NORDIC SHOTCRETE

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FINAL REPORT

CONCRETE REHAB PILOT PROJECT
WHARF FJORDGATA
2018–2019

Bridge and Wharf Inspections

Contents

Report from wharf pilot project at Fjordgata, Port of Trondheim.

1. Introduction

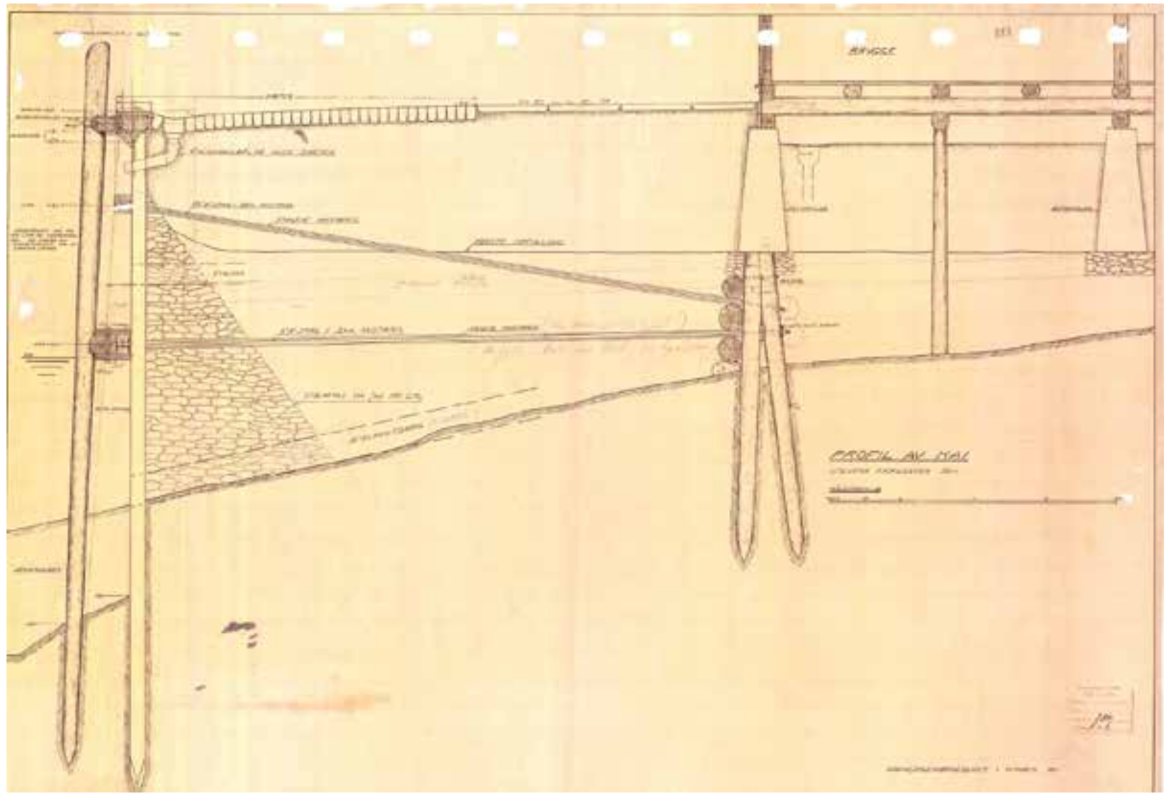
On assignment for the Port of Trondheim, Nordisk sprøytebetong, in close collaboration with Momek and BruKon AS, has completed one pilot project, rehabilitating 25 m of wharf front. After consulting with the Port of Trondheim, we negotiated a suitable approach, which was executed.

The planning for this assignment began winter 2018, and inspections, trial digs, core samples and testing of the concreted were completed in the spring/summer and autumn 2018. Detailed project planning took place in autumn 2018 and winter 2019. The execution of the measure was implemented on site in the period February/March–April 2019.

Assignment review and SJA were completed with all involved parties prior to start-up.

1.2 Information about wharf structure

Drawings from the 1930s were reviewed. The wharf is made of concrete, with non-tensioned reinforcement. Trial digs were performed to reveal the dimension of the tendons and to collect chemical samples from the concrete beam. Several rounds of measurements and misc. planning of different solutions were required before a final rehab. solution was chosen.



