P|$
- P = vertical load at foundation base level
- M_x = moment about x axis at base level
- M_y = moment about y axis at base level
- L_x = Length of the foundation in x direction
- L_y = Length of the foundation in y direction



b) For strip and mat foundations the calculation shall be performed using finite element method, according to Winkler's theory of elastic soil applying the geotechnical parameters indicated on soil investigation report.

Maximum soil pressure due to allowable settlements, determined considering dimensions and shape of foundation, shall be lower than the allowable values in all SLS applicable loading combination (maximum vertical load, or maximum overturning moment or both) using the *Meyerhof Area reduction method*.

- In absence of more specific studies, the ***design friction resistance*** for footings, $\mathbf{F_{Rd}}$, may be calculated according with the following expression (EN1997-1 para. 6.5.3)

$$F_{Rd} = N_{Ed} \cdot \frac{\tan\delta}{\gamma_M}$$

Where:

- γ_M Partial factor for material property, γ_M =1.25
- N_{Ed} Design Normal force on the horizontal base.
- δ Structure-ground interface friction angle (EN 1997-1 6.5.3) $\delta = 2/3\phi_{cv,d}$
- ϕ_{cv} Critical state angle of shear resistance
- $\phi_{cv,d}$ Design value of ϕ_{cv}

$$\frac{F_{Ed}}{F_{Rd}} \leq 1/\gamma_R$$

$$\frac{F_{Rd}}{F_{Ed}} \geq 1.1$$

Where:

- F_{Ed} Acting horizontal force
- F_{Rd} Friction resistance

More detailed calculation may be executed according to results shown in the soil report.

- **Overturning check** shall be carried out according to ULS (EQU) combinations as indicated in EN 1997-1. It shall be verified that:

$$\frac{E_{stb,d}}{E_{dst,d}} \geq 1$$

$$E_{dst,d} = E\{\gamma_F F_{rep;} X_k / \gamma_M\}_{dst} \qquad E_{stb,d} = E\{\gamma_F F_{rep;} X_k / \gamma_M\}_{stb}$$

- $E_{dst,d}$ Destabilizing actions
- $E_{stb,d}$ Stabilizing actions
- F_{rep} Value of an action
- γ_F Partial factor on actions (EN 1997-1 Annex A Table A.1)
- X_k Value of soil action ; if any.
- γ_M Partial factor of soil (EN 1997-1 Annex A Table A.2)

- Foundations of vertical equipment higher than 30 m having ratio total height/diameter higher than 10 shall be designed as follows:
  - 85% of foundation shall result in compression for all loading combinations in erection;
  - 100% of foundation shall result in compression for all loading combination in operating;

- Minimum *Safety Factor* against *buoyancy* shall be verified to be 1.2

7.3. Allowable settlements

Allowable settlements, due to permanent loads are shown in the following table:

FOUNDATION TYPE	MAXIMUM TOTAL SETTLEMENT	MAXIMUM DIFFERENTIAL SETTLEMENT
Towers and vertical equipment	25 mm	Deviation from vertical line due to differential settlement shall not exceed 1/500
Horizontal equipment	25 mm	15 mm
Vibrating machinery	10 mm	approximately 0
Process structures	25 mm	10 mm
Buildings	25 mm	15 mm

Maximum differential settlement between two adjacent equipment shall not exceed 15 mm.

Special care shall be taken for heavy permanent loads (storage tanks and storage buildings) with regard to long term settlements.
For storage tanks, the values of total edge estimated settlement after hydraulic test and after long term loads shall be reported in the IFC drawings.

The allowable differential settlements for tank foundations are defined by the EEMUA 159 “User’s guide to inspection, maintenance and repair of aboveground vertical cylindrical steel storage tanks” (quoted by PGS29 " Richtlijn voor bovengrondse opslag van brandbare vloeistoffen in verticale cilindrische tanks”).

