MEMO

Job	Sjøtunnel Tønsberg
Client	Statens Vegvesen
Memo no.	02 – Estimation of consequences of open construction pit for tunnel part.
Date	12/04/2017
To	Steiner Aspen
From	Søren Gamst, Ton Hemel
Copy to	Lars Lundberg, Jan Ole Kaupang, Kai Midtskogen
Appendices	1. WBS from main report and WBS for open construction pit alternative for tunnel

1. Background

Date 12/04/2017

This memo has been prepared as an addition to the sketch design of the sub sea tunnel crossing “Undersjøisk tunnel Nøtterøy-Tønsberg” prepared by Rambøll, end of March 2017. In the sketch design, two different alignments have been considered (alignment 12200 situated east-west and alignment 16730 situated south-north). For each alignment two different tunnel lay-outs have been considered.

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One lay-out consisting of one traffic tube containing one traffic lane in each direction (H5, 12.50 meter internal width) combined with one tube for pedestrians and cyclists (6.5 meter internal width).

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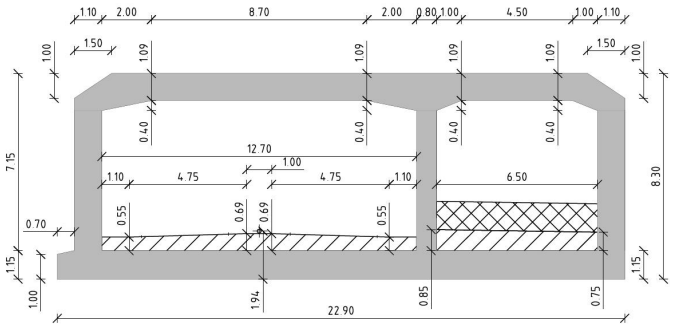

NORMAL TVÆRSNIT, IMT ELEMENT VED H5, 1:100
Figure 1. Cross section, IMT tunnel, H5

The other lay-out consisting of two traffic tubes containing each 2 traffic lanes in one direction (H6, each tube 9.5 meter wide) combined with one tube for pedestrians and cyclists (6.5 meter internal width).

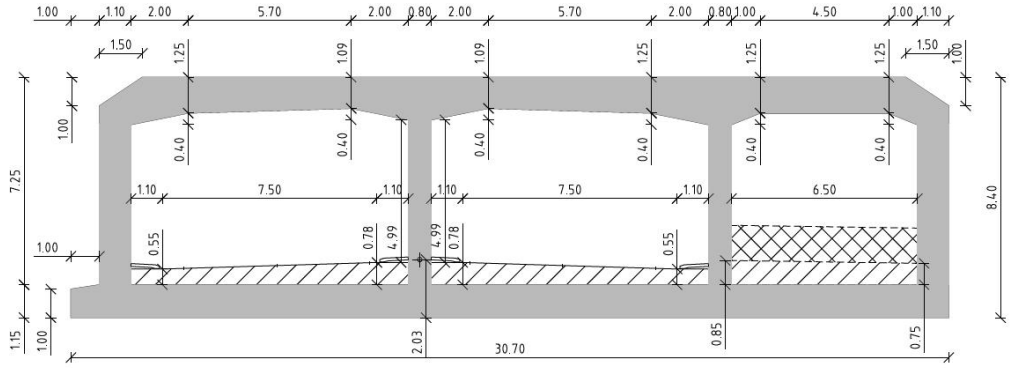

Figure 2. Cross section, IMT tunnel, H6

Types and length of structures along alignment 12200 (east-west):

Item	Length [m]
Ramp east	295
C&C east	45
Immersed tunnel	490
C&C west	45
Ramp west	120

Total tunnel length: 580 meter.
Total length connection: 995 meter.

Types and length of structures along alignment 16730 (south-north):

Item	Length [m]
Ramp south	210
C&C south	45
Immersed tunnel	580
C&C north	45
Ramp north	120

Total tunnel length: 670 meter.
Total length connection: 1,000 meter.

