Engineering and execution of tight sheet walls

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Abstract: *The Eurocode 7 dated 2004, Eurocode 3: Design of steel structures Part 5 and EC NS-EN 12063 dated 1999 contain technical requirements on engineering, contractual description and execution of sealing for steel sheet piles. In 1992 a geotechnical model was developed in the Netherlands in order to enable the designer to make a rational assessment of the rate of seepage for a specific case. In 1998 there was executed research in the Netherlands on oblique bending with steel sheet walls, also with treaded interlocks. Several suppliers of interlock filling materials offer technical information on seepage resistance with the inverse interlock resistance ρ. Comparison of the Eurocode's supplements applying for the Nordic countries reveals that not all the necessary parameters for engineering tight steel sheet walls are available yet. This paper describes a guideline to enable the designer to engineer, contractually formulate, draw and execute sealed steel sheetpiles according to actual requirements, recommendations and guidelines.*

1.1 Engineering tightness of sheet walls

Eurocode NS-EN 12062 supplement E gives an example on how to engineer tightness with the introduction of the new concept of "inverse joint resistance" which was developed as a variation on Darcy's law:

$$q_z = \rho \frac{\Delta p_z}{\gamma_w}$$

with:

q_z = discharge per unit of the joint length at level z, ($m^3/s/m$)
Δp_z = pressuredrop at level z, (kPa)
ρ = inverse joint resistance, (m/s)
γ_w = unit weight of water, (kN/m^3).

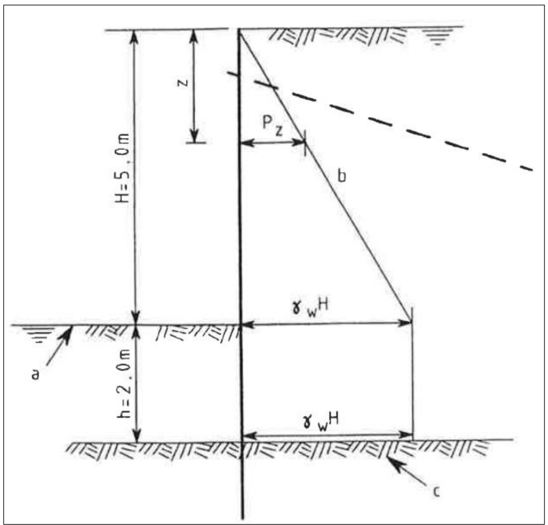


Figure 1: Geometry and units.

Example 1: discharge steel sheet pile wall

<u>Building pit:</u>
Length of perimeter building pit L = 180 m
Steel sheet pile width b = 600mm
Excavation depth H = 5 m
Top excavation – tight layer h = 2 m
Inverse joint resistance $\rho = 5 \times 10^{-10}$ m/s

<u>Total discharge Q:</u>
Number of interlocks:
$n = L/b$
$= 180/0{,}6$
$= 300$ elements.

Discharge per joint:
$Q_1 = \rho \cdot H \cdot (0{,}5H + h)$
$= 5 \cdot 10^{-10} \times 5 \times (0{,}5 \times 5 + 2)$
$= 1{,}125 \times 10^{-8}\ m^3/s$

Total discharge into the excavation pit:
$Q = n \cdot Q_1$
$= 300 \times 1{,}125 \times 10^{-8}$
$= 3{,}375 \times 10^{-6}\ m^3/s$
$= 3{,}375 \times 10^{-6} \times 60 \times 60 / (5 \times 180/1000)$
$= 0{,}013\ m^3/hr/1000m^2$

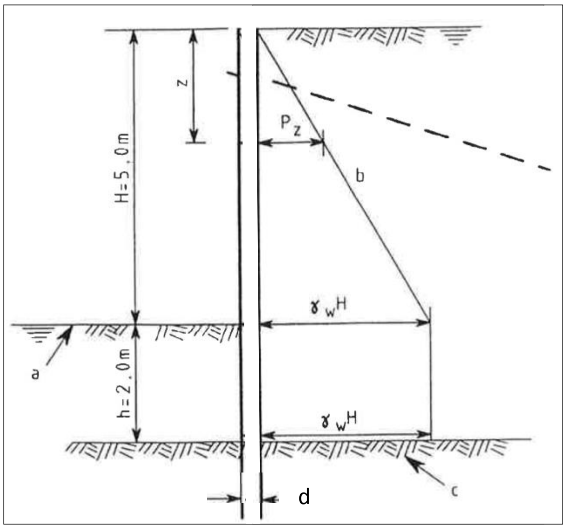
<u>Check with permissible discharge as stated in Eurocode 7 art. 9.4.1 (8).</u> NB: the model can result in a larger amount of discharge than the surrounding area is capable in providing. A check has to be performed with «open» interlocks.

There are no rules to calculate the water seepage for diaphragm walls in Eurocode NS-EN 1538 «Execution of special geotechnical works. Diaphragm walls», and neither for secant-, cut off- or slurry walls. Formulas which apply to this field are according Darcy's law, se reference /1/:

$$Q_{sv} = \frac{K_e(\Delta p/\gamma_w)}{d}$$

with:

Q_{sv} = discharge pr unit of wall, (m^3/s),
K_e = equivalent permeability (m/s),
$\Delta\rho$ = pressure drop on both side of the wall, (kPa)
p_z = inverse joint resistance, (m/s),
γ_w = water density, (kN/m^3)
d = thickness of the wall, (m)



Figur 2: Geometri and units.