They are resumed as follows:

- maximum rigid tilt: 1/100
- maximum edge-to-center (according to DIN 4119)

$$\max.(100\,f/d) = \sqrt{(100 f_0/d)^2 + 3280\,K/E}$$

Where:
f_0 = the initial cone-up or cone-down distance, in the same units as d
E = Young's modulus of elasticity, in the same units as K
K = the yield strength of the bottom plate
d = tank diameter.

- maximum out-of-plane:

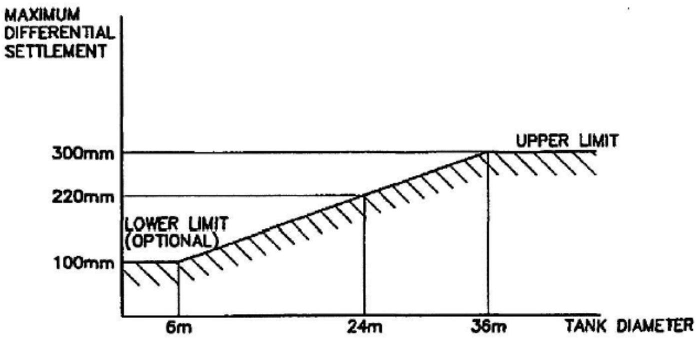
  a) for tanks with floating roofs (see mechanical data sheet)[1].

[1] according to “Criteria for Settlement of Tanks” by W. Allen Marr et al., Journal of the Geotechnical Engineering Division, Vol. 108, No. 8, August 1982, pp. 1017-1039

$$S \leq \frac{11000 \times YS \times L^2}{2[E \times H]}$$

Where:
S = maximum permissible deflection in mm (out-of-plane distortion)
L = arc length between measurement points in metres
YS = yield strength in MPa
E = Young's modulus in MPa
H = tank height in metres

b) for other tanks:



7.4. Piles Foundations

For design bearing capacities of piles refer to Geotechnical Recommendations.
The minimum centre to centre spacing between circular piles shall be *three times* the pile width; the minimum centre to centre spacing between square piles shall be the perimeter of the pile section.

The maximum spacing shall be governed by the concrete cap rigidity. Concrete caps shall extend a minimum of 200 mm beyond the edge of each pile, and the distance to the outer edge of the pile to the outer edge of pile cap should be such that the tie forces in the pile cap can be properly anchored.
Reinforcement in a pile cap should be calculated either by using strut and tie model or flexural methods as appropriate.
Pile embedment into foundation caps shall be minimum 50 mm. Assume tolerance of + /- 20 mm for pile top elevation.

The design pile capacities shall be limited to ½ when supporting reciprocating equipment under operating conditions.

8. TANKS FOUNDATIONS

Tank Diameter (D)	Foundation Type
9 m < D ≤ 50 m	Ring wall or pile foundation if requested
3 m < D ≤ 9 m	Slab or pile foundation if requested
D ≤ 3m	Solid octagon, solid square or pile foundation if requested.

9. FOUNDATIONS AND STRUCTURES FOR VIBRATING MACHINERY

9.1. General

General design criteria for vibrating machinery foundations shall conform to the criteria listed below (according to EN 1997-1 and EN 1991-1).

All foundation blocks shall have minimum skin reinforcement Ø16 at 200 mm spacing, which shall be provided on all faces of foundation.
If the foundation is over 1.0 m thick an intermediate mesh Ø16 at 400 mm spacing shall be provided as shrinkage reinforcement.

A dynamic analysis shall be performed for foundation of vibrating machineries based on the following criteria:

- **centrifugal machineries**

foundation of machineries greater than 500 horsepower shall be designed for expected dynamic forces.

- **reciprocating machineries**

foundation of machineries greater than 150kW and all table-top vibrating equipment shall be designed for expected dynamic forces.