1.3 Collection of core samples, compressive strength, spring 2018

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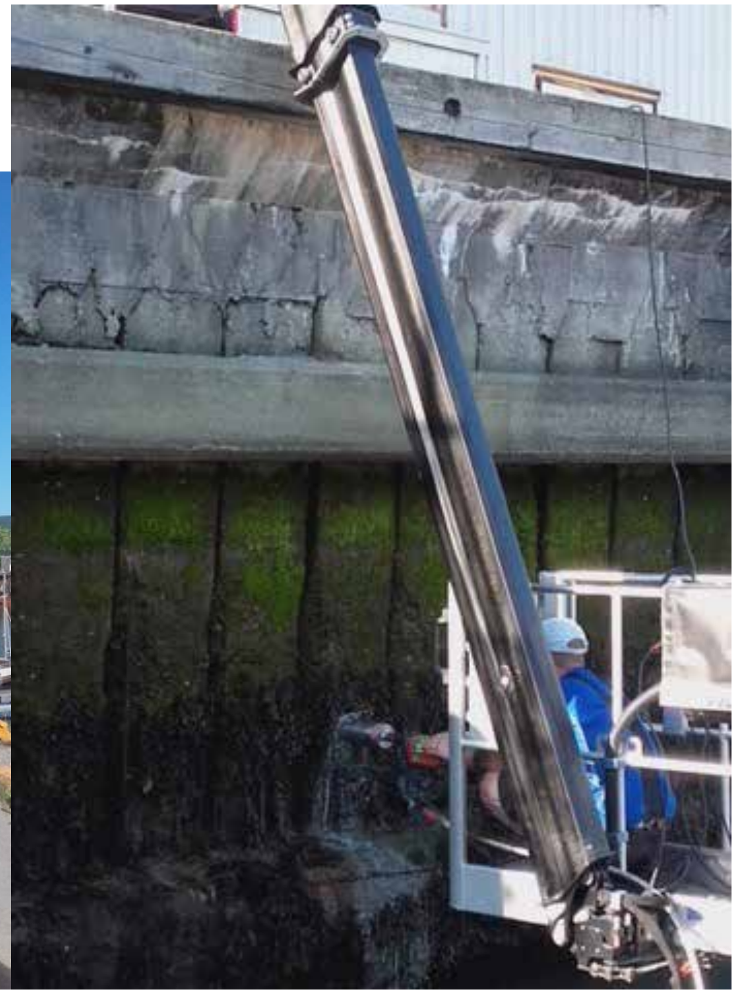

Concrete has good strength, and the corrosion of reinforcements inside the concrete is minor. The concrete surface is degraded, severely in some places, primarily due to external chemical weathering, as well as some frost damage.

Sample 1A. Nice homogeneous concrete, well-proportioned. Minimal cracking, minimal damage. Good impression of sample.

1.4 Testing of samples.

The plan was to perform the following tests on the core samples:

- Carbonation
- Alkali content
- Chloride content
- Concrete strength

All samples are tested in accordance with the Norwegian Public Roads Administration’s methods for Testing of cured concrete, R210 Laboratory testing.

Carbonation. Phenolphthalein testing of the concrete:

A phenolphthalein test of the concrete was performed. The results show how much of the concrete that has carbonized. Over time, concrete will “absorb” CO2 and carbonize, which lowers the concrete’s pH level and corrodes the reinforcement.

Testing indicates a carbonization of between 5 mm and 11 mm in 4 samples. This is very low, given the age of the concrete: 85 years. The undamaged concrete in the piles still have a long remaining life.

Alkali content:

Upon inspection of the samples, the concrete seems visually intact and without cracks/fractures. There is reason to assume alkaline reactions are minimal! This is an assumption, and due to limited time, this has not been explored further. The absence of alkali content has not been verified, but based on the samples and the overall impression of the concrete, this does not appear to be a problem! In short, alkali reactions in concrete means that the concrete swells/increases in volume, as well as cracks from within, over an extended period of time. The concrete samples collected have no cracks/fractures, only erosion on the concrete surface.

Chloride content:

No tests have been performed to analyze chloride content. The concrete piles stand in sea water!, so the concrete is saturated with salty water. It is not clear how deep the piles have absorbed chloride. Reinforcement elements in the samples collected do not show any significant chloride damage, and the chloride content inside the concrete is likely low. Long residual life, but recommend exploring this further if time/opportunity allows.

2. Summary/residual life assessment from the contractor/consultant's perspective, after rehabilitation of the project area.

The concrete that was hydro-blasted was in general of good quality, homogeneous/well-composed stone fraction. The concrete surface on the edge beam was eroded and affected by mechanical wear over time. Samples were collected, and the finished hydro-blasted concrete surfaces of both the edge beam and the pile were checked for signs of delamination. There were no indications of delamination or other damage behind the hydro-blasted surface. The concrete in both the beam and the concrete piles was of good quality. We observed pouring joints from the actual construction of the concrete wharf. The concrete pile was eroded, in some areas quite severely in hollows and the tidal zone.

The reinforcement revealed after hydro-blasting was also of good quality. What had not corroded away was largely intact, but very minor damage! The reinforcement showed local damage/pitting. It was therefore quite straightforward to replace the reinforcement that had corroded away in the years that had passed. New reinforcement, B500NC. New reinforcement was installed with overlap, and mesh reinforcement was installed on the outside. This mesh was bolted to the original concrete with strong grip/strength. Surface rust on the hydro-blasted reinforcement was removed by the alkaline formation water when the concrete was applied. There was no accumulation of fouling/kelp, etc. in the period between hydro-blasting and shotcrete application. Consequently, new surface rust on the hydro-blasted reinforcement is not a concern in terms of the residual life of the measures performed.

Concrete elements:

Concrete elements B35 MF40 were installed and secured, through tendons were inserted and secured. Then, concrete elements were poured behind this, with concrete suitable for this type of pour, AUV concrete with a low d_{max}.