Example 2: discharge diaphragm wall

Building pit:

Length of perimeter pit	L = 180 m
Steel sheet pile wide	b = 600mm
Excavation depth	H = 5 m
Top excavation – tight layer	h = 2 m
Inverse joint resistance	$\rho = 5 \times 10^{-10}$ m/s

Total discharge $Q = 3{,}375 \times 10^{-6}$ m^3/s

Calculate equivalent seepage permeability K_e

Specific discharge per unit diaphragm wall:

$$Q_{sv} = K_e \cdot (\Delta p/\gamma_w) / d \qquad (1)$$

Specific discharge per unit steel sheet wall:

$$Q_{sp} = (1/b) \cdot \rho \cdot (\Delta p/\gamma_w) \qquad (2)$$

Comparison of (1) and (2):

$$Q_{sv} = Q_{sp}$$
$$K_e \cdot (\Delta p/\gamma_w) / d = (1/b) \cdot \rho \cdot (\Delta p/\gamma_w)$$

Equivalent K_e-value with estimated diaphragm wall thickness d = 1000 mm:

$K_e = \rho \cdot (1m) / b$
$= 5 \times 10^{-10} / 0{,}600$
$= 8{,}33 \times 10^{-10}$ (m/s)

1.2 Control groundwater

In both examples 1 and 2 groundwater flow around the pile wall toe has been neglected. This assumption is only correct if the bottom layer is much less pervious than the wall. If this is not the case, then the water flow both trough and around the wall needs to be considered. This is done with the aid of a 2D-seepage calculation program like Slide or Plaxis. Due to the fact that these programs deal with Darcy's flow type only, the behaviour of the steel sheet pile wall has to be treated as a porous media flow, using an equivalent diaphragm wall defined by its thickness <u>d</u> and its permeability <u>K_e</u>.

With <u>K_e</u> the designer is then able to:

1. ConFigure groundwater flow and flowrate along the pile foot, see Figure 3;
2. Estimate sinking of the groundwater level, see Figure 3;
3. Predict influence on groundwater level and perimeter or distance, se Figure 4;

Eurocode 7 article 9.4.1 (8), see Figure 13 states "*The resulting equilibrium ground-water flow problem shall be assessed*". The described method enables the designer to control this demand. Further investigation with Eurocode 7 Annex H "*Limiting values of structural deformation and foundation movement*" is also possible now.

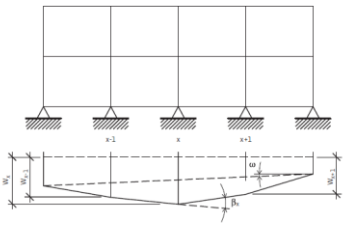


Figure 3: Deformation and movement EC7.

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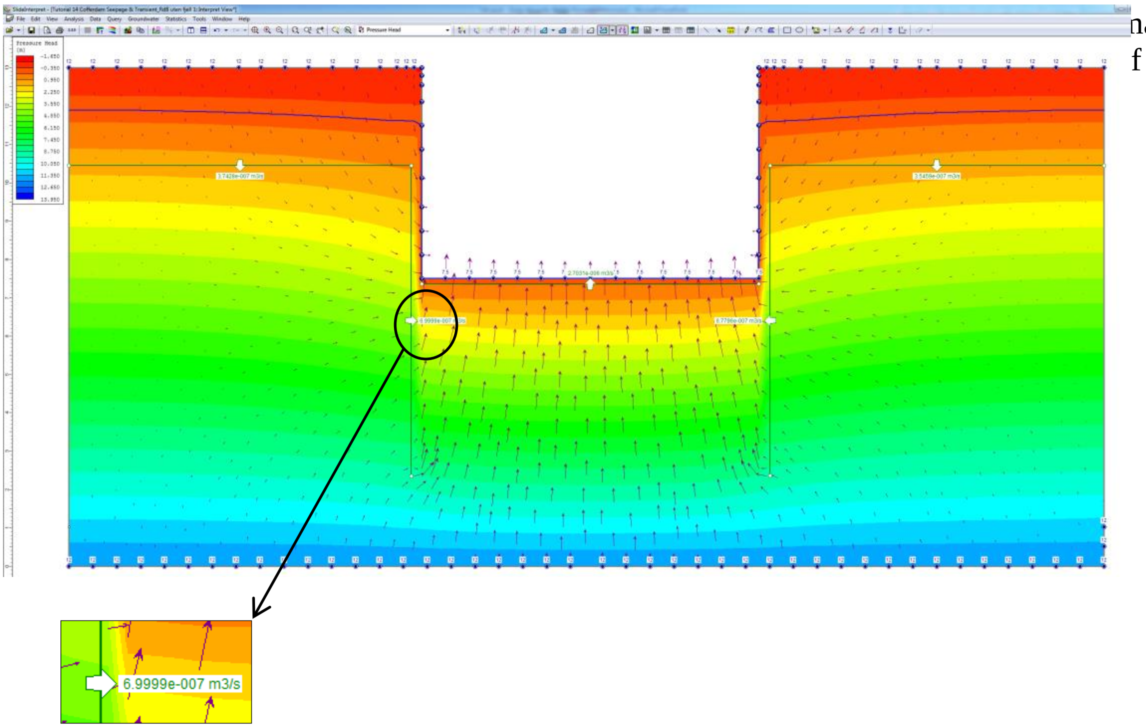


Figure 4: Configuring groundwater flow and estimation of sinking of the groundwater level.

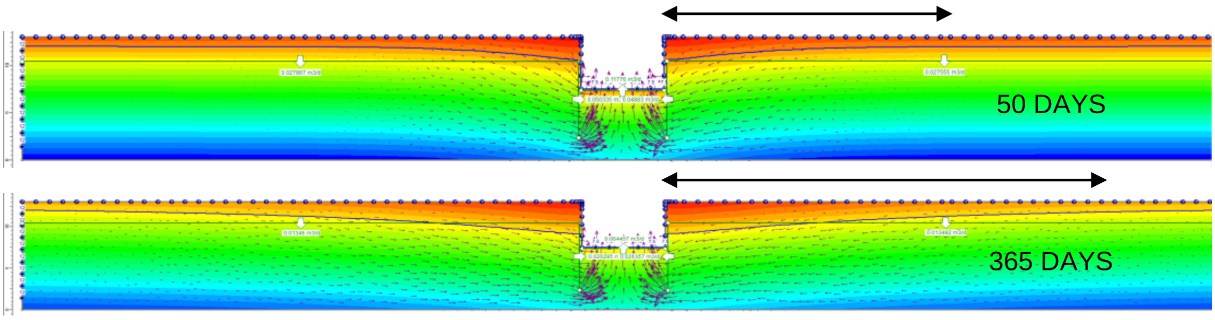


Figure 5: Prediction of influence on the groundwater level and perimeter or distance.