Dynamic modulus of elasticity (E'), of concrete to be used in dynamic analysis shall be as per DIN 1045:

$$E' = 6560 * (f'_c)^{0.5} \text{ (MPa)}$$

9.2. Design Criteria for Reciprocating Machinery

9.2.1. Criteria

Design of foundation for reciprocating machinery shall be carried out in accordance with the following criteria:

- a) Total foundation weight shall be at least 5 times the total weight of machinery;
-

- b) The horizontal eccentricity in any direction, between the centroid of the machine + foundation system and the centroid of the base contact area shall not exceed 5% of the respective base dimension;
-
- c) The center of gravity of the machine-foundation system should be as close as possible to the lines of action of unbalanced forces;

- d) Groups of reciprocating machinery could be tied together with a common foundation slab when allowed by their location and service and the combined foundation results in reduced amplitudes.

9.2.2. Dynamic Analysis

Dynamic analysis shall be carried out as follows:

a) Natural frequencies in the modes being excited shall preferably be out of 0.8 to 1.20 time the disturbing frequencies of any machine on the foundation.
- If it is not possible to fulfill this prescription, frequencies within the above mentioned range may be accepted if the maximum calculated amplitudes are within the limits listed in the following point e);

-
b) damping shall not be higher than 3%;

-
c) primary forces, couples and moments shall be applied at machine speed for calculation of primary amplitudes;

-
d) secondary forces, couples and moments shall be applied at twice the machine speed for calculation of secondary amplitudes;

-
e) total amplitude shall be calculated by combining, in phase, primary and secondary amplitudes. Total peak-to-peak amplitude on foundation shall not exceed 0.05mm, unless otherwise specified by manufacturer.

9.3. Design Criteria for Rotary Machinery

9.3.1. Structural Typology

Rotary machinery may be supported either on a direct foundation or on elevated structure. Structures and foundation supporting rotary machines shall be designed in accordance with the requirements of DIN 4024, 1988 ed.

Foundation and elevated structures shall be dimensioned applying the criteria mentioned in paragraph. 9.2.1 b) and c). Furthermore weight of basement (foundation and elevated structure) shall be at least 3 times the weight of the machinery.
For table foundations, foundation slab minimum thickness shall not be less than 1/10 of its maximum dimension.

9.3.2. Dynamic Analysis

Structure model shall be defined in accordance with the requirements of DIN 4024.

Dynamic analysis may be dispensed if the mass of rotating elements is less than 1/100 of the mass of the whole system (machine + foundation).
Foundation shall be neglected in dynamic analysis if the requirements of DIN 4024 paragraph 5. 2. 3. are fulfilled.

If evaluation of damping of concrete is not carried out, the damping factor of system machine + foundation shall be assumed 0.02.
Higher values of damping factor shall be considered in loading condition in which the loads are significantly higher than that during normal operation.

Natural frequencies of the system machine + foundation shall be calculated in accordance with the following criteria.
Number of natural frequencies to be calculated shall be defined so that the highest natural frequency calculated is at least 10% higher than the maximum operating frequency
This prescription may be neglected in case of machines having operating frequency higher than 75 Hz.
However, depending on the analysis model, the number of natural frequencies to be calculated, n, shall meet the following:

- n=10 for two-dimensional models in which only displacements out of the plane are considered and in which vibration in one direction has influence in other directions.

- n=6 for two dimensional models in which only displacements out of the plane are considered and in which vibration in one direction has only secondary influence in other directions (the system may be represented by independent models).

An assessment of the vibration behavior of a machine foundation may be based on the relationship of the natural frequencies, f_n, to the service frequencies, f_m, according to prescriptions of DIN 4024 ch.5.3.2.

If both conditions 1 and 2 below are met for each decoupled model, subsequent analysis may be dispensed with.

- First order natural frequency (lowest frequency):

  $f_1 \geq 1.25\ f_m$ or $f_1 \leq 0.8\ f_m$

  where f_m is the lowest service frequency.

- Higher order natural frequencies:

  a) $f_n \leq 0.9\ f_m$ and $f_{n+1} \geq 1.1\ f_m$

b) if condition a) is not met, it shall be enough that f_n is less than f_m where n is equal to 6 or 10.

