



Masthuggskajen

Construction of peninsula

Masthuggskajen, General



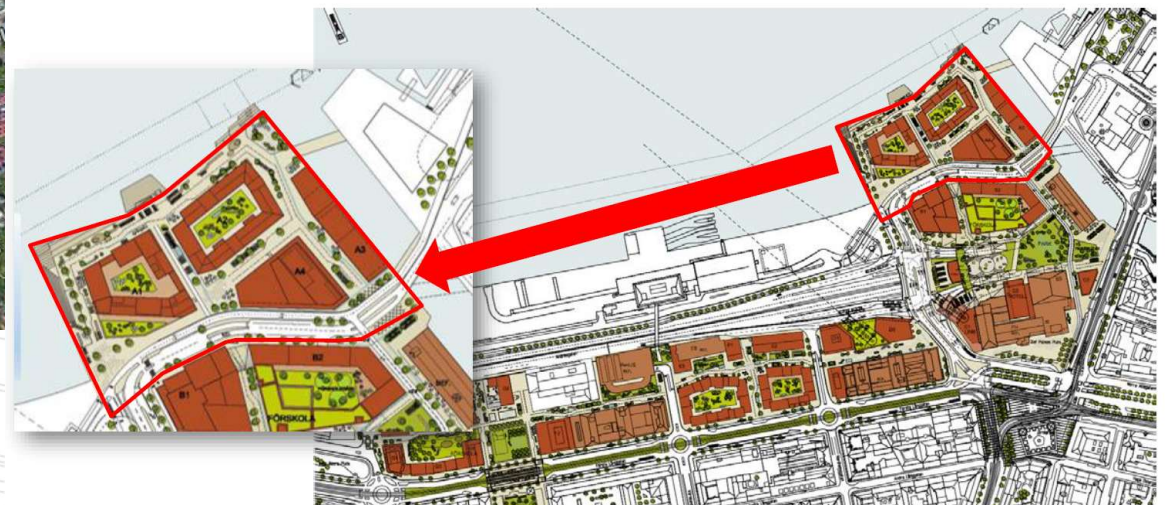
The peninsula will be approximately 200 meters wide and will extend approximately 100 meters into the Göta River. The construction involves construction work in deep soft clay with high technical complexity. It includes dredging, piling (sheet piles and piles), underwater casting, concrete pile deck, foundations, basement, quay structure, sewage work etc.



Masthuggskajen is located near Stena Line's "Danmarkskaj" in central Gothenburg, a couple of kilometers from the mouth of the Göta River .

The project is a building development project and is offered as a total undertaking (mainly design & build). Contract Sum SEK 1,35 billion.

The project started May 2022 with a hand-over of the overall project October 2025



Masthuggskajen, General



Division:

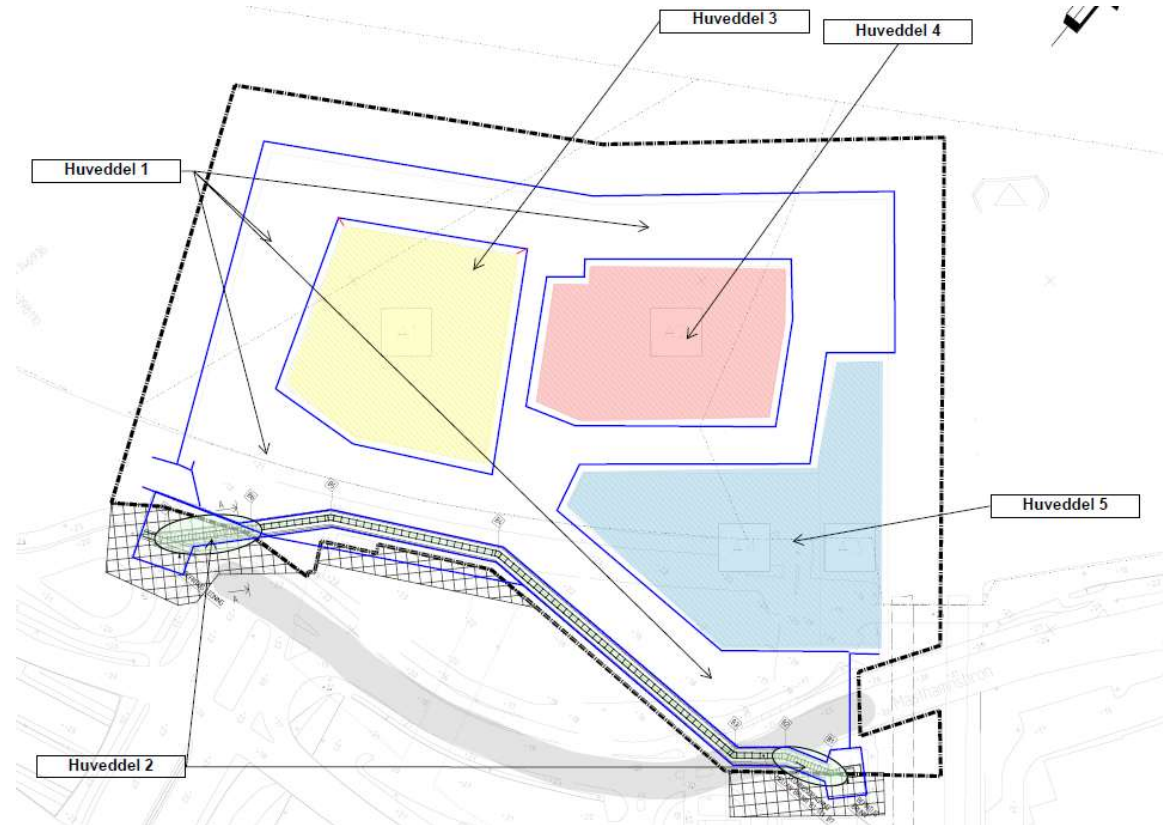
Huvuddel 1: Public area (pile deck) and Quay Wall

Huvuddel 2: New sewage line

Huvuddel 3: Construction pit/piles for building A1

Huvuddel 4: Construction pit/piles for building A2

Huvuddel 5: Construction pit/piles, foundations and 2-storey basement for building A3 & A4 incl. P-basement.



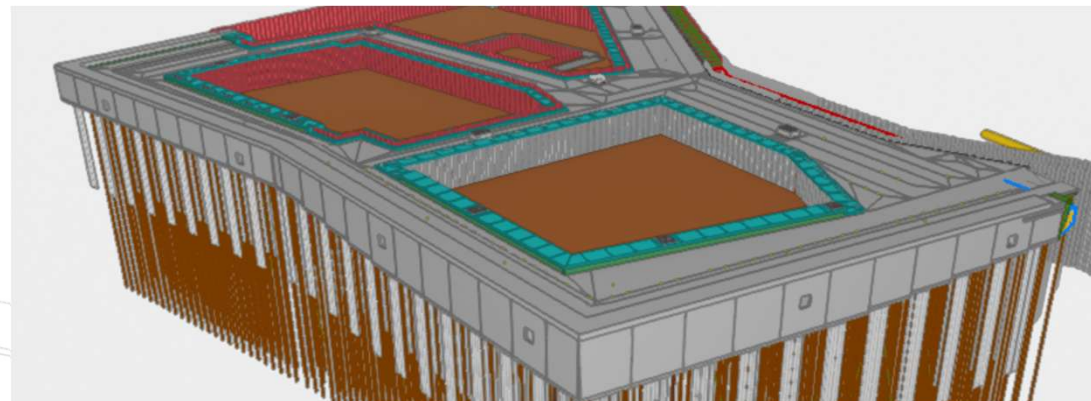
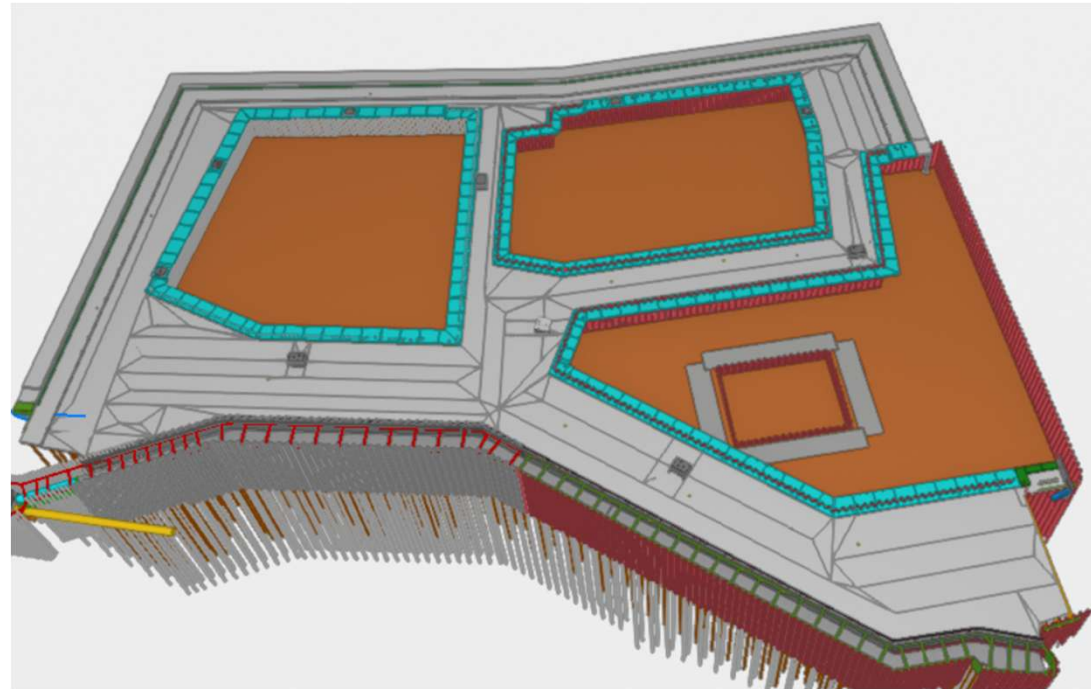
Masthuggskajen, Project description