1.3 Reduce strength and stiffness U-piles

U-shaped piles with treaded interlocks contain less sectional modules and stiffness than ordinary piles. This phenomenon has been investigated by the European Coal and Steel Community to provide background for design guidelines to be included in Eurocode. Oblique bending has to be taken into account according Eurocodes:

- NS-EN 12063 art. 7.2.2 and 8.5.2;
- NS-EN 1997-1:2004:2008 art. 9.4.1(8);
- NS-EN 1993-5:2007/NA2010 art. 5.2.2.

Reduction factors which apply to this calculation method can lead up to 70% reduction in section modulus for U-shaped steel sheet pile with treaded interlocks according Tables in the English Eurocode,

Tabel NA.1 fra det tyske nationale anneks DIN EN 1993-5/NA, Dezember 2010.

Tabelle NA.1 — Abminderungsfaktoren β_B (Biegetragfähigkeit) und β_D (Biegesteifigkeit) für U-Bohlen

Bodenart Festigkeit/Konsistenz	Abminderungsfaktoren β_B	Abminderungsfaktoren β_D
	0,6	0,4
locker bis mitteldicht breiig bis weich[b]	0,7	0,6
dicht bis sehr dicht steif bis fest[c]	0,8	0,7
locker bis mitteldicht breiig bis weich[b]	0,8	0,7
dicht bis sehr dicht steif bis fest[c]	0,9	0,8
locker bis mitteldicht breiig bis weich[b]	0,9	0,8
dicht bis sehr dicht steif bis fest[c]	1,0	0,9

Table 1: Copy of BS NA EN 1993-5: DL National Annex to Eurocode 3.

Factors β_B (for strength) and β_D (stiffness) in the German and the Danish Eurocode include the same factors, see resp. Table 1 and 2.

Jordtype fasthed/konsistens	Reduktionsfaktor	
	β_B	β_D
	0,6	0,4
Løs til middel tæt lejret Meget blød til blød[2)]	0,7	0,6
Tæt til meget tæt lejret Stiv til fast[3)]	0,8	0,7
Løs til middel tæt lejret Meget blød til blød[2)]	0,8	0,7
Tæt til meget tæt lejret Stiv til fast[3)]	0,9	0,8
Løs til middel tæt lejret Meget blød til blød[2)]	0,9	0,8
Tæt til meget tæt lejret Stiv til fast[3)]	1,0	0,9

Table 2: Copy of BS NA EN 1993-5: DK NA to Eurocode 3: Design of steel structures.

Table NA.2 Reduction factors for U shaped sheet piles.

Type of U-pile unit	Number of structural support levels (see Note 1)	Reduction factors β_B and β_D referred to in 5.2.2 (2); (see Notes 2, 3, 4, and 5)			
		Highly unfavourable conditions (see Note 6)		Unfavourable conditions (see Note 7)	
		β_B	β_D	β_B	β_D
Singles or uncrimped doubles	0	0,40	0,30	0,50	0,35
	1	0,55	0,35	0,60	0,40
	>1	0,65	0,45	0,70	0,50
Crimped or welded doubles	0	0,70	0,60	0,75	0,65
	1	0,80	0,70	0,85	0,75
	>1	0,90	0,80	0,95	0,85

Table 3: Copy of BS NA EN 1993-5: UK NA to Eurocode 3: Design of steel structures.

Other Nordic countries like Sweden, Finland and Norway do not offer parameters for β_B and β_D, see Figure 6 for the Norwegian Eurocode. This needs further research and updating.

NS-EN 1993-5:2007/NA:2010
Nasjonalt tillegg NA

NA.5.2.2 Spunt i bøyning og skjær

NA.5.2.2(2) Dette nasjonale tillegget angir ingen verdi for β_B basert på lokal erfaring.

NA.6.4 Konstruksjonsmessige hensyn for stålspunt

NA.6.4(3) Dette nasjonale tillegget angir ingen verdi for β_D.

Figure 6: Copy from NS-EN 19935:2007/NA: 2010. Eurocode 3; Part 5: Piles.

1.4 Reduced overall bending resistance

In the case of differential water pressure exceeding 5 m head for Z-piles and 20 m for U-piles the effects of water pressure on transverse local plate bending should be taken into account to determine the overall bending resistance, see Table 4:

- NS-EN 1993-5:2007/NA2010 art. 5.2.4

Table A-3: Reduction factors ρ_P for plate thickness due to differential water pressure

w	$(b/t_{min})\ \varepsilon = 40{,}0$	$(b/t_{min})\ \varepsilon = 60{,}0$	$(b/t_{min})\ \varepsilon = 80{,}0$	$(b/t_{min})\ \varepsilon = 100{,}0$
1,0	0,99	0,98	0,96	0,94
2,5	0,98	0,94	0,88	0,78
5,0	0,95	0,86	0,67	0,00
7,5	0,92	0,75	0,00	0,00
10,0	0,88	0,58	0,00	0,00

Key:

b is the width of the flange, but b should not be taken as less than $c/\sqrt{2}$, where c is the slant height of the web;

t_{min} is the minimum thickness of flange or web;

w is the head of differential water pressure in m;

$\varepsilon = \sqrt{\frac{235}{f_y}}$, with f_y in N/mm²

Note: These values apply to Z-piles and are conservative for Ω- and U-piles. An increase of ρ_P is possible (for instance if interlocks are welded), but an additional investigation is then necessary.