For the complete sketch design reference is made to the sketch design report and the drawings prepared for “Undersjøisk Tunnel Nøtterøy-Tønsberg, Skisseprosjekt” (dated March 2017).

2. Purpose of the memo

Among the various alternatives for crossing of Byfjorden that has been suggested previously, an alternative consisting of a in-situ constructed concrete tunnel in a open, dry pit, has been investigated. The purpose of this memo, is to investigate this alternative further, and to estimate the cost compared with the immersed tunnel alternative.

This exercise is only applied to the H6 cross section lay-out of alignment 16730.

The specific design and construction considerations for this alternative are described in chapter 3. The cost consequences are described in chapter 4 and the other consequences/aspect are described in chapter 5. In chapter 6 the conclusion of the considered alternative is given.

3. Specific considerations

In the sketch design from March 2017, the immersed tunnel part of alignment 16730 is 580m long, and only this section is considered constructed as an in-situ cast tunnel in an open construction pit. The other structures (ramp etc) are kept unchanged compared to the sketch design. This is reflected in the attached Work Breakdown Structures (see appendix).

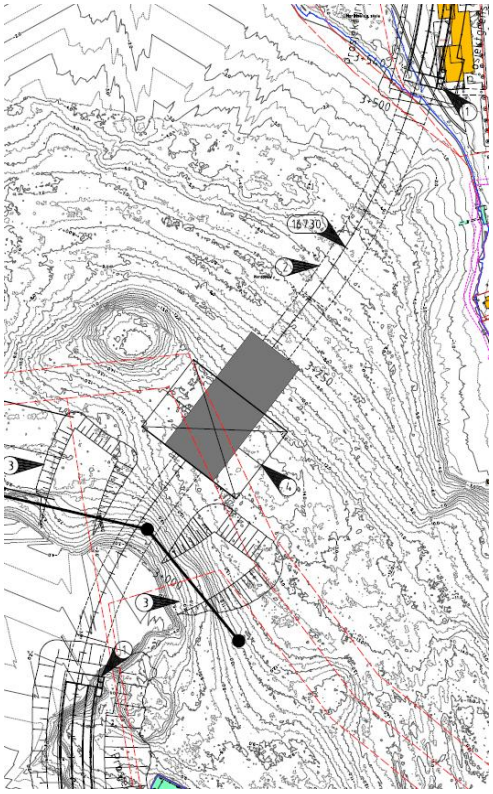

Figure 3. Alignment 16730 from the sketch design

3.1 Design considerations

For the design of the open construction pit, the following assumptions are made:

- The cross section of the tunnel (permanent works; reinforced concrete structure and ballast concrete) is that same as in the sketch design.
- The temporary retaining structure of the pit consists of a single sheet-pile/combi-wall supported by props/struts on multiple levels (see schematic figure below).
- On the outside of the open construction pit no temporary fill is foreseen to reduce the horizontal load on the retaining structure and reduce the need for ground improvement (chalk/cement stabilisation).