Analysis of the dynamic response to vibrations of foundation shall be carried out using the *unbalanced forces* provided by machine's manufacturer.
In case of absence of such information, *unbalanced forces* may be calculated according to ISO 1940/1, on the base of the nominal quality of balance of machine, as follows:

a) Operating state

The balanced quality of machine shall be assumed one grade lower than that for the relevant machine group specified in ISO 1940/1:

$F = M\,\omega^2 e = M\,(\omega e)\,\omega$

where:

M = Rotor mass in Kg;
ω= Speed in rad/sec;
(ω e) = quality of balance of machine.

All forces shall be considered applied at the bearings.

b) Malfunctioning state

Forces due to malfunctioning shall be assumed 6 times the values for operating state and shall be used for static design and stability checks of structure.

Allowable displacements given by machine manufacturer shall be used for the check of structure.
In absence of such information, *maximum amplitudes* effective at the bearings shall be assumed, for the particular machine group, as follows, in accordance with VDI 2056:

a) Operating state

The value associated with the operating frequency for the assessment criterion given in VDI 2056 which is one grade higher than that guaranteed by the manufacturer, shall be taken as the amplitude under service conditions.

b) Malfunctioning state

The amplitude in case of malfunctioning shall be assumed to be 6 times the value used for operating state.

10. PRECAST PIPE-RACKS DESIGN

Transverse bracing across frames shall not be allowed. Transversal frames shall be designed as rigid frames having end socket foundation designed to develop the frame moments.
Longitudinal stability shall be provided by corbels supporting precast longitudinal beams connecting each frame to braced bays, where required by design.
Typology and location of longitudinal bracing shall be established considering access clearance requirements.
Connections shall be able to resist action effects consistent with design assumptions, to accommodate the necessary deformations and ensure resistance of the structure.

11. REINFORCED CONCRETE PAVINGS

11.1. Definitions

<u>Light duty paving</u>

Light duty paving will be used in areas not subjected to vehicle traffic, or occasionally subjected to transit of light movable equipment with maximum axial load equal to 10 kN plus impact.
Concrete slab shall be of uniform thickness of 100 mm.
Reinforcement consists of single welded wire mesh (ϕ 8 150 X 150).

<u>Medium duty paving</u>

Medium duty paving is provided for areas subjected to light and medium traffic and to transit of maintenance vehicles and designed to withstand a maximum load of 60 kN per axle of truck.
Concrete slab shall be of uniform thickness of 150 mm.
Reinforcement consists of single welded wire mesh (ϕ 8 150 X 150).

<u>Heavy duty paving</u>

Heavy duty paving is provided for areas subjected to heavy vehicle, maintenance and designed to withstand a maximum truck-load per axle of 130 kN.
Concrete heavy duty paving shall be of uniform thickness of 200 mm.
Reinforcement consists of double welded wire mesh (ϕ 8 150 X 150).

Where situations of heavy traffic are foreseen, paving shall be verified for a maximum truckload of 200 kN/axle in compliance to EN 1991-2 + National Annex code.

11.2. General Design Requirements

The construction of concrete paving shall be in accordance with standard drawings.
Curbs, where required to retain spilled material, shall generally be 150 x 150 mm.

Concrete paving may support minor equipment (small pumps, staircase and light skid mounted packages) provided that the local strengthening results in max 10 kN/m^2 soil pressure.
Concrete paved areas shall be parted into rectangular sections limited by joints.
The joints shall be detailed and located on the design drawings.
Four types of joints are normally used in the design of slabs:

- **Isolation Joints**
  Isolation joints shall be foreseen between paving and any adjacent concrete work.

- **Control (Cut) Joint**
  Control joints induce cracking at pre-selected locations; this will prevent random and unsightly cracking.

- **Construction Joints**
  Construction joints provide stopping places during construction.