Table 4: BS NA EN 1993-5- Table A-3.

Transverse bending is a relatively newly recognized mode of failure in sheet piling. Although it interacts with classical bending, it is a separate failure mode of its own.

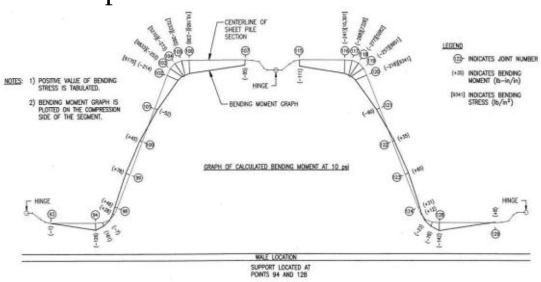


Figure 8: transverse loading on sheet pile.

See Figure 8. In essence, the lateral pressure is flattening the sheet; the plate bending at the corners is the resistance of the sheeting to this flattening.

1.5 Control of driveability

Requirements on driveability are set in Eurocode:

- NS-EN 1997-1:2004-NA:2008, art. 9.4.1
- NS-EN 12063 art. 5.2.1, 5.2.2 and 8.5.

These demands need further investigation in order to reduce the chance of damage and to avoid sheet piles coming out of their locks. The change on declutching is less with U-piles than with Z-shaped steel sheet piles.

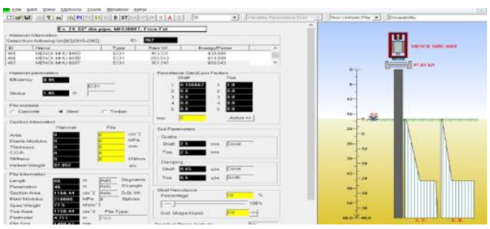


Figure 9: Driveability prediction GRL-Weap

1.6 Proportional contribution leakage

Leakage into building pits often occur as a result of following causes, shown in fig.10:

1) Through the sheet pile wall;
2) Trough and along the anchors;
3) Up along the outside of bored piles;
4) Through cracks and fractures in bedrock.

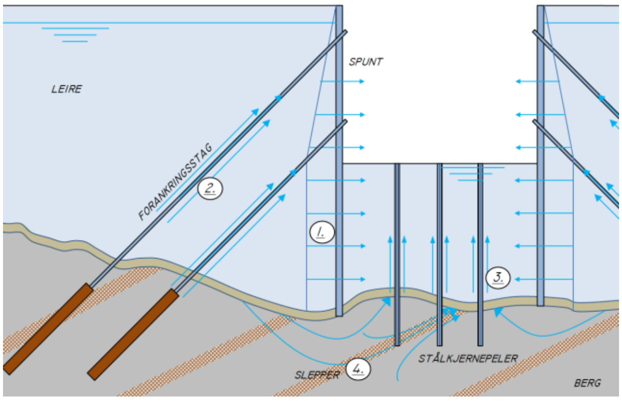


Figure 10: 4 types of leakages.

Modelling these last 3 types of leakage is possible by using Darcy's law, as used for modelling seepage with steel sheet walls. The models are represented in Figure 11 to 13.

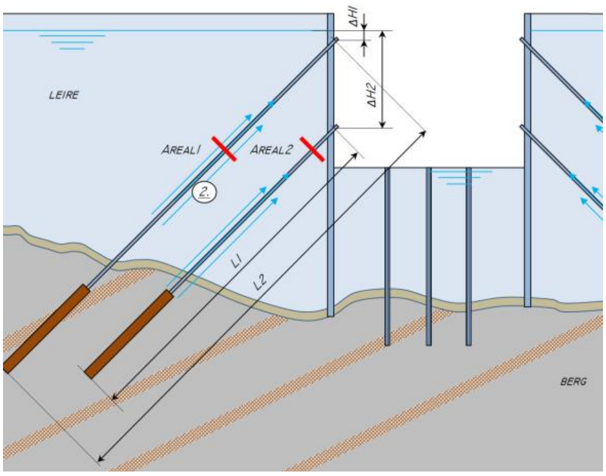


Figure 11: Leakage along / trough anchors.

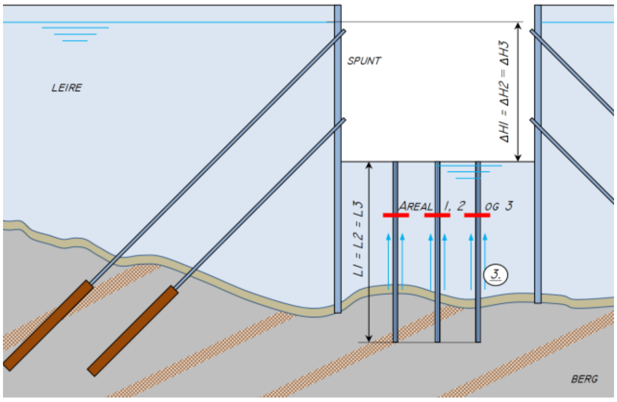


Figure 12: Leakage along bored piles.

Groundwater flow along rammed piles can be calculated using (Darcy's law based) models developed for rammed piles through contaminated landfills, see ref. /8/ and /9/. Leakage trough bedrock can be modelled with (Darcy's law based) models for cracks as plates or channels see ref. /11/.