Concrete cover to mesh reinforcement, two layers, was measured to 40 mm, and the cover to horizontal structural reinforcement is 48 mm from the outer edge in the splash zone to the horizontal structural longitudinal reinforcement. Two layers of mesh reinforcement were installed, taking into account tension distribution and stress from production/lifting and transport of the concrete elements; the objective was to have as few/small cracks as possible in the concrete element.

C_{nom} according to Eurocode 2, 1991-1 outlines a cover requirement of 60mm, which in turns gives a calculated project lifetime of 100 years. We have an actual cover of 40/48 mm in concrete elements, which gives an estimated lifetime of 66–68 years.

Shotcrete:

Finally, shotcrete was applied to the part of the concrete structure that was above water, and later sanded. B35 M45 was used. Added 3 kg basalt fibres per m3.

Finished cover is C_{nom} +60mm. Shotcrete has an estimated lifetime of +100 years.

Conclusion lifetime assessments:

- **Shotcrete has a lifetime of 100 years**

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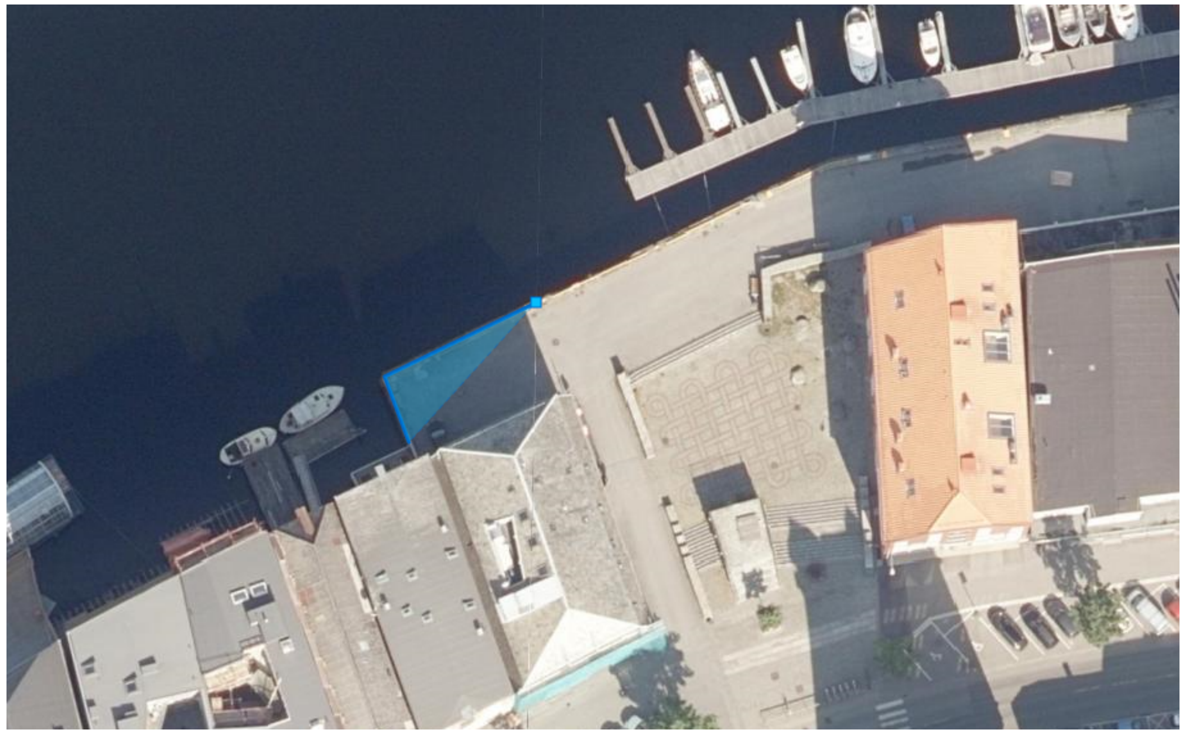
- **Concrete elements have a lifetime of +- 67 years.**
-

Trondheim, 21 May 2018

Arne Mathias Selberg, Graduate Engineer

3. Rehabilitated area



Aerial view of wharf. Blue area shows rehabilitated wharf front. 25 m.

4. Measurements of wharf structure after hydro-blasting.

This was performed on the entire concrete wharf structure:

Testing for delamination

The concrete structure was tested for delamination. No delamination detected in the beams. Some delamination/cracking in the upper floor slab. Some localized damage in the concrete surface. No penetrating cracks, as the concrete on the inside/underside of the wharf structure has a nice, homogeneous quality.

Compressive strength

The compressive strength of the concrete structure was measured with a digital Schmidt hammer.

The measurements showed an average compressive strength, cube strength, of 40 MPa–60 MPa! The concrete proved resistant to cracking and appeared to be of good, strong quality. These results are likely a good indication of compressive strength. The concrete is homogeneous, with minimal/no cracking or damage. Some damage to the underside of beams, but this is due to poor pouring/stone nests.

Image 1. Brick hammer, digital Schmidt hammer and cover meter.

Chemical testing

Chemical tests showed no indication of harmful chemical compounds.