- **Expansion/ Contraction Joints**
  Expansion/ Contraction Joints will be provided to allow movements of paving due to changing of volume caused by weathering. Expansion joints shall be generally located around each drained area. The top of expansion joint shall be sealed.

12. REINFORCED CONCRETE SERVICEABILITY LIMIT STATES

All concrete structures shall be designed such that the relevant serviceability limit states criteria, listed below, are satisfied.

- Stress limitation;
- Crack control;
- Deflection control;

12.1. Stress limitations

The compressive stress in the concrete shall be limited in order to avoid longitudinal cracks, micro-cracks or high level of creep; reference values are reported in EN 1992-1-1, section 7.2.

12.2. Crack control

Cracking shall be limited to an extent that will not impair the proper functioning or durability of the structure.
Crack width control shall satisfy the requirements of Eurocode 2, checking SLS load combinations, with a limiting width of cracks of:

- 0.3 mm for ordinary reinforced concrete structures (foundations, culverts …)
- 0.1 mm for liquid retaining structure (basins …)

Width of crack shall be limited to 0.2 mm for exposures XD, XF2, XF4, XS and XA.
The following check according to EN 1992-1-1 shall be performed.

Checking if concrete is cracked using SLS combinations and checking that the tensile stress in concrete is less than f_{ctm}; values of f_{ctm} depending on concrete class are in accordance with the following table :

Class	f_{ctm} [MPa]
C16/20	1.9
C25/30	2.6
C30/37	2.9
C40/50	3.5
C50/60	4.1

➢ If <u>concrete is not cracked</u>, the maximum bar diameter is indicated in EN 1992-1 table 7.2 depending on the level of stress in the steel reinforcement and on cracks width limits as follows (control of cracking without direct calculation):

Steel stress	**Maximum bar size** [mm]		
	w_k [mm]	w_k [mm]	w_k [mm]
σ_s [MPa]	0.4	0.3	0.2
160	40	32	25
200	32	25	16
240	20	16	12
280	16	12	8
320	12	10	6
360	10	8	5
400	8	6	4
450	6	5	-

➢ If <u>concrete is cracked</u>, the **maximum spacing between cracks** in the tensile zone shall be:

$$s_{r,max} = k_3 c + k_1 k_2 k_4 \phi / \rho_{p,eff}$$

Where:

$k_1 = 0.8$; $k_2 = 0.5$; $k_3 = 3.4$; $k_4 = 0.425$

$\rho_{p.eff} = A_s / A_{c.eff}$

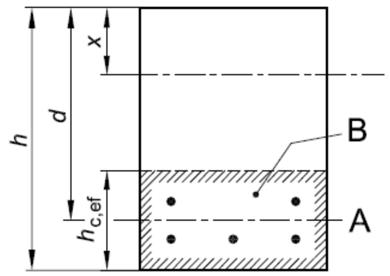
and the **maximum cracks width** is determined by the following formula:

$$w_k = s_{r,max} (\varepsilon_{sm} - \varepsilon_{cm})$$

where

$$\varepsilon_{sm} - \varepsilon_{cm} = \frac{\sigma_s - k_t \frac{f_{ct,eff}}{\rho_{p,eff}}(1 + \alpha_e \rho_{p,eff})}{E_s} \geq 0,6 \frac{\sigma_s}{E_s}$$

$\alpha_e = E_s/E_{cm}$
$k_t = 0.4$ (for long term loads)
σ_s = steel stress in a cracked concrete section correspondent to a specific crack width and to a defined bar size.
$f_{ct.eff} = f_{ctm}$



B indicates $A_{c.eff}$
A indicates geometric centre of rebars

12.3. Deflection control

The deformation of a member or structure shall not be such that it adversely affects its proper functioning or appearance. The appearance and general utility of the structure may be impaired when the calculated sag of a beam, slab or cantilever subjected to quasi permanent loads exceeds span/250.
Deflection that could damage adjacent parts of the structure should be limited. For the deflection after construction span/500 is normally an appropriate limit for quasi permanent loads.