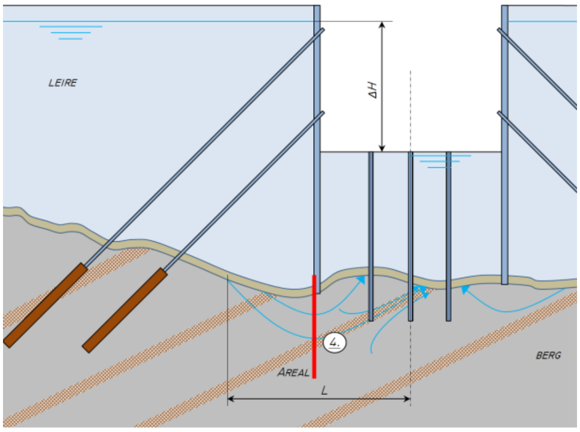


Figure 13: Leakage through cracks and fractures in the bedrock.

Insight into contribution of steel sheet walls compared to other leakage types is shown in Table 5. This approach allows the designer to conFigure the building pit: rammed piles instead of bored piles, struts instead of anchors or extra measures as jet piling.

PERCENTAGES OF DISTIBUTION OF LEACKAGE	4 types of leakage	Rammed piles instead of bored piles	Struts instead of ground anchors
	(%)	(%)	(%)
Trough steel sheet walls	5 – 20	25 – 80	93 – 98
Trough and along ground anchors	5 – 25	15 – 75	0
Trough and along bored piles	65 – 95	0	0
Through cracks / fractures in bedrock	0,1 – 5	2 – 10	2 – 7
Numbers calculated with $K_{\text{cracks in bedrock}} = 2\cdot10^{-6}$(m/s), $K_{\text{along bored piles}} = 1\cdot10^{-2}$(m/s) og $K_{\text{along anchors}} = 1\cdot10^{-2}$(m/s) $Q_{\text{total discharge}}$ = 3 - 20 (m^3/time/1000m^2), groundwater flow along bored piles presumed coming under pile foot.			

Table 5: Proportional distribution of leakage types.

1.7 Tightening in relation to demands

Eurocode 7 refers to “required degree of water tightness of the finished wall”, see Figure 14. There are no defined limits for this degree in Norway.

9.4 Design and construction considerations

9.4.1 General

(8)P The design of retaining structures shall take account of the following items, where appropriate:

— the required degree of water tightness of the finished wall;

— the practicability of constructing the wall to reach a stratum of low permeability, so forming a water cut-off. The resulting equilibrium ground-water flow problem shall be assessed;

Figure 14: Demand on tightness EC 7 art. 9.4.1 (8).

In Germany execution took place of more than a hundred building pits between 1993 and 2000. Authorities responsible for groundwater came to a limit for permissible daily leaking water rates into building pits, see Table 6 ref./6/ and /7/.

Bauwerksart	Leckagerate	
	l/sec je 1.000 m²	m³/h je 1.000 m²
Bauwerke und Baugruben mit normalen Dichtigkeitsanforderungen	1,5	5,4
Bauwerke wie Klasse N, jedoch mit hohen Dichtigkeitsanforderungen	0,05	0,18
Bauwerke wie Klasse N, jedoch mit geringen Dichtigkeitsanforderungen	2,5	9,0

Table 6: Tightnessklasses after Kluckert /6/

These tightness classes were in addition defined as a <u>contractually results obligation</u>: bound to a reference area: 1000m2. This was done to avoid contractual matters with entrepreneurs. The same way as done with tightness classes for tunnels (litre/min/100m). Besides this, the number for permissible daily leaking water rates into building pits is not related to hydraulic head. Tightness classes for building pits in Norway are not yet developed, however tightness classes for tunnels are, see Table 7 from Publication 103 of the Norwegian Public Roads Administration.

3.1 Krav til tetthet og tetthetskriterier
Ekstremt strengt < 1–3 liter pr. minutt pr. 100 m tunnel
Strengt < 3–7 liter pr. minutt pr. 100 m tunnel
Middels strengt < 7–15 liter pr. minutt pr. 100 m tunnel
Moderate krav > 15 liter pr. minutt pr. 100 m tunnel.

Table 7: Permissible leakage water rates in Norwegian tunnelling for diameter 8,5m.

Tightness classes for German tunnels are also defined, see Table 8, ref. /6/.

Tightness Class	Moisture Characteristics	Intended Use	Permissible Daily Leakage Water Quantity (l/sq. m), Given a Reference Length of:	
			10 m	100 m
1	2	3	5	6
1	Completely dry	Storerooms and workrooms, restrooms	0.02	0.01
2	Substantially dry	Frost-endangered sections of traffic tunnels; station tunnels	0.1	0.05
3	Capillary wetting	Route sections of traffic tunnels for which Tightness Class 2 is not required	0.2	0.1
4	Weak trickling water	Utility tunnels	0.5	0.2
5	Trickling water	Sewage tunnels	1.0	0.5

Table 8: Permissible leakage water rates in German tunnelling, use and length related.

Both tunnels and building pits can create groundwater drainage with similar effects on the surrounding area and environment: settlement of buildings due to groundwater level change etc. This makes a comparison possible between the 3 known tightness classes: German and Norwegian tunnels and German building pits, in order to estimate a tightness class for Norwegian building pits. Next to this the following factors were taken into account:

- Measured leakages in Norwegian pits;
- Leakages in building pits abroad;
- Sensitivity analyses on leakage limits;
- Comparison with drainage engineering;
- Compliance on groundwater restrictions;
- Engineering judgement.

A Table with permissible leakage rates and tightness classes for building pits in Norway is defined in Table 10 and was presented on the "Geoteknikkdag 2015". With these proposed requirements the demand in Eurocode 7 art. 9.4.1 (8), see Figure 14, are fulfilled and it is now possible for the designer to combine the models shown in Figure 11 to 13 with the newly defined limit.

Proposal for permissible leakage for Norwegian building pits		
Class	**Permissible leakage (m^3/time/1000m^2)**	**Functional demands**
Extremely strict	**0,5 – 2**	Sensitive environment
Strict	**2 – 6**	Moderate sensitive
Average	**6 – 12**	Moderate sensitive / Construction dependent
Moderate	**> 12**	Construction dependent

Table 9: Proposal for permissible leakage water rates for Norwegian building pits.