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4. Resultater og vurderinger

Resultater av prøvingene er gitt i vedlegg 1: Tabell over normverdier og prøveresultater". Resultatene er sammenlignet med normverdier for tilstandsklasser fra stf veileder TA 2553, 2009. Prøveresultater finne i vedlegg 2 "ALS Rapport "

Vedlegg på etterfølgende sider:

Vedlegg 1

Tabell 1. Normverdier og prøveresultater

Stoff (mg/kg)	Normverdi Tilstandsklasse 1*	Normverdier Tilstandsklasse 2*		Prøve 18240A-1
Arsen	< 8	8-20		1,0
Kadmium	< 1,5	1,5-10		0,13
Krom $^{3+}$	< 50	50-200		66,0
Kopper	< 100	100-200		29,0
Kvikksølv	< 1	1-2	<	0,01
Nikkel	< 60	60-135		31,0
Bly	< 60	60-100	<	1,0
Zink	< 200	200-500		22,0
Sum PCB 7	< 0,01	0,01-0,5		n.d.
Sum PAH-16	< 2	2-8		n.d.
Benso(a)pyren	< 0,1	0,1-0,5	<	0,01
Alifater C10-C12	< 50	50-60	<	5,0
Alifater C12-C35	< 100	100-300		12,0

n.d = under deteksjonsgrense (not detekted)

**Statens forurensningstilsyn, veileder "Helsebaserte tilstandsklasser for forurenset grunn", TA 2553, 2009. Tilstandsklasse 1 er beste klasse "meget god" og kan anvendes til boligområder.*

Informativ note:
Krom 3 er høyere enn normvedier. Prøven oppfyller kravet til tilstandsklasse 2 "meget god".