13. REINFORCED CONCRETE ULTIMATE LIMIT STATES

All concrete structures shall be designed such that the relevant ultimate limit states criteria, listed below, are satisfied.

- Bending with or without axial force;
- Shear;
- Torsion;
- Punching shear;
- Fatigue (for structure subjected to regular load cycles e.g crane-rails)

Second order effect should be taken into account where they are likely to affect the overall stability of a structure and for the attainment of the ultimate limit state at critical section.

14. BUILDINGS

Design loads and loading combinations to be used for structural design of buildings and shelters shall be in accordance with paragraphs 4 and 5.
Design shall be carried out according to Eurocodes and local codes.

15. STEEL STRUCTURES

15.1. Materials

15.1.1. Structural Steel

Structural steel material shall be as, per EN-10025, type S275J0 with minimum yield strength Fy = 275 N/mm^2 or type S355J0 with minimum yield strength Fy = 355 N/mm^2.
Steel material for stairs, railing ladders shall be according to EN-10025 type S235JR with minimum yield strength Fy = 235 N/mm^2.

- Mean value of density may be assumed to be 78.5kN/m^3;
- Poisson ratio v = 0.3 ;
- Coefficient of thermal expansion α = 12 10^{-6} °C^{-1};
- Modulus of Elasticity E = 210.000 N/mm^2
- Shear modulus G = E / 2(1 + v) = 81.000 N/mm^2

15.1.2. Grating

Structural steel material shall be, as per EN-10025, type S235JR with minimum yield strength Fy = 235 N/mm^2

Grating shall be electro welded anti-slip with serrated bearing bars.
Grating shall be hot dip galvanized.
Grating types shall be as follows:

- 30x50 mesh and 30x3 mm bearing bars for steel structure decks ;
- 30x100 mesh and 60x5 mm bearing bars for ditch covers.

15.1.3. Checkered plates

Checkered plate 6 + 2 mm thk. shall be hot dip galvanized.
Steel for floor checkered plate shall be “base quality” type S235JR with minimum yield strength Fy = 235 N/mm^2.

15.1.4. Bolts

All structural connections, including equipment connections, shall be performed by bolted connections, except where welding is shown on construction drawings.

All structural bolted connections are bearing type connections.

Bearing type bolts for shear and moment connections shall be conform to grade 8.8 according to EN-ISO 898.

Bolted connections shall use a minimum of two bolts.

15.2. General Design Criteria

All steel structures shall be bolted type, unless otherwise specified on drawings.

For the development of the connection details, joint loads shall be attached to the structure calculation report.

Grating shall be used for the deck of all platforms, unless otherwise specified on drawings. Span length between support members shall be limited to 1300 mm maximum.

15.2.1. Pipe-racks

Transverse bracing across frames shall not be allowed. Transverse frames shall be designed as rigid frames having end plate moment connections designed to develop the frame moments.
Longitudinal stability shall be provided by struts connecting each frame to braced bays. The compression flange of longitudinal tie beams shall be braced laterally or the full unbraced length shall be considered in design.
Typology and location of longitudinal bracing shall be established considering access clearance requirements.
Snow shall be neglected except when large objects such as air coolers are placed on pipe supports.

16. ALLOWABLE DISPLACEMENT AND DEFLECTION

16.1. Allowable deflection

Maximum deflections in structures shall be checked for the Serviceability Limit State and shall conform to EN 1993-1-1: Eurocode 3 – Design of steel structures and to the additions and modifications herein specified.
Loading Combinations to be considered for maximum deflection check are defined in chapter 5.

a) Maximum live load deflection of grating and floor plate shall not exceed 6 mm.