The designer can also estimate the discharge which belongs to a number of bored piles or anchors and hydraulic head towards the limits from Table 6 or Table 9, see Figure 15 and 16.

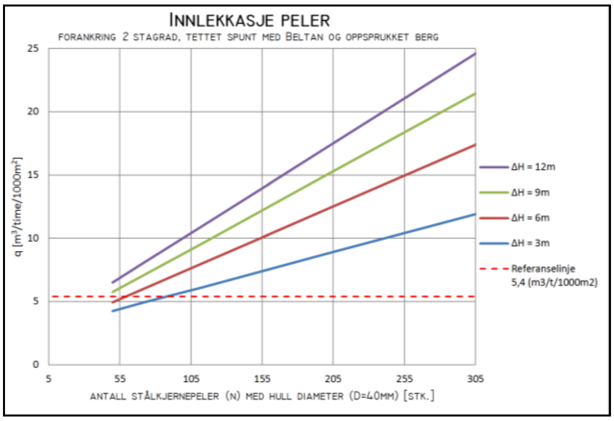


Figure 15: Discharge with bored piles.

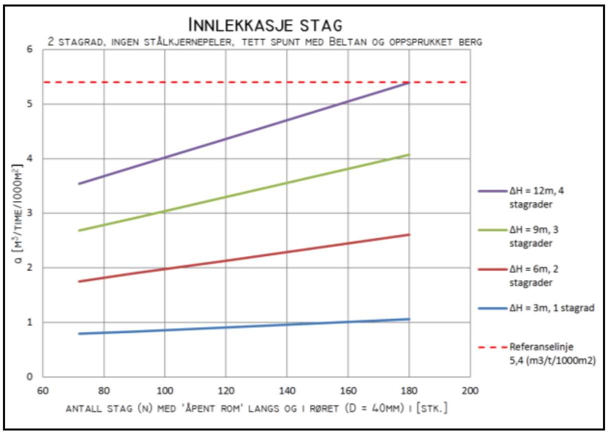


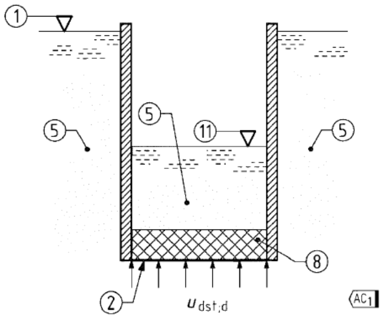
Figure 16: Discharge along anchors.

Figures 15 and 16 are also sensitivity analyses of the defined limit of the permissible leakage: 5,4 m^3/hour/1000m^2.

1.8 Hydraulic failure

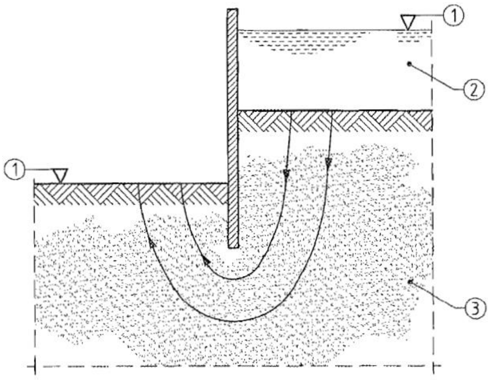
Eurocode 7 applies to four modes of ground failure induced by pore-water pressure or pore-water seepage, which shall be checked:

- failure by uplift: EC 7 -2.4.7.4 / 10.2;
- failure by heave: EC 7 – 2.4.7.5;
- failure by internal erosion: EC 7 – 10.4(1)
- failure by piping: EC 7 – 10.5



d) Execution of a slab below water level

Figure 17: Uplift.



1 excavation level (left); free-water level (right)
2 water
3 sand

Figure 18: Heave.

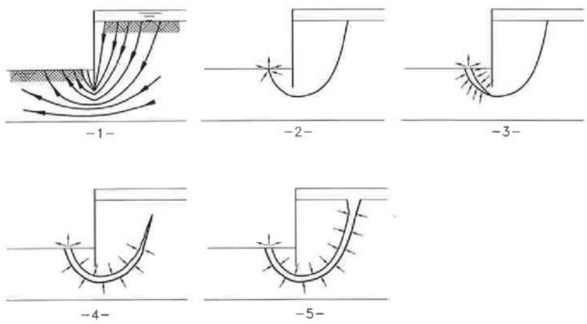
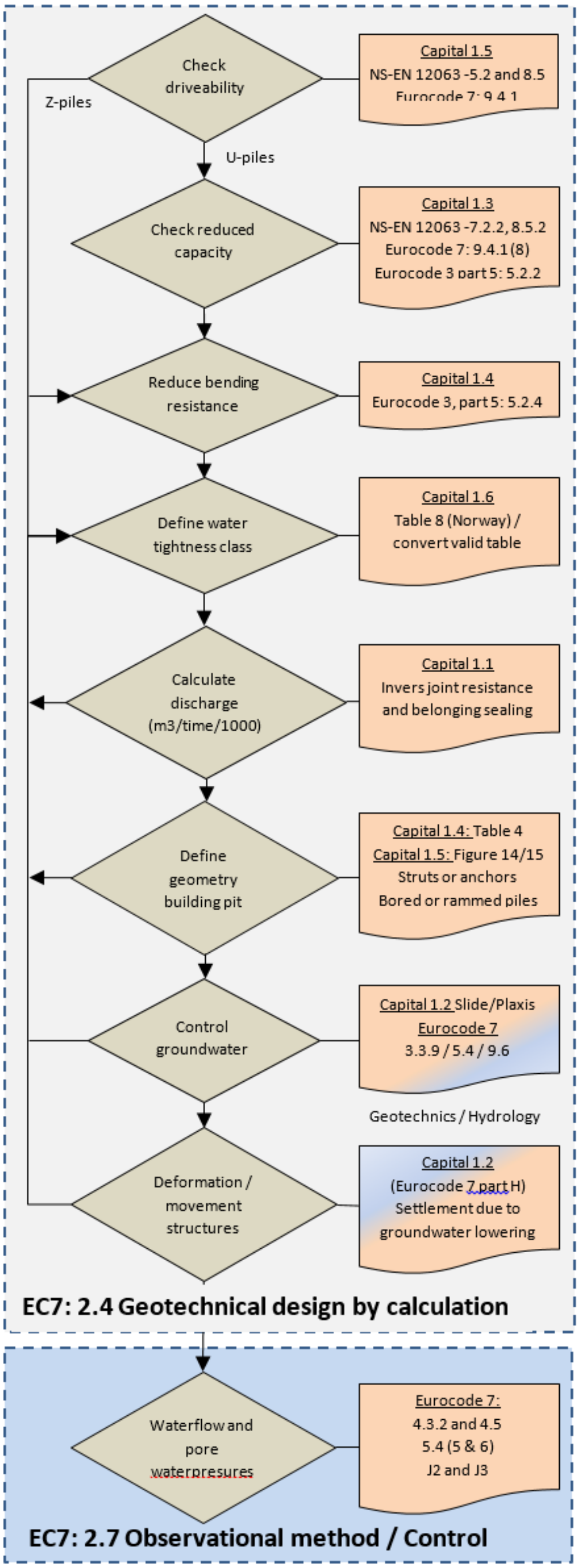