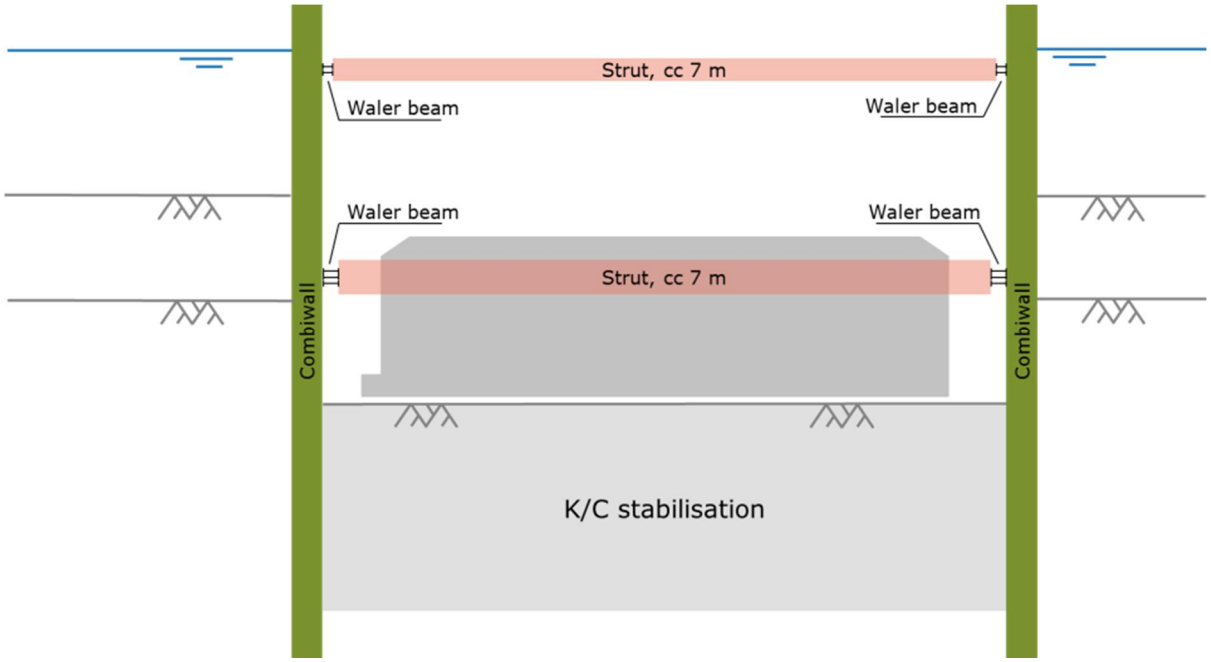

Figure 4. Principle of the open construction pit alternative

3.2 Construction considerations

During the construction of the tunnel with the open construction pit alternative it is considered that there should be the possibility for vessels to pass the alignment. Looking at the vertical alignment of the tunnel, the existing seabed levels and the required depth of the shipping channel; the northern part, including the planned location of the shipping channel, needs to be constructed first. After construction of this section (length of about 400 meter) the shipping can be relocated over the constructed tunnel and the last section of tunnel (length of about 180 meter) can be constructed in an open construction pit.