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Main part (huvuddel) 1:

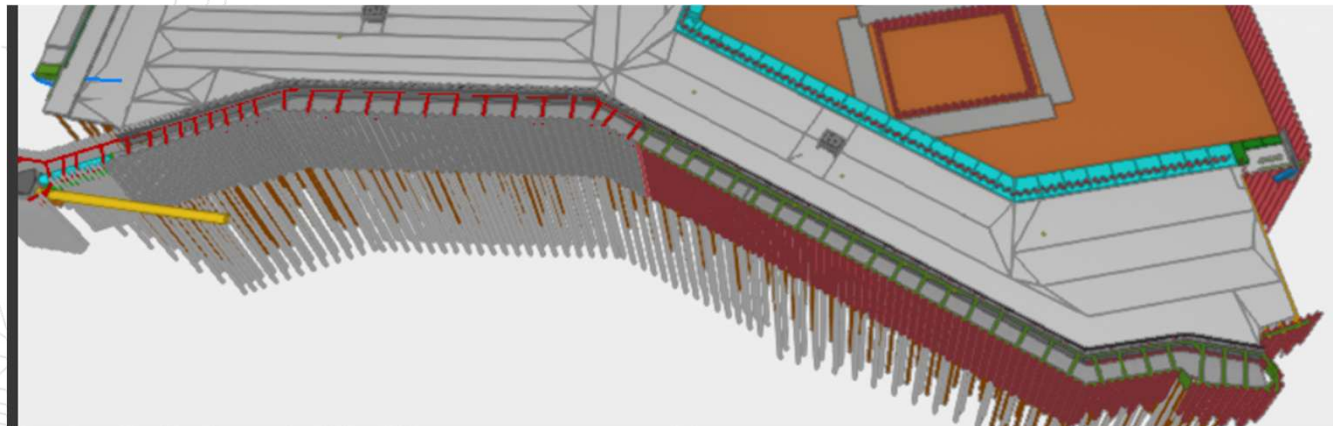
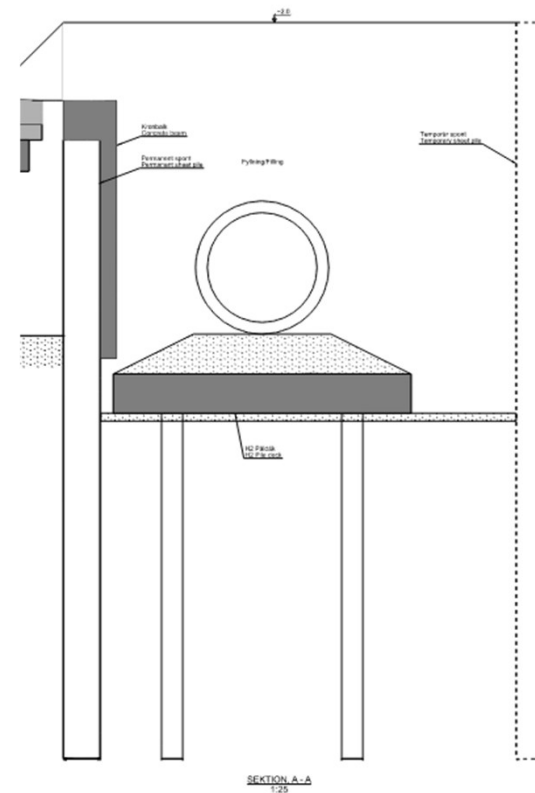
- Sedimentation protection , consisting of 400m of sheet piling around the peninsula
- Demolition of existing quay structures,
- Dredging in the river to app. level -7.
- Piles (concrete and steel) for concrete pile deck and quay structure, 1400 piles in total
- Concrete pile deck t = approx. 600mm around buildings, 8.000m³ of concrete
- Quay structure of precast L-elements around the peninsula. 35 large L-elements for the 400 m long quay front. Approximately 2000 m³ of concrete.



Masthuggskajen, Project description

Main part (huvuddel) 2 (Rerouting sewage line)

- Establishment of a new 230 m Ø1400 concrete line incl. 7 wells for diverting the waste water through the area. The sewage line must be connected to the existing system at both ends.
- 3.8 m wide concrete slab under sewage line, built on 150 piles
- Establishment of sheet piling on each side of the line. Northern pile wall is permanent and covered with a minimum of 200 mm of concrete.



Masthuggskajen, Project description

Main part (huvuddel) 3:



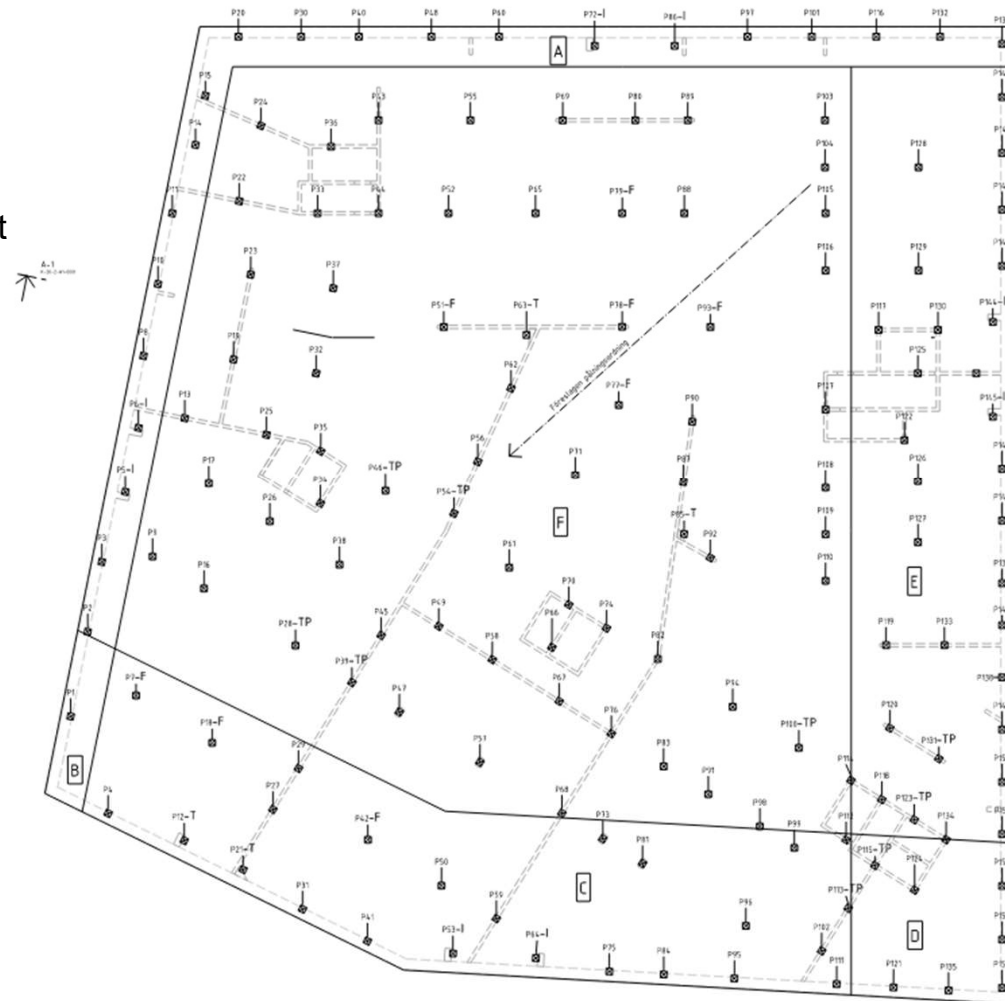
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Design:

- Pile loads and pile types given by Client
- Detailed design of piles, stability calculations, and sheet pile design is with Contractor.

Scope of Work:

- Dredging and filling with gravel.
- Sheet pile wall around the construction pit.
- 154 precast concrete piles 56 m long, including 8 Inclinator piles and 6 strain gauge piles
- Underwater concrete slab, emptying of water from pit



Masthuggskajen, Project description

Main part (huvuddel) 4:



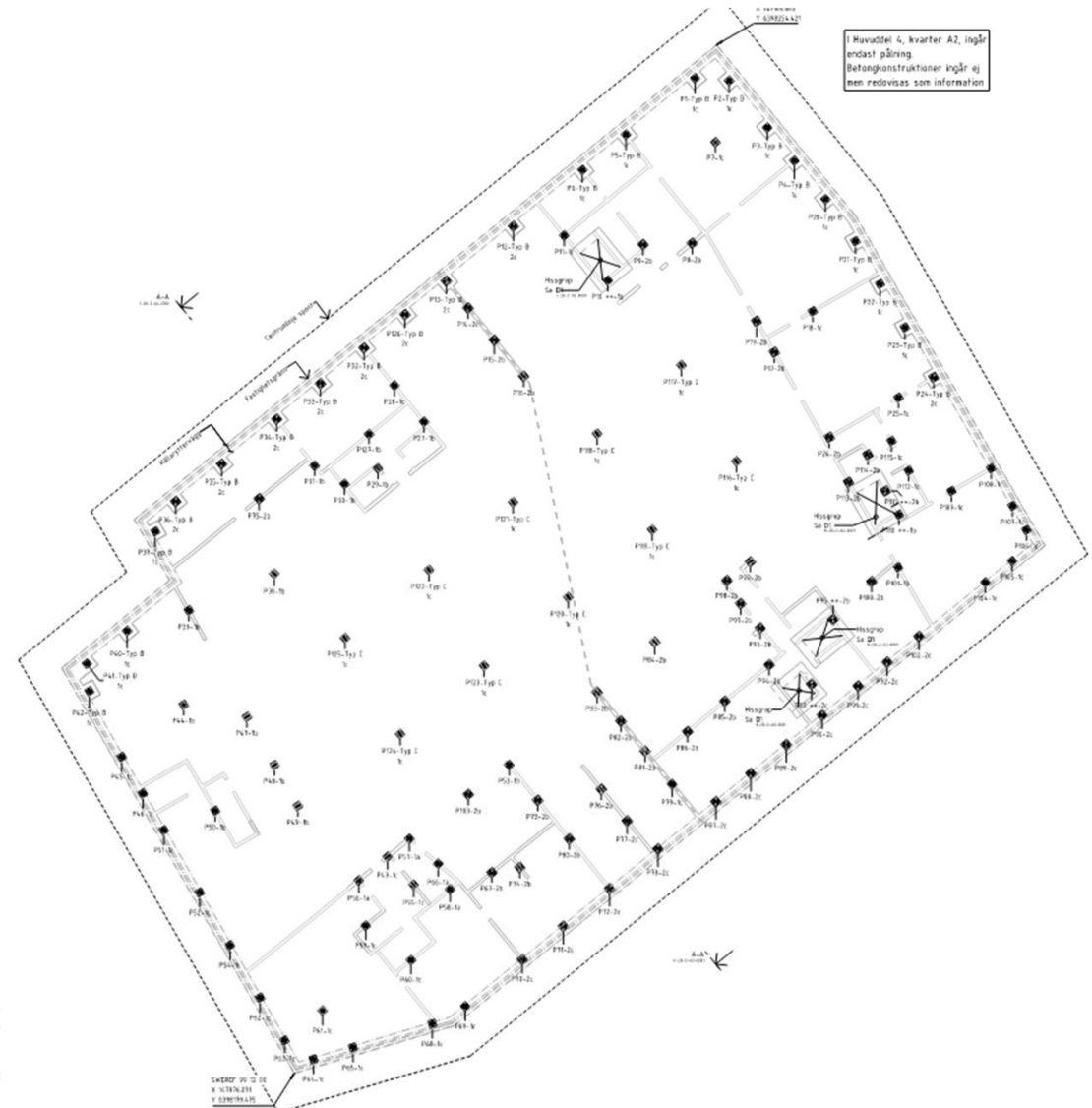
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Design:

- Detailed pile design given by Client
- Stability calculations, and sheet pile design is with Contractor.

Scope of Work:

- Dredging and filling with gravel.
- Sheet pile wall around the construction pit.
- Underwater concrete slab, emptying of water from pit
- 127 driven steel piles with open rock shoe in H4



Masthuggskajen, Project description



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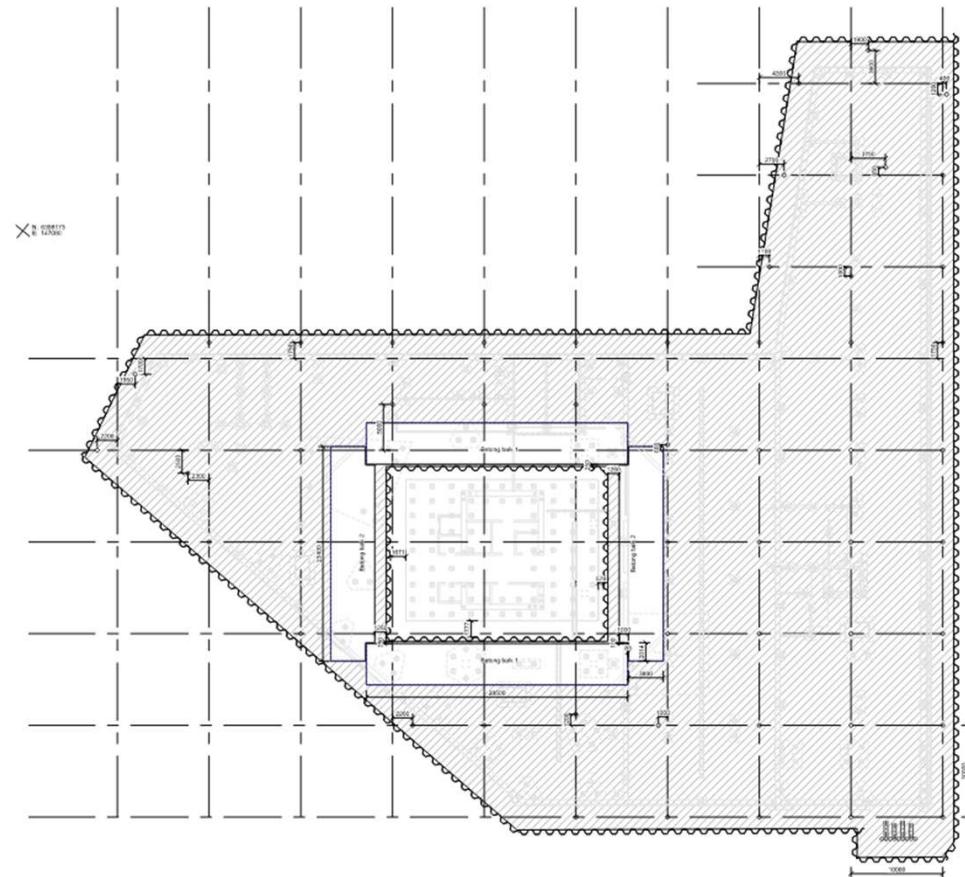
Main part (huvuddel) 5:

Design:

- Detailed pile design and concrete design for basement given by Client
- Stability calculations and sheet pile design is with Contractor.

Scope of Work:

- Dredging and filling with gravel.
- Demolishing existing quay wall within H5 footprint
- Sheet pile wall around the construction pit and H5 Core
- Underwater concrete slab and concrete beam around H5 Core
- Emptying of water from pit
- 306 steel piles drilled to rock.
- 2 storey basement incl. 9.000 m³ cast-in-place concrete, 5.000 m³ of precast concrete and electricity, plumbing, insulation of external walls, etc.

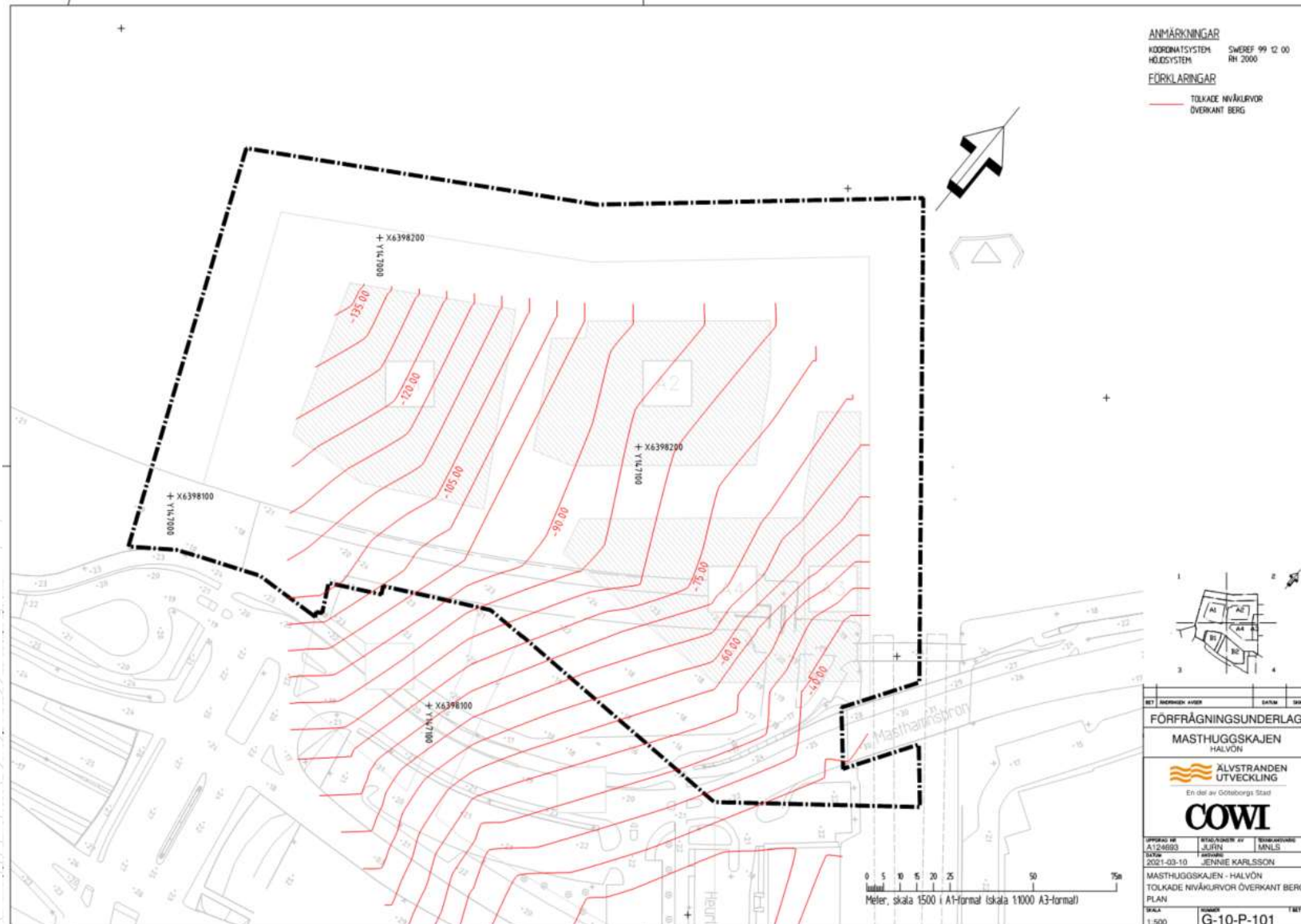


Masthuggskajen, Geotechnical Conditions

Levels – Rock



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Masthuggskajen, Geotechnical Conditions