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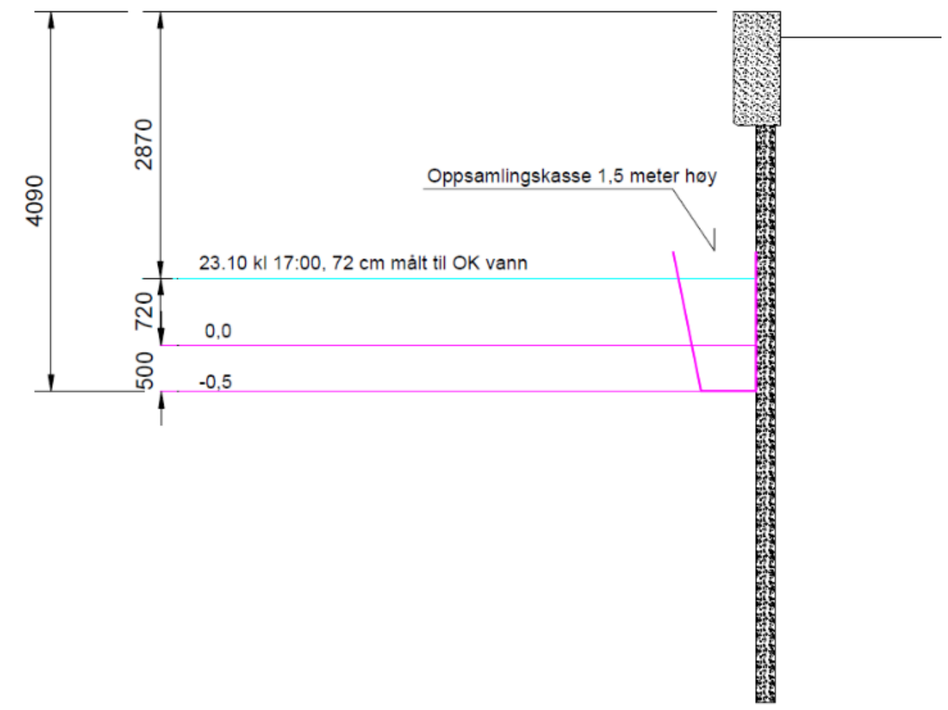
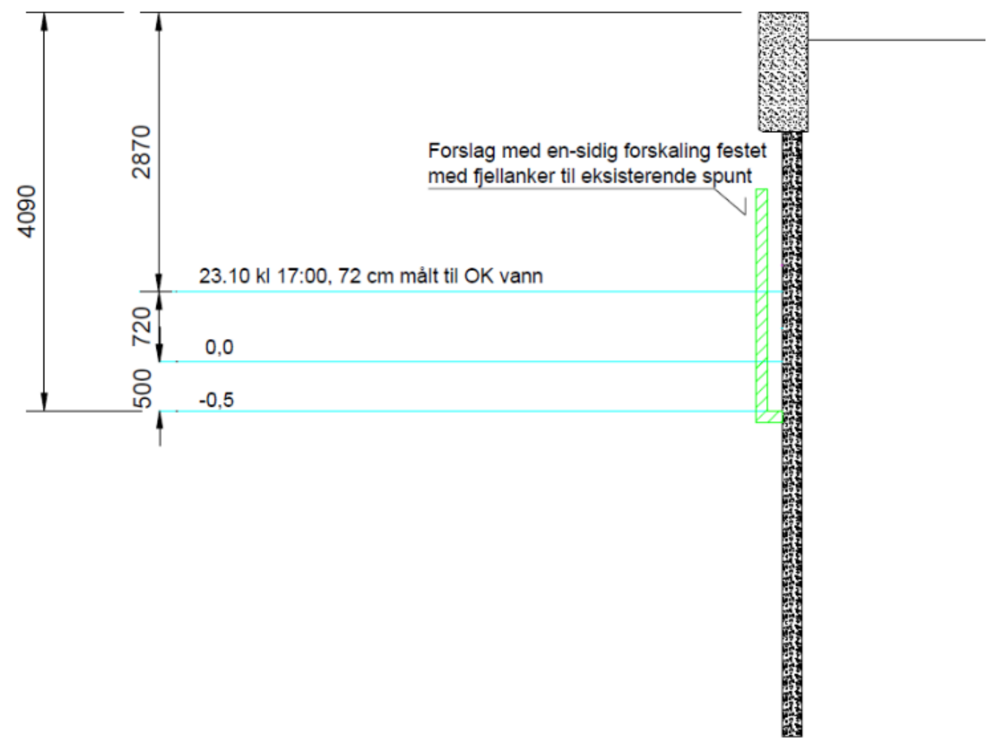
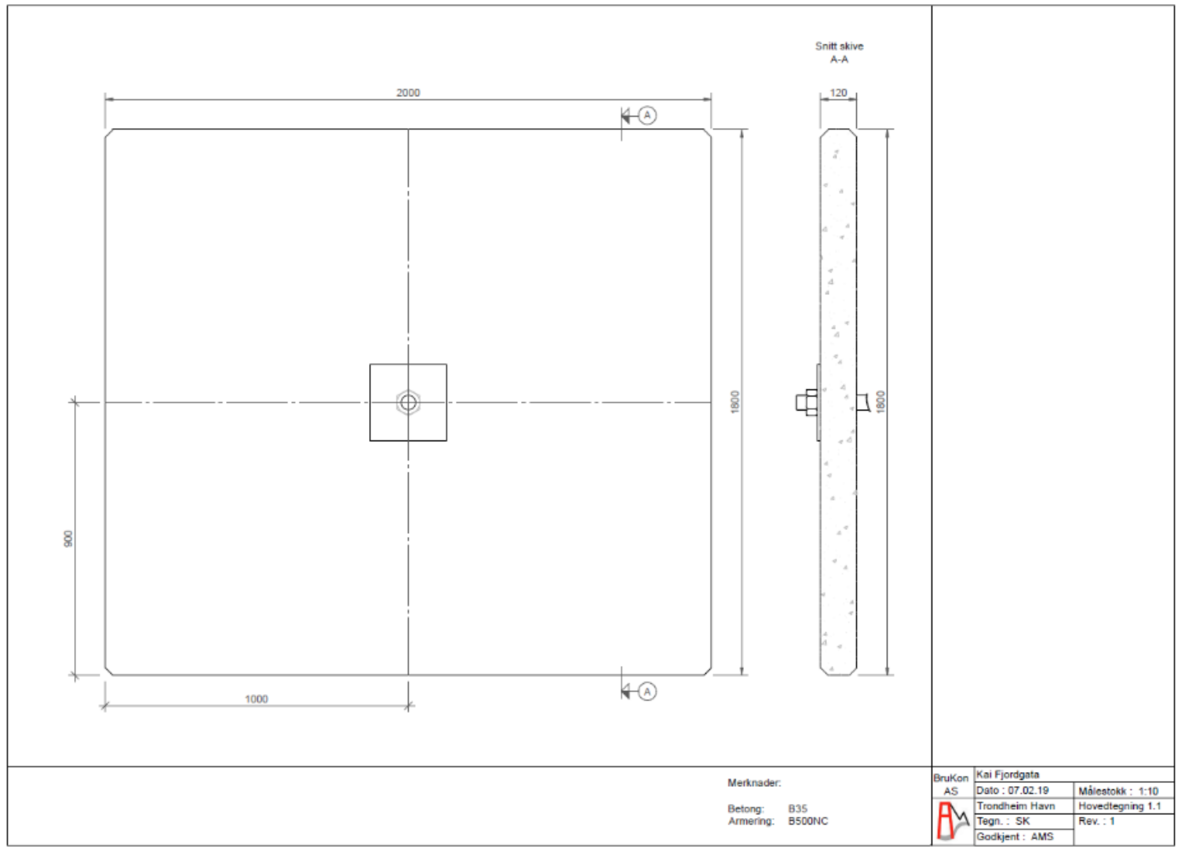
5. Planned execution of concrete rehabilitation.





6. Planned solution.



The final solution called for reinforcements in both directions, allowing for the distribution of the point load from the anchors to be distributed across a larger surface. The planning also took into account a potential horizontal displacement, to adjust the holes to the tendons on site. All concrete elements were therefore reinforced with this in mind. See also image below, for additional reinforcement, which would fill the same space as the existing *Larsen profile* of the original solution. This means that our solution has the same (or greater) load-bearing properties as the original solution. The bolted connection has a greater capacity than the original anchoring solution. The bolt has greater tensile properties than the original tendon.