Figure 19: Development of piping.

1.8 Engineering proces for tightness

Engineering a tight building pit is a proces with a number of steps. In order to place the belonging steps in the proper way one can folow the proposed flow chart, after designing length and profile of the sheetpile:



Flow chart 1: engineering tightness in steps.

2.0 Driving with vibrator or drop hammer

In general, both Hoesh and Arcelor Mittal recommend percussively driving.

> It is essential not to overdrive sealed sheet piles with a vibratory hammer as the heat generated by vibro driving may cause the sealant to decompose or burn. If hard driving or refusal is encountered it is recommended that vibro driving ceases at once. The pile should then be driven to level with an impact hammer.

Figure 20: Recommendations on pile driving equipment «Piling handbook» ArcelorMittal.

> **Piledriving instructions**
> Selecting the driving process:
> For preference, piles featuring the HOESCH interlock sealing system should be installed by percussive driving. If circumstances allow, it is also possible to use the vibration driving process.

Figure 21: Recommendations on pile driving equipment: «Piling handbook» Hoesch.

> **Instructions for pile driving**
> Decide on the direction of driving for filled sections at the planning stage. Sheet piling filled with SIRO 88 should be preferably driven with a vibrator, while sheet piling filled with bitumen-based grout should be percussively driven.

Figure 22: Recommendations on pile driving equipment: «Piling handbook» Hoesch.

Control engineers need this information and a way is to take this on working drawings.

2.1 Penetration rate with pile installation

The supplier gives recommendations on minimum penetration rate with vibrodriving. Slow speed gives more energy to the steel sheet wall with viscus sealing as a result that drips out of the interlocks.

> **Piledriving instructions**
> Selecting the driving process:
> For preference, piles featuring the HOESCH interlock sealing system should be installed by percussive driving. If circumstances allow, it is also possible to use the vibration driving process.
> For this, the ground must have good vibrating properties; driving progress must be continuous and no slower than 10 seconds per metre. If it takes longer than this to install the pile, or progress is interrupted, it is better to continue using percussive equipment.

Figur 23: Recommendations on pile driving speed «Piling handbook» Hoesch.

2.2 Puling steel sheet piles

With pile driving it is usual and common to sporadically pull a pile in order to check the condition of the pile foot or to correct the angle of the piles. In this case he sealing should be repaired or the pile should be replaced by a new pile with sealing. See Figure 24.

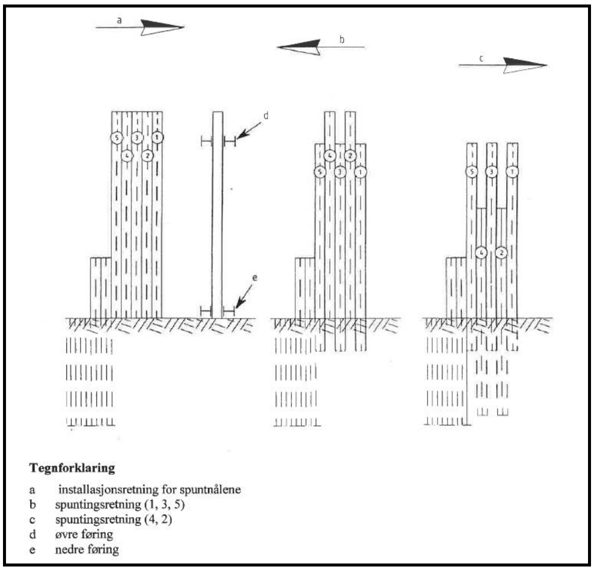
> To ensure good joint integrity it is important to control the alignment of the piles in both the horizontal and vertical planes but excessive corrective actions can damage the sealants. If it is necessary to remove a pile then suitable repairs should be carried out to the sealant before reuse. If repair is not practical, withdrawn piles should be replaced by new ones.

Figure 24: Recommendations on pile driving equipment «Piling handbook» ArcelorMittal.

Eurocode NS-EN 12063:1999, article 8.11 handles about puling steel sheet piles

2.3 Ramming method

It is important that steel sheet walls with sealing are installed on a proper way. Eurocode NS-EN 12063 supplement D gives guidelines on ramming methods, see Figure 25.