b) Beams with at least two supports:

a.1	Purlins and roof girders	L/250
a.2	Beams not supporting equipment and *pipe-rack* beams	L/300
a.3	Beams supporting equipment (*):	
	a.3.1 operating	L/400
	a.3.2 hydraulic test	L/200
a.4	Crane runway beams and monorails (*):	
	➢ vertical	L/600
	➢ horizontal	L/400

c) Cantilevers:

b.1	not supporting equipment	L/150
b.2	pipe supports	L/150
b.3	supporting equipment (*):	
	b.3.1 operating	L/200
	b.3.2 hydraulic test	L/100
b.4	Crane runway beams and monorails (*):	
	➢ vertical	L/300
	➢ horizontal	L/200

16.2. Allowable displacement

Frames:

c.1	One storey walkways and shelter without bridge cranes	H/150
c.2	Multi-storey frames without equipment	H/200
c.3	Pipe-racks	H/150
c.4	Frames supporting equipment (*) and enclosed buildings:	
	c.4.1 total displacement	H/250
	c.4.2 storey drift	h/150

c.5 Frames supporting bridge cranes (*):

	c.5.1 total displacement	H/500
	c.5.2 storey drift	h/400

where:

H = total height of structure;
h = height between two storey;
L = beam or cantilever span.

(*) Unless otherwise specified by Vendor.

17. FIREPROOFING

General requirements of fireproofing shall be in accordance with EN 1993 and National Annex.

18. UNITS OF MEASURE

Construction drawings for all works covered by this specification shall be carried out using International System Units (S.I.).
In particular the following units shall be used:

Length:	meter	m
	millimeter	mm
Area:	square meter	m^2
	square millimeter	mm^2
Force:	Newton	N
	KiloNewton	kN
Mass:	Kilogram	kg
Pressure:	Bar absolute	.bar
	Millibar	.mbar
Density:	Kilogram per Cubic meter	kg/m^3
Temperature:	degree Celsius	°C

Symbols shall be strictly those indicated above.

19. ATTACHMENT N°1

7.7 Structural elements with sharp edged section

(1) The force coefficient c_f of structural elements with sharp edged section (e.g. elements with cross-sections such as those shown in Figure 7.25) should be determined using Expression (7.11).

$$c_f = c_{f,0} \cdot \psi_\lambda \tag{7.11}$$

ψ_λ is the end-effect factor (see 7.13)

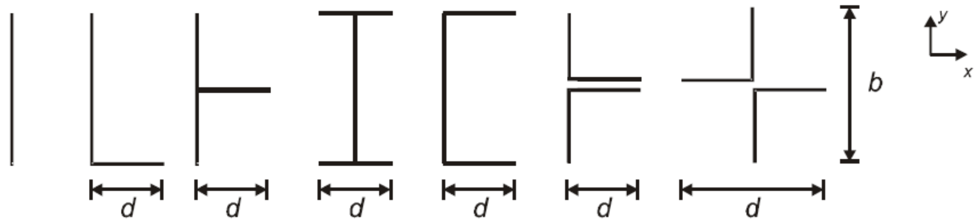


Figure 7.25 — Sharp edged structural sections

NOTE 1 The National Annex may specify $c_{f,0}$. For all elements without free-end flow the recommended value is 2,0. This value is based on measurements under low-turbulent conditions. It is assumed to be a safe value.