Clay



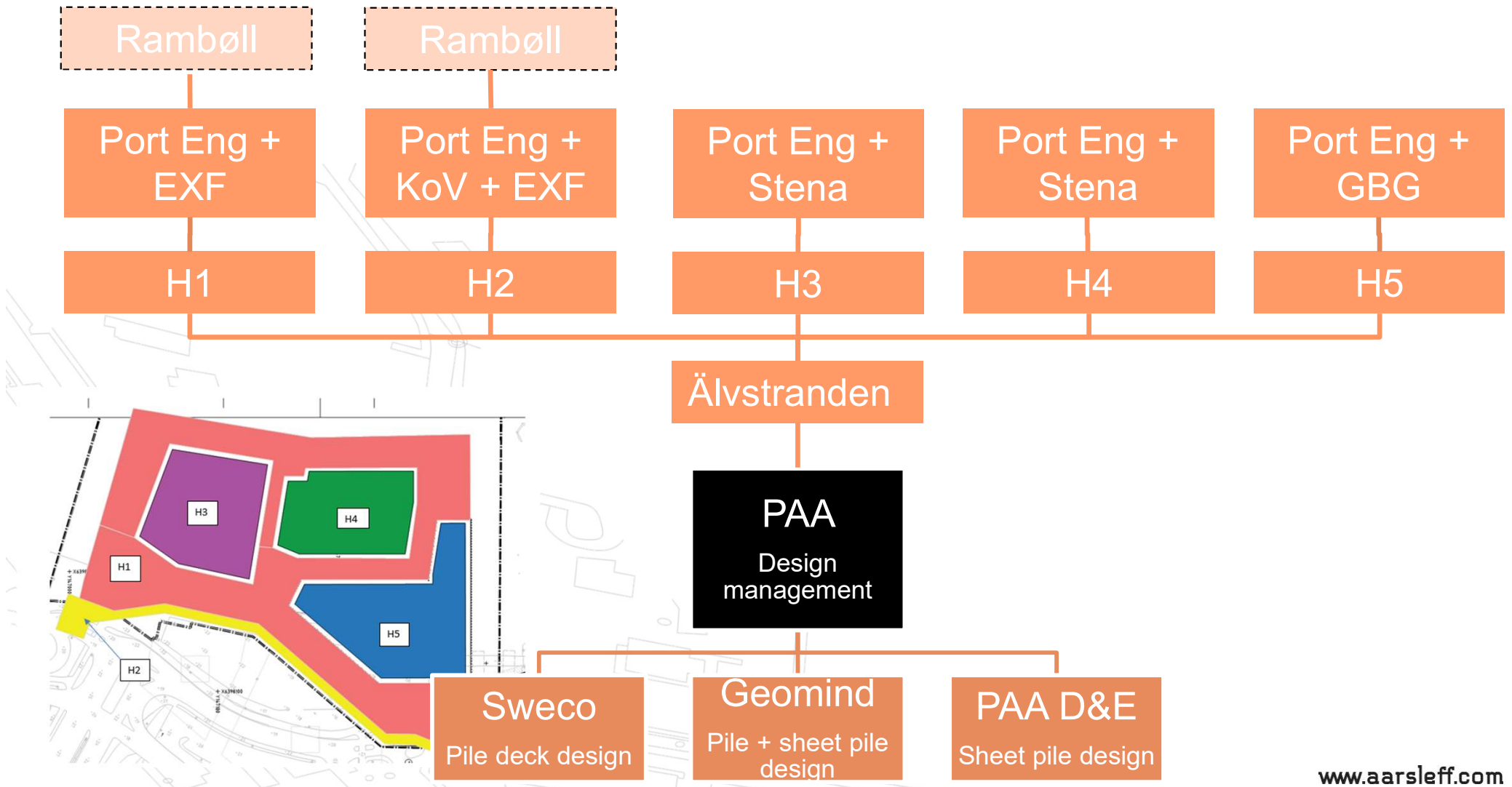
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- Soft clay
- Low undrained shear strength $C_u=5-25\text{kPa}$
- Up to 100m deep clay
- Displacement masses (pile driving) create movements due to the soft clay
 - Pile installation in construction pit H3, caused movement of entire construction pit H4
 - Displacement masses reduced by taking clay props
- Loading or unloading of clay (filling or excavation / dewatering)
 - Long term and short-term settlement
 - Heave
- Stability of excavations – large failure mechanism



Design Responsibility

- Split design responsibilities
- Many stakeholders to coordinate the design
- Complex matrix of design review

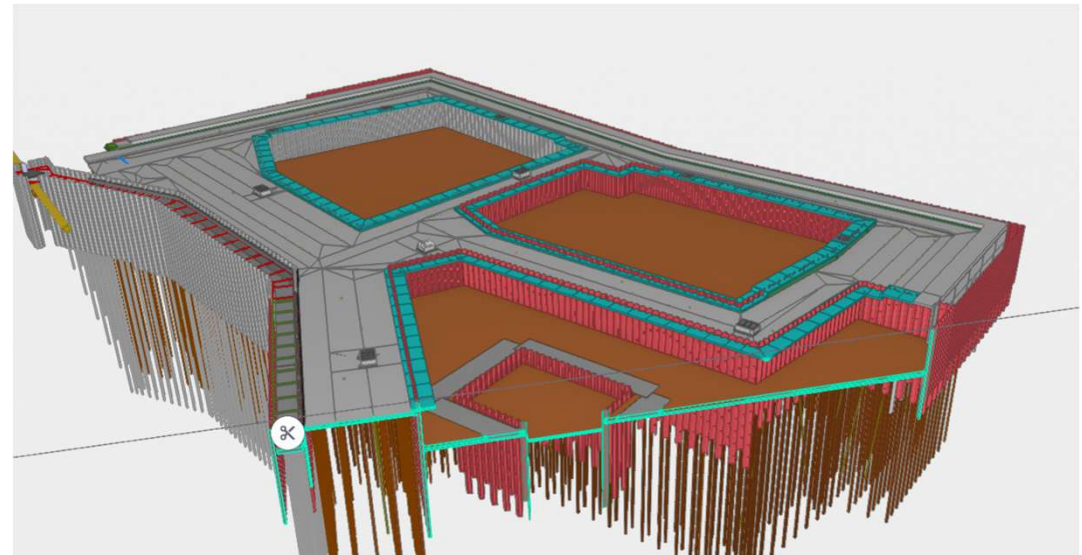


H5 Construction Pit Design

General design challenges



- Documentation of global stability
- Forced to use advanced FE analysis (2 material models in Plaxis)
- Strict deformation requirement of nearby structures
- Large failure mechanics
 - Work executed in one excavation pit introduce deformations in other excavation pits
 - Surface load on distance has influence on stability of the excavation pit
- On the edge of constructability
 - Design on limits
 - Have introduced strict/non allowed surface load inside the project area
 - Any change in sequence of works requires verification from design

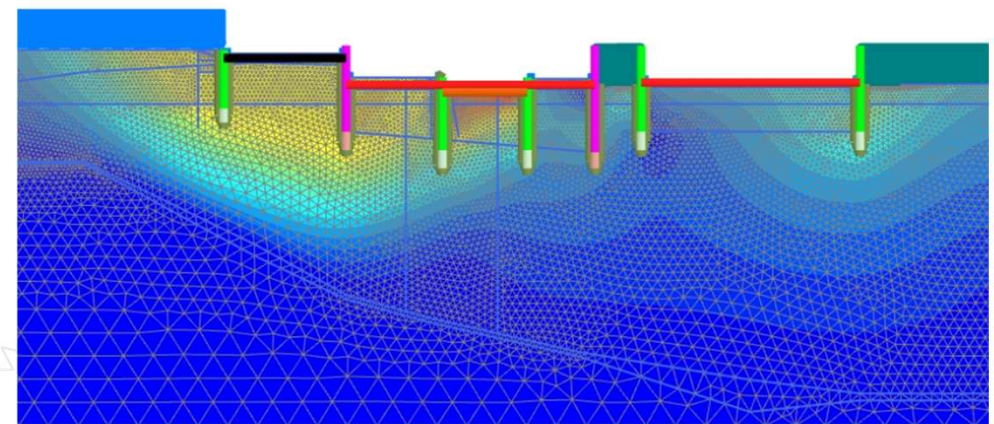
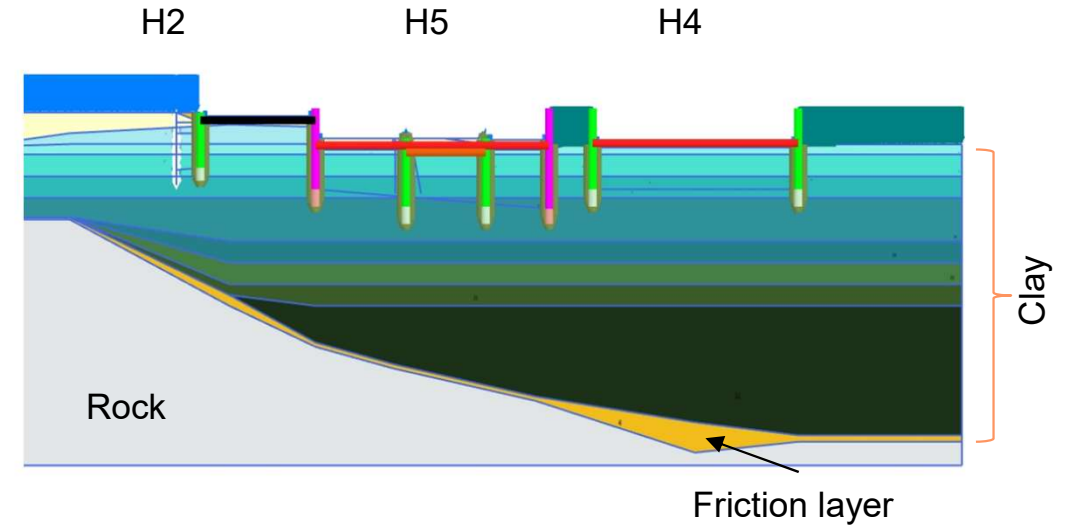