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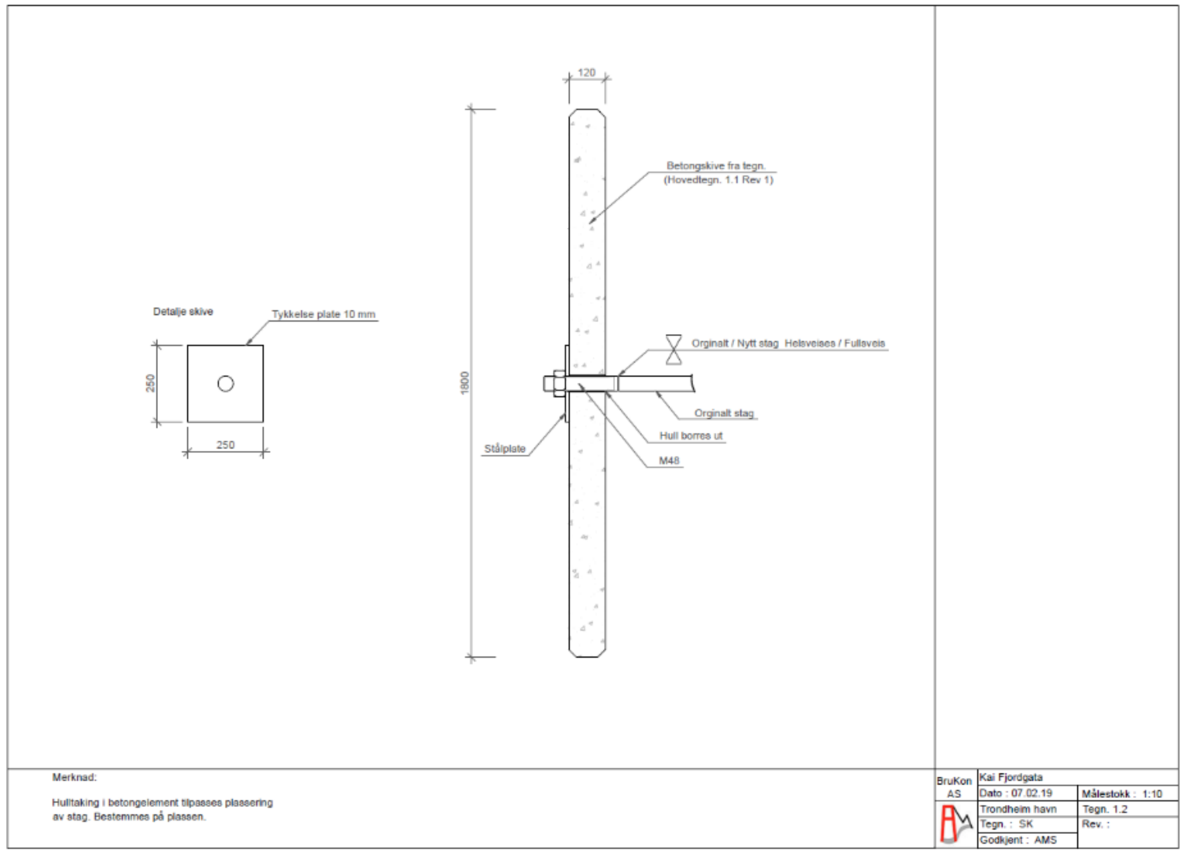

Reinforcement not shown in image, but reinforcement has been added in both the vertical and the horizontal direction. Additional reinforcement in the area near the bolt.

7. Joint testing

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7.1 Production of elements

8. Procedures

8.1 Procedures for hydro-blasting of concrete walls and wharf front:

Procedure for hydro-blasting:

- Assess on site whether hydro-blasting (single jet) or rubbing (several rotating jets) is the best approach

- Blast entire height, length of each "interval" to be decided on the spot

- Blasting ideally to take place from a raft

Procedure for collection of concrete:

Collection in containers below. See drawings/former drawings.

Suction of collected waste by way of standard vacuum collection vehicle.

Deposit to approved waste collection facility.

8.2 Procedure for application of shotcrete to walls and wharf fronts:

Purpose

The purpose of this procedure is to maintain a high level of quality and safety in the work performed.

Scope

This procedure applies to the application of shotcrete to walls, supporting walls, etc, as well as to rocks and wharf fronts.

Responsibility

All employees of Norsk Sprøytebetong and/or contracted personnel must comply with the contents of this procedure.

Preparations:

- Get a good overview of the site upon arrival.

  If non-conformities, etc., are discovered, call the closest superior and fill out a non-conformity report including pictures.
- Make sure to bring all necessary and appropriate equipment.
- Compliance with HSE guidelines, incl. safety instructions, is required. All members of the shotcrete team must sign to confirm the review of the instructions.
- Verify that all 4 weights and other cleaning equipment is in place inside the vehicle.
- If a lift is used, the basket must be covered in plastic. The lift operator MUST be certified for personnel lift operations. The same applies to forklifts; a C2 certificate is required.
- Life vests must be available during operations on wharfs/rafts.

  The foreman is responsible for the following:
- The foreman will order concrete from the mixing plant, and efforts shall be made to have the truck mixer arrive as early as possible (07:00–08:00), depending on light conditions and time of year.
- Take efforts to have concrete deliveries overlap, so that the shotcrete team does not have to wait for concrete between each delivery.
- Ensure sufficient working lights are set up prior to start-up.