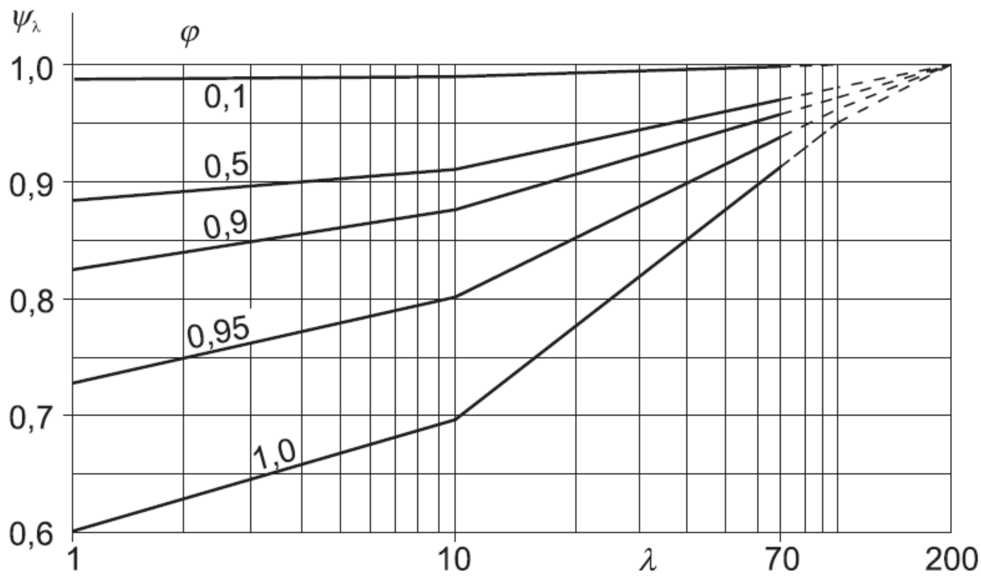


Figure 7.36 — Indicative values of the end-effect factor ψ_λ as a function of solidity ratio φ versus slenderness λ

20. ATTACHMENT N°2

EC1 - WIND LOAD

According to EN 1991-1

$V_{b.0}$ =	*foundamental value of basic wind velocity*		= 30.0 m/s	
c_{dir} =	*directional factor*		= 1.0	
c_{season} =	*season factor*		= 1.0	
$\mathbf{V_b}$ =	*Basic wind velocity*		**= 30.0 m/s**	$V_b = V_{b.0}\, c_{dir}\, c_{season}$
	Terrain category table 4.1		**0**	
z =	*height above terrain*		= 10 m	
z_{min} =	*Minimum height*		= 1.000 m	
Z_{max} =	*Maximum height*		= 200 m	
z_0 =	*Roughness lenght*		= 0.003 m	
$z_{0.II}$ =	*Terrain category II, table 4.1*		= 0.05 m	
$k_r = 0.19\,(Z_0/Z_{0.II})^{0.07}$ =	*Terrain factor*		= 0.16	
$c_r(z) = K_r\, l_n(z/z_0)$ =	*Roughness factor for*	$z_{min} < z < z_{max}$	= 1.266	
$c_r(z) = c_r(z_{min})$ =	*Roughness factor for*	$z < z_{min}$	= 0.906	
$c_0(z)$ =	*Orography factor*		= 1.000	
$\mathbf{v_m}(z)$ =	*Mean wind velocity at height z*		**= 37.97 m/s**	$\mathbf{v_m}(z) = \mathbf{V_b}\, c_r(z)\, c_0(z)$
k_I =	*Turbulence factor*		= 1	
$I_v(z) = k_I/c_0(z)\ \ln(z/z_0))$ =	*Turbulence intensity*	$z_{min} < z < z_{max}$	= 0.123	
$I_v(z) = I_v(z_{min})$ =	*Turbulence intensity*	$z < z_{min}$	= 0.172	
$\mathbf{I_v}(z)$ =	*Actual turbulence intensity*		= 0.123	
ρ =	*Air density*		= 1.25 kg/cu.m	
$\mathbf{q_b}$ =	*Basic velocity pressure*		**= 0.56 kN/sqm**	$\mathbf{q_b} = 0.5\, \rho\, \mathbf{v}^2_b$
$\mathbf{c_e}(z)$ =	*exposure factor*		= 2.990	(figure 4.2 EC1)
$\mathbf{q_p}(z) = [\,1+7\, I_v(z)\,]\ 0.5\, \rho\, \mathbf{v}^2_m(z)$ =	***Peak velocity pressure***		**= 1.68 kN/sqm**	
$\mathbf{q_p}(z) = \mathbf{c_e}(z)\, \mathbf{q_b}$ =			= 1.68 kN/sqm	