H5 Construction Pit Design

Global Stability



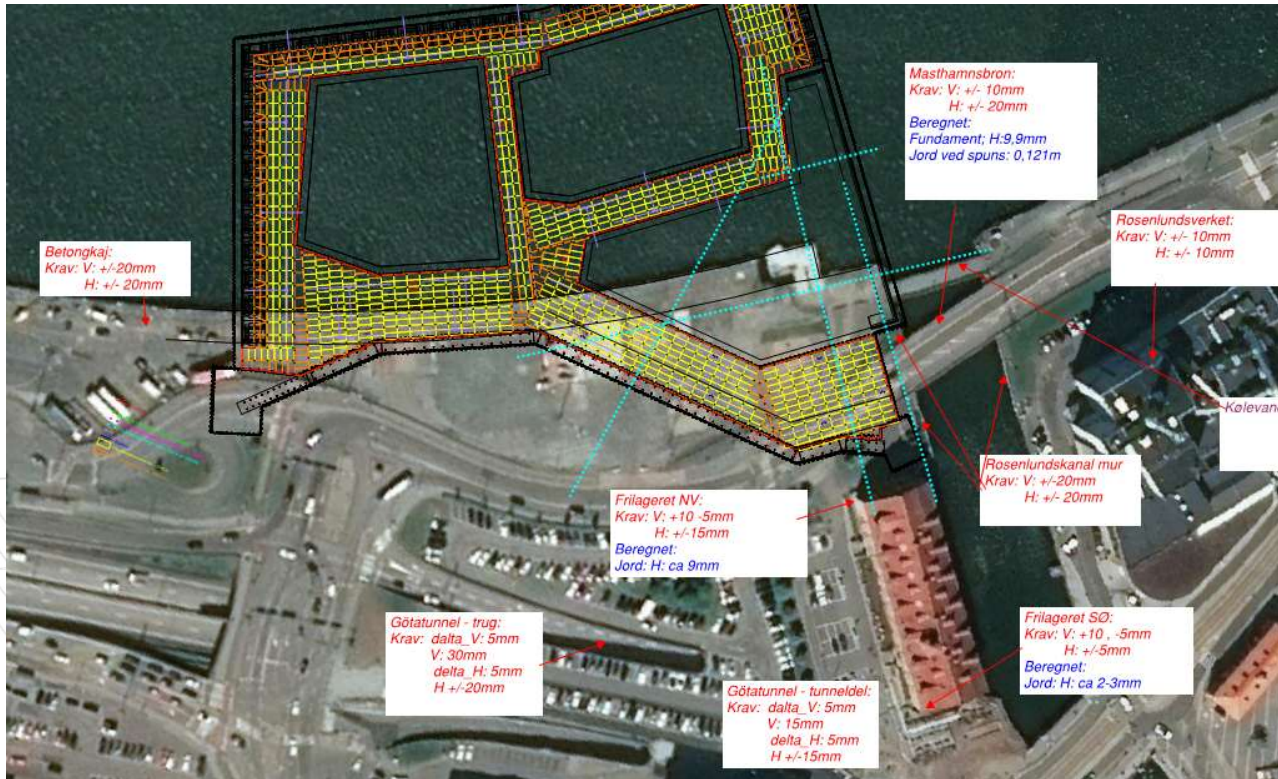
- Global stability of the area is decisive factor in the design
- Uneven earth pressure on H5 excavation pit
 - Pit located partly onshore – partly in river
- Large failure mechanics, Unloading (dredging and dewatering) introduce large deformation towards the river
- Brain storming included KC-stability, earth freezing, soil anchors
- Solution: Sheet piles supported by underwater casted concrete slab and anchored to H2



H5 Construction Pit Design

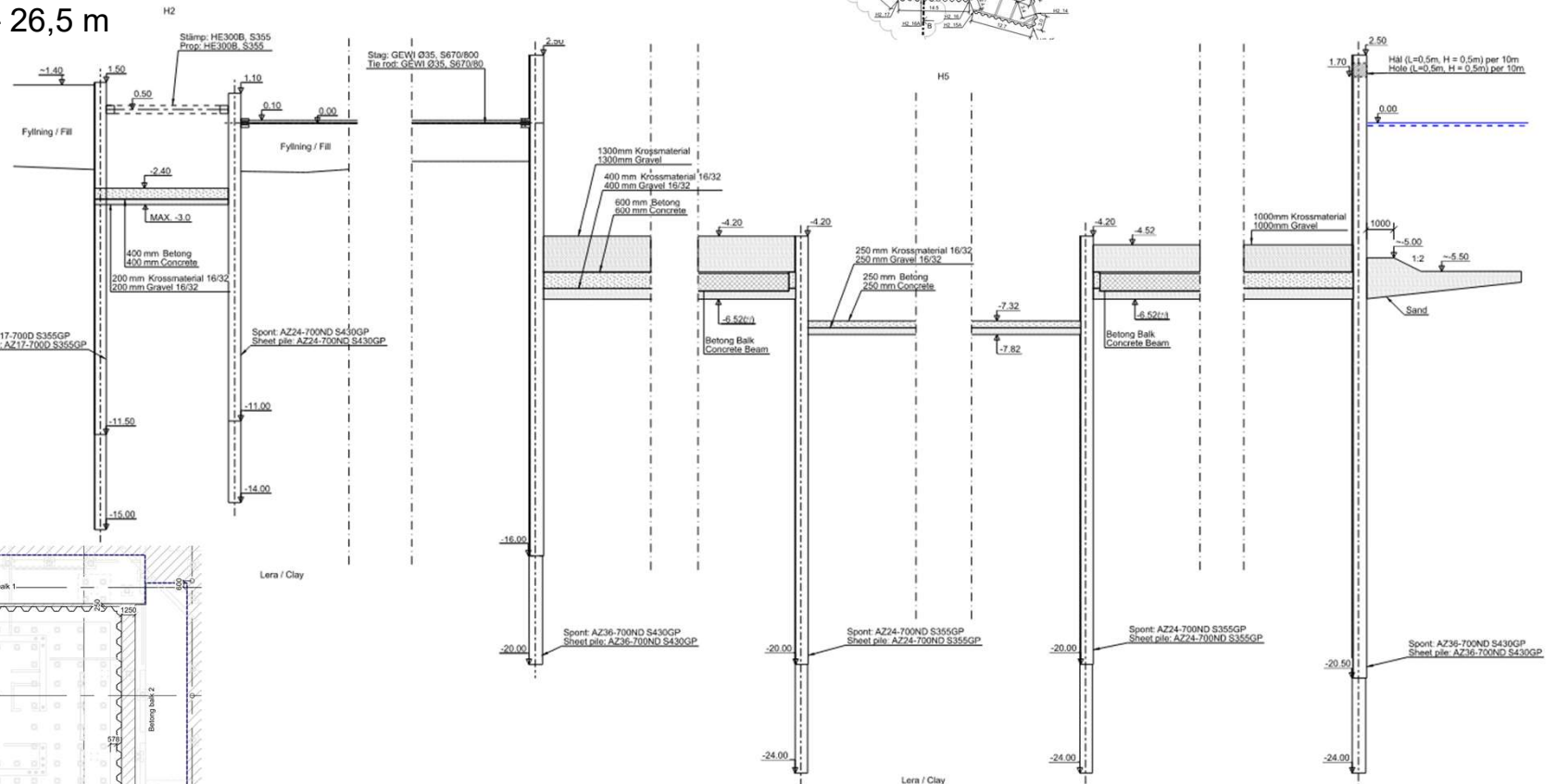
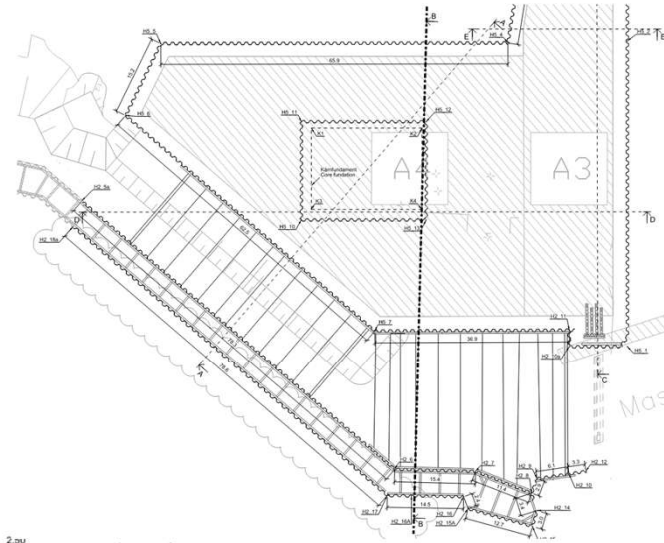
Deformation requirements

Strict deformation requirements for existing buildings



H5 Construction Pit Design

- Inner support by a 60cm UW-concrete slab and 1,3m fill on top
- Anchored back to H2 sheet piles towards land
- Free standing towards water
- Surface loads not allowed
- Staggered sheet piles AZ28-AZ40 S430GP
- Length between 15 m – 26,5 m



H4 Construction Pit Design

Current design:

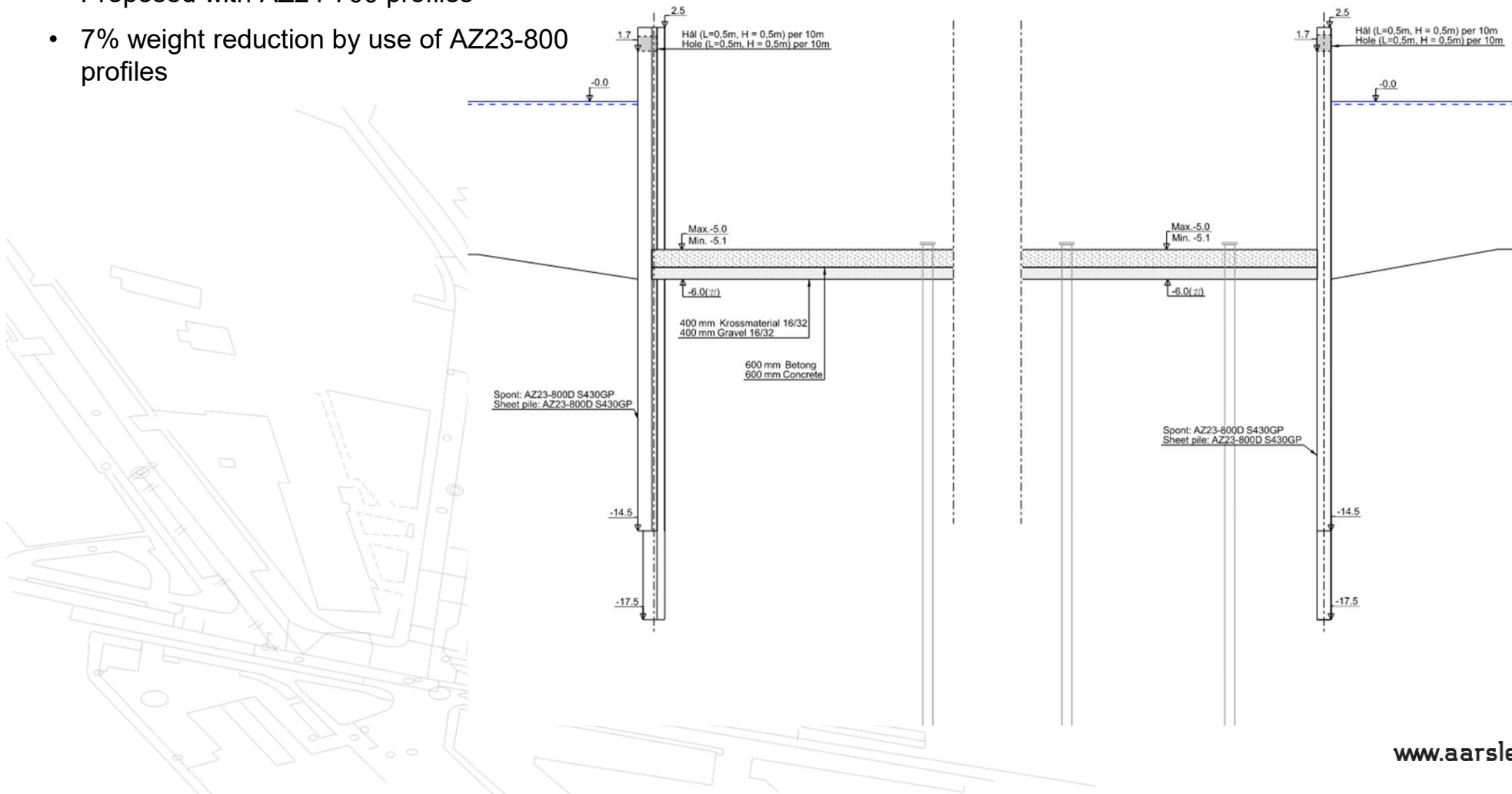
- Free standing sheet piles supported by a 60cm UW-concrete slab
- AZ23-800 staggered sheet piles 17m – 20m

Original design:

- Proposed with AZ24-700 profiles
- 7% weight reduction by use of AZ23-800 profiles



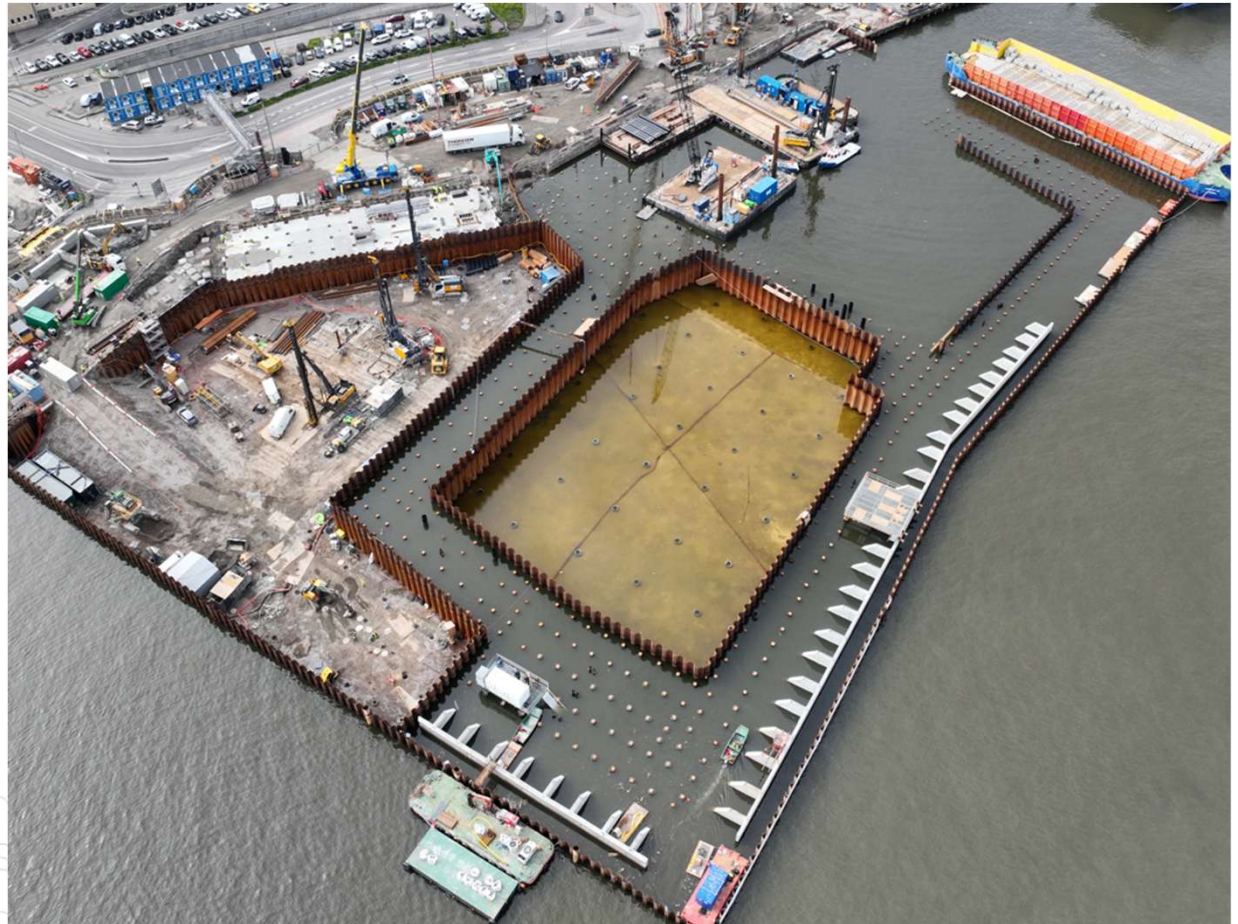
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Foundation Works – Pile Deck



- 796 concrete piles, 52m
 - ✓ Friction piles (floating piles)
 - ✓ 40x40 pre-cast concrete
 - ✓ Mainly on water
 - ✓ Clay extraction for each pile
 - ✓ PE-pipe around piles as corrosion and frost protection
- 115 drilled steel piles
 - ✓ Drilling into rock (tip bearing)
 - ✓ Dia323
 - ✓ On land
- 12 pairs inclined steel piles
 - ✓ Friction piles
 - ✓ Dia320
 - ✓ Spread in pile deck
 - ✓ For the horizontal loads on pile deck



Foundation Works – Pile Deck

Concrete pile driving in soft clay



- Low energy required for pile driving in clay
- 40x40 pile sinks under own weight app. 7m
- In the upper clay layers, the pile can be pushed down by hammer

Rammejournal

Sag:	Masthuggskajen	Sagsnr.:	131012-200
Rådg. Ing.:	Geo Mind Sweco	Side:	1
Pæleplan nr.:	XXXXX	Ramslagets vægt:	70 kN
Udgangskote:	0,2	Effektivitetsfaktor:	1
Rambuktype og nr.:	Junttan PMx 26-1, 42 273	Ramning udf. af:	Arne Hansen / Dan Strøm
Dato:	08-02-2023		
Materiale:	Beton		

7 to hammer

- Last 5m driving
- 2-6 cm drop height
- 14 blows for 20cm driving

Pæl nr.	Længde (m)	Pæle dim. (cm)	Hældning	Faldhøjde (cm)					Antal slag pr. 20 cm.					Meter angivelse	Pæle-spidsk. (m)	Asfalt (m)	Dykning (m)	Bemærkninger
				2	2	3	2	2	12	14	12	13	12					
121	17+17+18	40x40	lod	2	2	3	2	2	12	14	12	13	12	36,00				
				2	2	2	3	3	14	13	14	14	13	37,00				
				2	3	2	2	3	14	15	14	15	15	38,00				
				3	3	3	2	4	15	16	15	16	17	39,00				Dykning 38,6
				5	6	6	3	2	15	16	16	19	30	40,00				
				2	2	2			38	36	15*		40,49	-52,30		1,89		