Execution:

- Plastic sheeting (protection) against concrete spills must always be laid down, protecting not just the work site, but neighbours, parked cars, etc.
- A dedicated place for excess concrete must be illuminated and identified before work begins.
- In the event one suspects that the concrete quality does not meet our standards, temperature and sink tests must be performed, see separate procedure.

Shotcrete:

- The driver and shotcrete operator set up the pump.
- The foreman and the rest of the team put down plastic and secure the site, install corner boards, valves, etc., or install reinforcement if necessary.

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- Shotcrete is applied from the bottom up. Any craters/holes are filled gradually.
- If the thickness of the concrete exceeds 15 cm, apply a thin layer across the entire wall first, and then the full thickness on the next coat.
- The use of floating rules, smoothers at the top and bottom should be as efficient as possible to prevent the shotcrete operator from having to wait for this process to be completed.
- Efforts must be made to reduce the amount of excess concrete in shotcrete application.
- The pump driver and shotcrete operator clean the pump and related equipment.
- The foreman and the rest of the team remove plastic, clears the site and help out in the clean-up process.
- The completed wall is either coated with a curing agent or covered in plastic.
- Clean **all equipment** that has come into contact with concrete.
- Always remove ALL waste left behind.
- Add checklist and photos to Smartdok.

Clean hose:

- The cleaning procedure must be performed as soon as the application of concrete is complete, while the concrete is still fresh.
- Make sure to use weights on the hose to clean it with a ball.
- Put down plastic on the ground or on a truck bed and empty the remaining concrete there. Remove the excess if it is not possible to leave it behind.
- Do not, under any circumstances, hold the hose in your hand or stand on it during the high-pressure cleaning process.
- In the event of a blockage, disconnect the compressed air and release any air in the hose through the valve before knocking the blockage out with a hammer or other suitable equipment. See drawing/image
- Do not risk personal injury/damage to equipment. Make sure to remove any blockages safely.

References:

Procedure for reception and measurement A01

Checklist for reception control A06

8.3 Execution/general description of project plan.

Where reinforcement has corroded away/is missing, replace with same reinforcement dimension as original.
Install reinforcement bars with overlap. BruKon As
Mesh reinforcement , Ø8, will also be added to the front of the wharf structure where shotcrete will be applied.
See drawing.
The mesh reinforcement will be bolted in place and anchored to the undamaged concrete behind. Number of anchor points to be determined in detail planning, when the project gets underway)

Shotcrete cover will be from 50 mm to 75 mm. This should be determined by the client prior to start-up.

The bottom beam, the current “Larsen profile”, is so severely corroded, that it will be rebuilt with reinforced concrete. Horizontal reinforcement, 4Ø16, will be added, forming a longitudinal beam absorbing the same loads as the original “Larsen profile”.

Protruding tendons will have extensions welded on!, which will serve as new joints. Joint is anchored with a steel plate and a new bolt/anchor.

This solution will have the same static stability as the original solution.

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9. Installation of collection vats

10. Hydro-blasting of concrete

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Collected waste. Was transported to waste collection facility by Port of Trondheim.