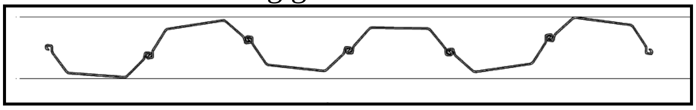


Figur 25: Supplement D Figure D1 from NS-EN 12063:1999.

Different methods for ramming steel sheet piles and guidelines are also available with the supplier: «Panel driving» og «Staggered driving». See also Figure 29. The proper method should be described on the working drawings and in the contract.

2.4 Driving guides

In order to prevent scraping of the sealing while ramming by piles which are twisted, see Figure 27, the supplier gives guidelines on the use of "driving guides".



Figur 26: Change on scraping of sealing.

Eurocode NS-EN 12063 article 8.5.8 and 8.5.9 also gives instructions and guidelines on use of driving guides for ramming.

> 8.5.8
>
> Spuntnålene bør ledes på ett eller flere nivåer under spuntingen.
>
> 8.5.9
>
> Føringsrammer bør være stabile og robuste og montert på nivåer som sikrer at spuntnålene holdes i riktig horisontal og vertikal stilling under spuntingen. Føringssystemet bør være konstruert for å unngå skade på overflatebelegget på spuntnålene (for eksempel ved å bruke føringsruller).

Figur 27: 8.5.8 and 8.5.9 NS-EN 12063:1999

2.5 Driving direction

Driving direction of steel sheet piles is dependent on type of sealant, type of steel sheet pile: U- or Z-shaped, single or double pile and the phenomenon's «Piles lagging» or «Piles leading», se Figure 28 and 29.

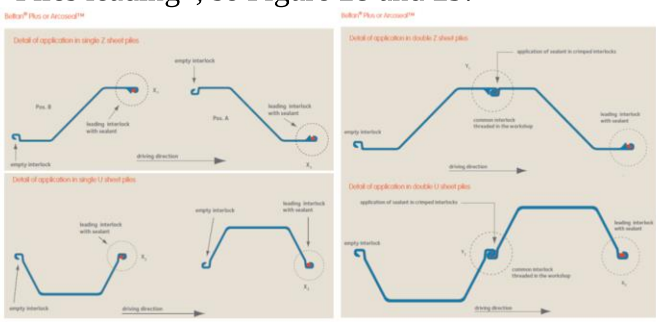
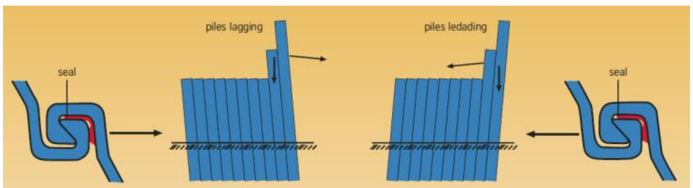


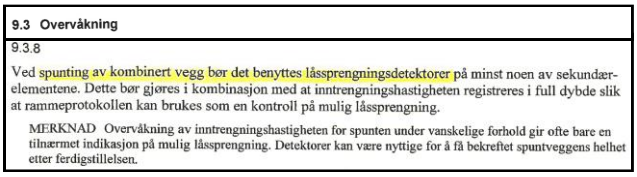
Figure 28: Directions from ArcelorMittal.



Figur 29: Directions «Piles lagging» / «Piles leading» from Hoesch Piling handbook.

2.6 Declutching detector

Declutching detectors can be used in soils that are technically difficult for driving, in order to guarantee a perfect hooking between interlocks. Requirements on monitoring sheet pile driving are given in Eurocode NS-EN 12063 article 9.3.8, see Figure 30. There are several suppliers of different systems for declutching detectors.



9.3 Overvåkning

9.3.8

Ved spunting av kombinert vegg bør det benyttes låssprengningsdetektorer på minst noen av sekundær-elementene. Dette bør gjøres i kombinasjon med at inntrengningshastigheten registreres i full dybde slik at rammeprotokollen kan brukes som en kontroll på mulig låssprengning.

MERKNAD Overvåkning av inntrengningshastigheten for spunten under vanskelige forhold gir ofte bare en tilnærmet indikasjon på mulig låssprengning. Detektorer kan være nyttige for å få bekreftet spuntveggens helhet etter ferdigstillelsen.

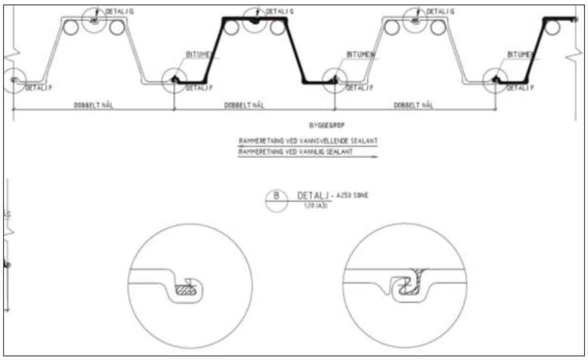
Figur 30: pkt.9.3.8 NS-EN 12063:1999

2.7 Working drawing

In Norway steel sheet piles are equipped with steel pipes in order to be able to bore trough these pipes after installation of the piles. This boring is done to install a bolt and therefore secure the foot of the pile. This occurs on the “dry side”. However, as Figure 31 shows, the steel sheet pile supplier connects at the factory first the two single piles into one double pile, before the sealing is applied.

Figure 31: Sealing (Arcoseal) project Bjørvikatunnel – Havnelageret.

This implies that the sealing also is placed at the so called ”dry side” of the pile, given water the possibility to push the sealing out. Sealing should always be on the ”wet side” of the wall. Figure 32 shows proper details on a working drawing.



Figur 32: Details on working drawing.

Conclusion

For the moment there are no tightness classes for building pits in Norway. The suggested method in the different chapters and proposed Table 9 is meant as a tool towards the designer and engineer to come to a tight building pit or retaining wall.

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