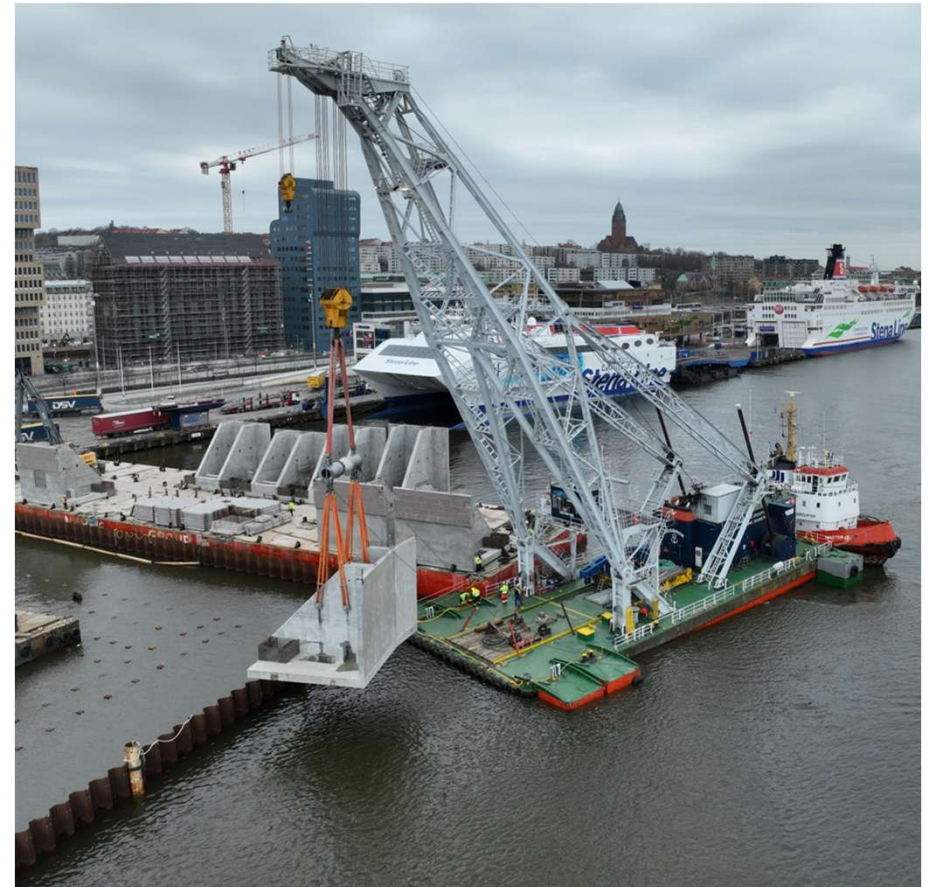
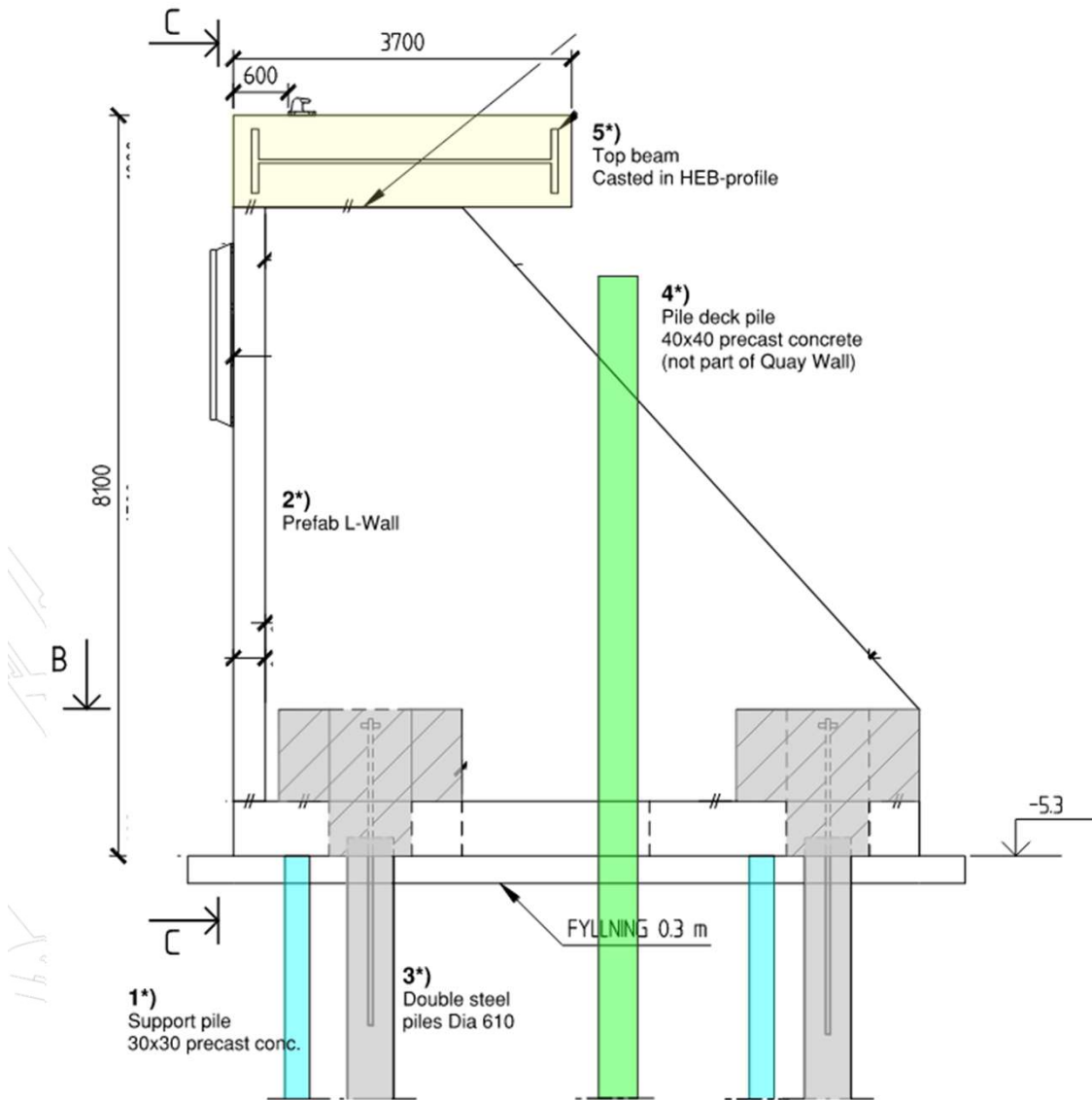
6 to hammer

- Last 5m driving
- 19 cm drop height
- 12 blows for 20cm driving

Pæl nr.	Længde (m)	Pæle dim. (cm)	Hældning	Faldhøjde (cm)					Antal slag pr. 20 cm.					Meter angivelse	Pæle-spidsk. (m)	Asfalt (m)	Dykning (m)	Bemærkninger
				14	13	14	19	19	15	15	14	11	12					
886	18+16+18	40x40	lod	14	13	14	19	19	15	15	14	11	12	14,00				
				19	19	19	19	19	12	13	12	13	13	15,00				
				19	19	19	19	19	12	14	13	14	14	16,00				
				19	19	19	19	18	14	14	14	14	15	17,00				
				18	19	19	19	20	15	14	16	15	15	18,00				Dykning 17,82
				19	19	19	19	19	16	16	15	16	17	19,00				
				19	19	18			16	17	10*			19,52	-51,90		####	

Målt dynamisk brudbæreevne Rdyn,m for pæl nr. 886 jvf. Den Danske Rammeformel: 516 kN

Foundation Works – Quay Wall



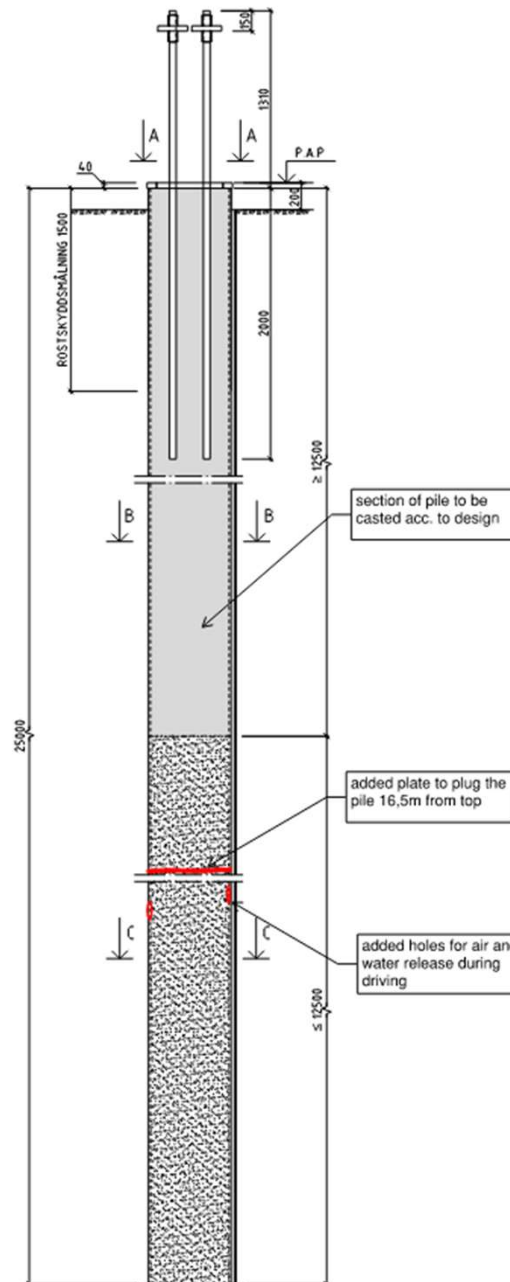
Foundation Works – Quay Wall



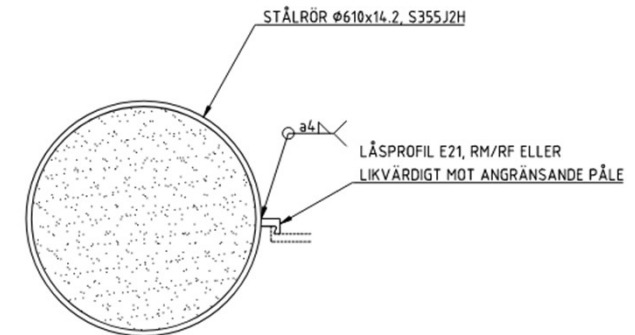
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Double Steel Piles

- Structural piles for L-Walls against horizontal loads
 - ✓ 4 st Dia610 double steel piles per L-Wall
 - ✓ 140 st double piles in total
 - ✓ Installed after placing the L-Walls through a recess
 - ✓ Casting of pile under water
 - ✓ Pile heads connected with L-Walls (under water works)
- Piles plugged with a plate 16,5m from top
 - ✓ To avoid cleaning of clay in concreted section
 - ✓ Clay had to be extracted before pile installation for displaced soil volume