11. Finished water-blasted surface

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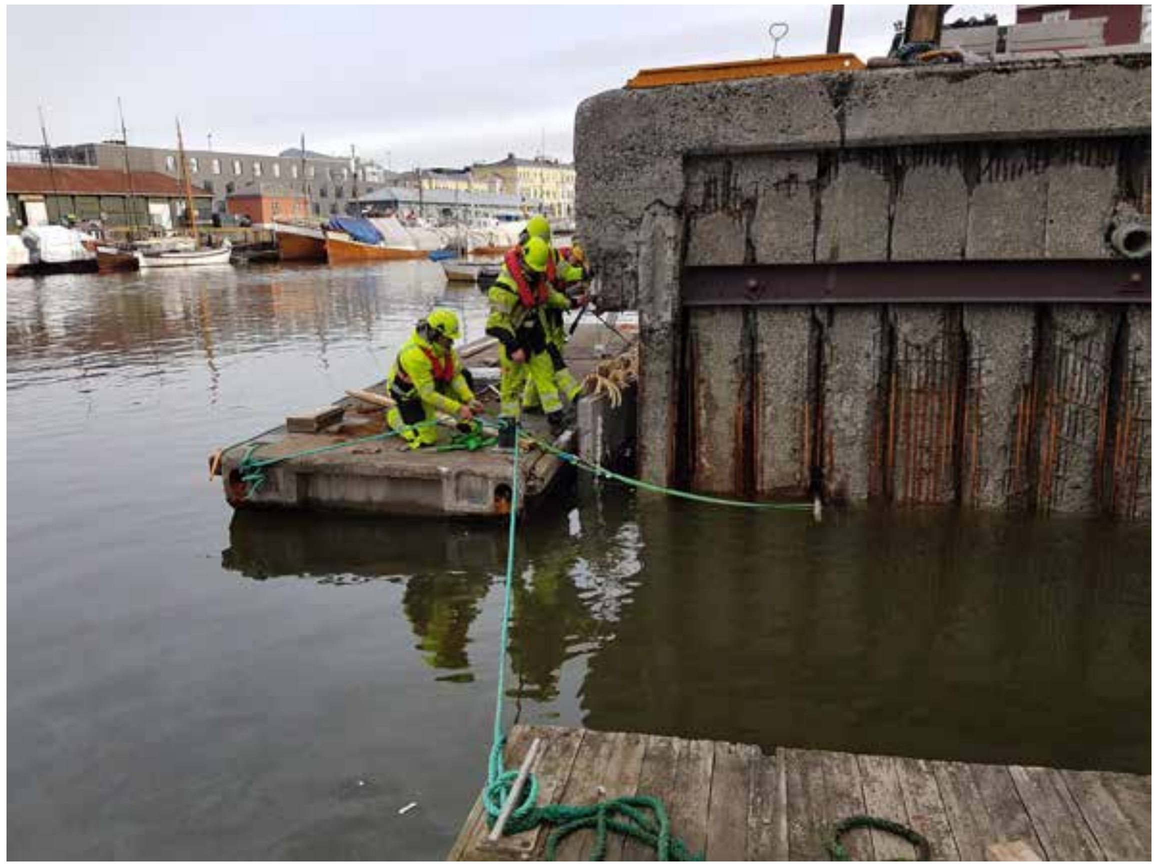
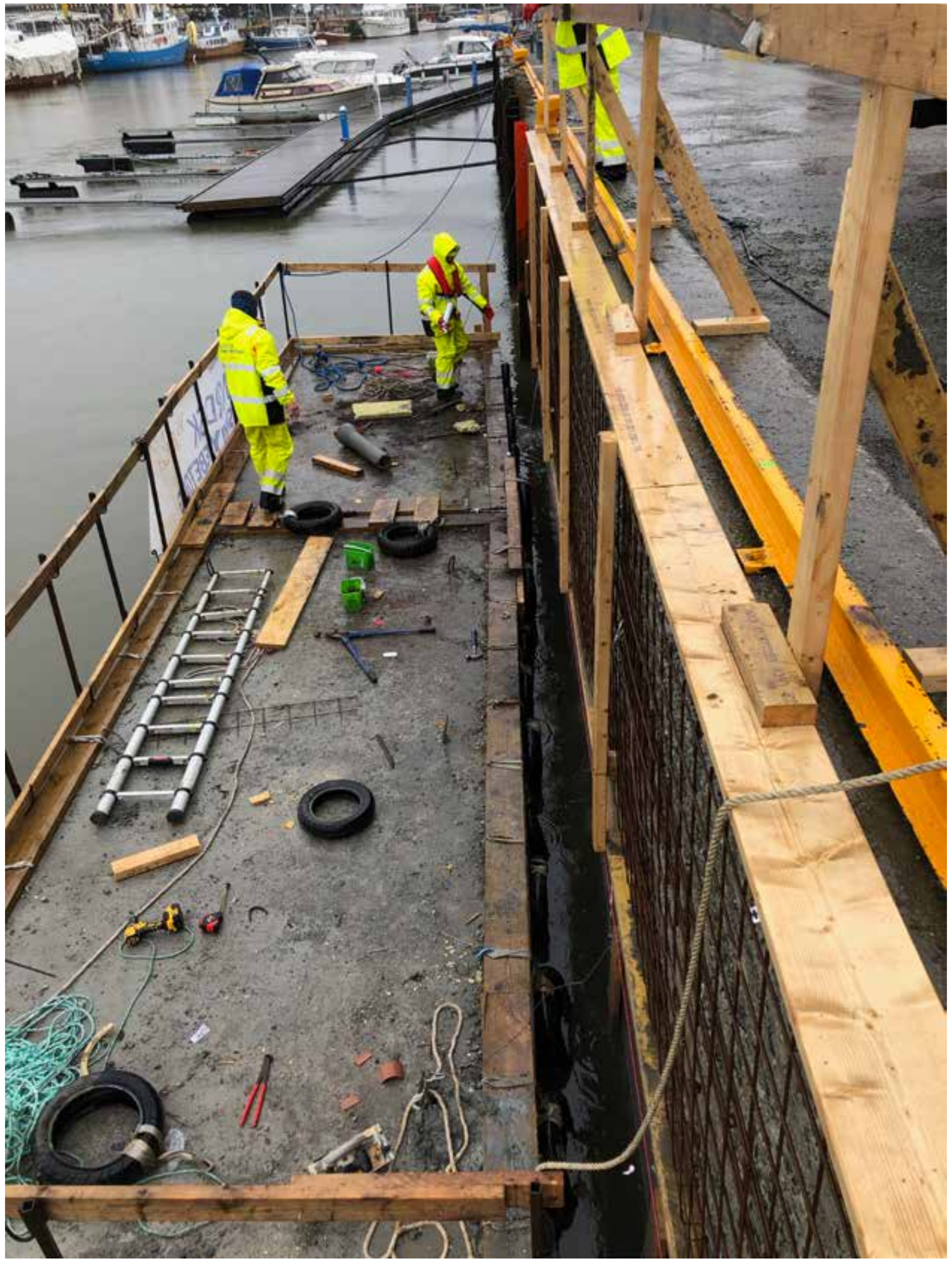
12. Installation of elements.



13. Installation of formwork, preparation for shotcrete.



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Challenges with large tidal range.

14. During application of shotcrete.

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15. After the pilot project was completed.

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