Client's design with interlocked piles, single pile installation



Aarsleff's proposal with welded piles, double pile installation



Foundation Works – Quay Wall

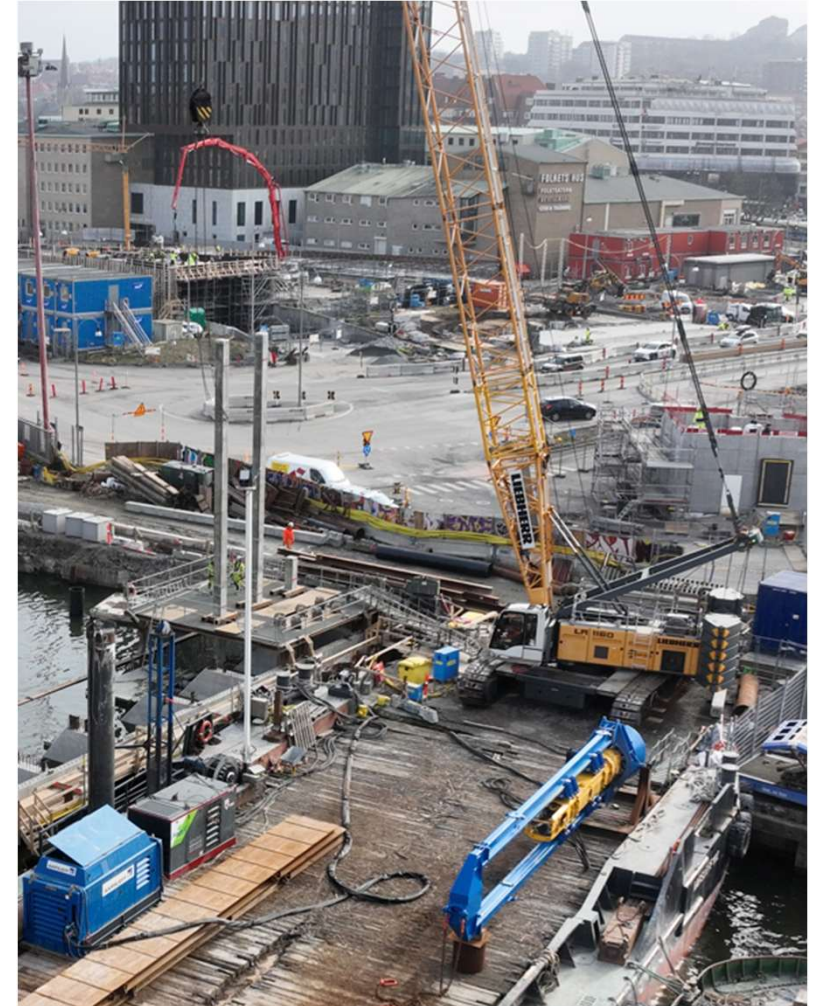
Installation of double steel piles



Foundation Works – Quay Wall

Installation of concrete piles with "flying leader"

- Part of pile deck piles, however in the footprint of L-Walls
- Installed after L-Walls due to risk of movements
- Pile position not accessible by a rig after L-Wall is placed, so ...
- A flying leader by Junttan with an integrated 5-to hammer used for piling

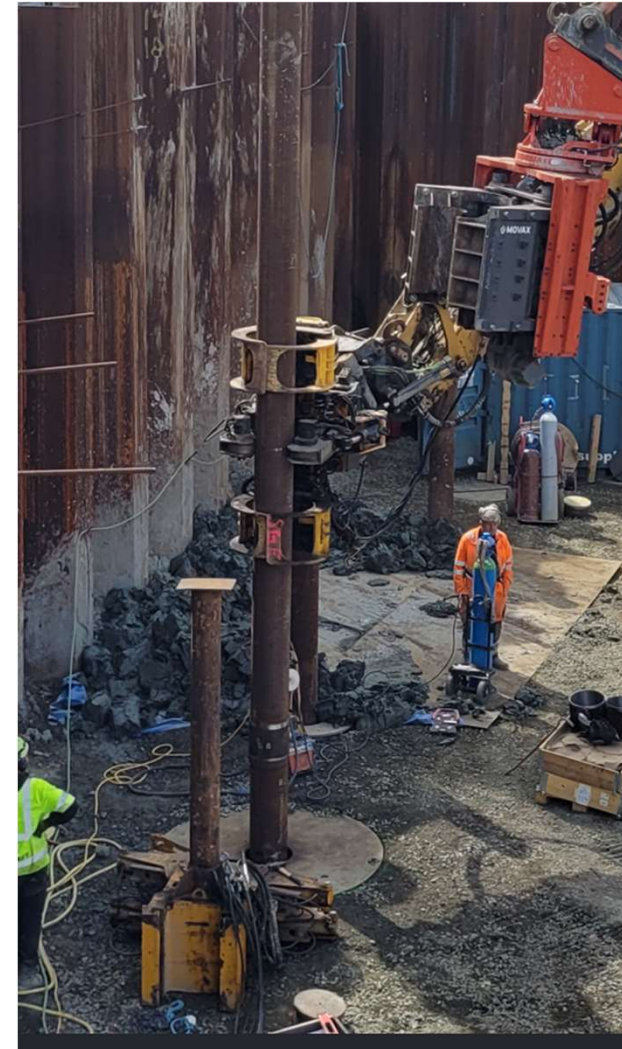


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Foundation Works – H4

Driven steel piles

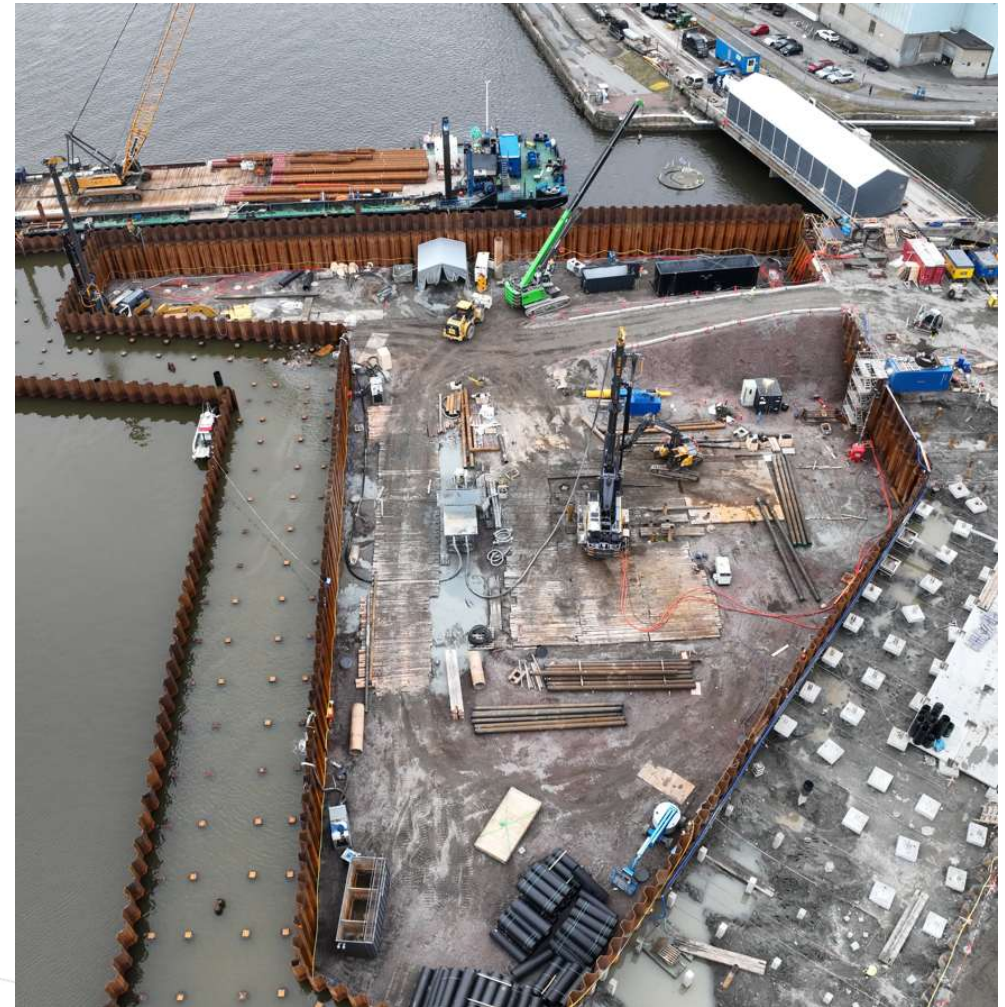
- Scope of piling
 - ✓ 127 piles, Dia 323 and 406
 - ✓ Pile lengths 70m to 90m
- Installation
 - ✓ Piles are jointed with treaded joints, not usual for driven piles
 - ✓ Piles installed with an open rock shoe
 - ✓ First 36-48m of pile vibrated in the ground by Movax
 - ✓ Remaining of pile installed by Pmx26 with 7to hammer
- Unique design requirements
 - ✓ Some piles end in rock and some in friction soil
 - ✓ Combination of friction and tip bearing
 - ✓ Different areas have different settlement criteria
 - ✓ An extensive PDA-test regime executed to find the stop criteria for different pile types



Foundation Works – H5

Drilled steel piles

- Scope of piling
 - ✓ 306 st Dia406 in length 45 m to 95 m
- Ground conditions
 - ✓ Clay, 40-70 m
 - ✓ Friction soil, 2-12 m
 - ✓ Rock
- Installation
 - ✓ Installed with two rigs rented by Bauer, RM20 / RG22
 - ✓ Piles are connected with treaded joints
 - ✓ drilled minimum 3xD into fresh rock
 - ✓ Extensive mud-handling process in confined space
- Drilling system
 - ✓ Friction soil 2-5m => air drilling
 - ✓ Friction soil > 5m => Wassara
 - ✓ RC-system used to contain the return sludge
- Unique design requirements
 - ✓ Designer didn't consider negative skin friction
 - ✓ Pile displacement limited to 10mm after fixing the pile top



Conclusion

Exciting project with many challenges

- Complicated underground conditions
- Complicated contractual set-up with many stakeholders
- Different design solutions and challenging in coordination
- Different foundation solutions
- Challenging in planning and logistics