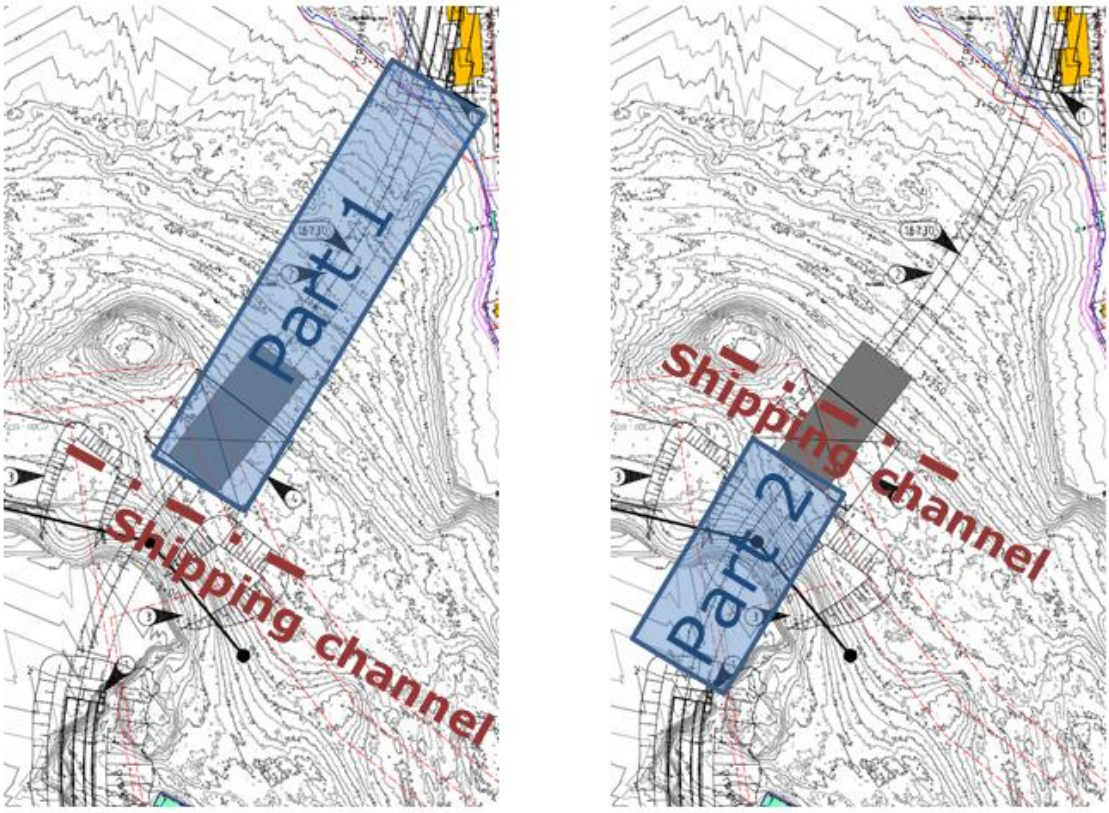

Figure 5. First and second part of the overall construction sequence, that allows the shipping channel to be kept open during construction.

To allow for the construction of the concrete structure within the open construction pit access and space for equipment, materials etc. is required. Within the open construction pit, the space is limited resulting in that working space is needed on the outside of the open pit. This working space can be created by a pontoon located on the side of the pit, effectively making this a “floating” site area. Access to the pontoon can be by means of vessels or a floating road. In the pictures below the construction of the East pylon of the Storebælt bridge is shown. The working pontoon situated on the side of the pylon has approximate dimensions of 30 x 100 meter (approximately 3,000 m^2).

Figure 6. Pictures of construction / working pontoon for construction of East bridge pylon Storebælt. ("*Concrete Technology, The Storebælt Publications, 1999*")

The material delivered to the work area pontoon is either pumped (concrete) or lifted (for example, reinforcement, machines, etc.) into the construction pit. The location of the pontoon along the construction pit is adjusted to assure the "work fronts" in the construction pit are in reach of the pumps/cranes on the pontoon.

Construction sequence construction pit

The principle construction sequence for realising the open construction pit is as followed:

- Installation of the retaining walls on either side of the construction pit;
- Installation of the upper waler beams;
- Installation of the upper strut level;
- Excavation in the wet in between the retaining walls to a level just below the lower strut level;
- Installation in the wet of the lower waler beams;
- Installation in the wet of the lower strut level;
- Backfilling in the wet to just above the lower strut level;
- Emptying the construction pit of water;
- Partly chalk/cement stabilisation (in the dry) of the deeper clay in the accessible areas between the struts;
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- Excavation to an intermediate level to allow for reaching the required depth with the chalk/cement stabilisation;

    - During the chalk/cement stabilisation mentioned in the previous step the horizontal position of the struts need successively to be adjusted to allow access to the areas not yet stabilised.
- Excavation to the required level for construction of the tunnel.

After this the construction of the permanent structure can start.

Overall construction sequence

The principle overall construction sequence for realising tunnel part of the connection with the open construction pit is as followed (construction of the ramp and cut&cover sections not considered):

- Construction of the open pit north of and including the planned shipping channel;
- Construction of the tunnel structure in the open pit (*during the construction of the tunnel wall/roof the lower strut level needs to be relocated/removed*) ;
- Backfilling around the structure;
- Removal of retaining structures some meter below seabed level;
- Placement of rock protection on constructed tunnel part;
- Relocation of the shipping channel over the constructed and protected tunnel;
- Construction of the open pit south of the shipping channel;
- Construction of the tunnel structure in the open pit;
- Backfilling around the structure;
- Removal of retaining structures some meter below seabed level;
- Placement of rock protection on constructed tunnel part.

4. Cost consequences

As only an alternative construction method is considered for the immersed tunnel part the cost consequence for this section of the work is considered in this memo. This is also reflected on the attached Work Breakdown Structures in the appendix (see also figure below).

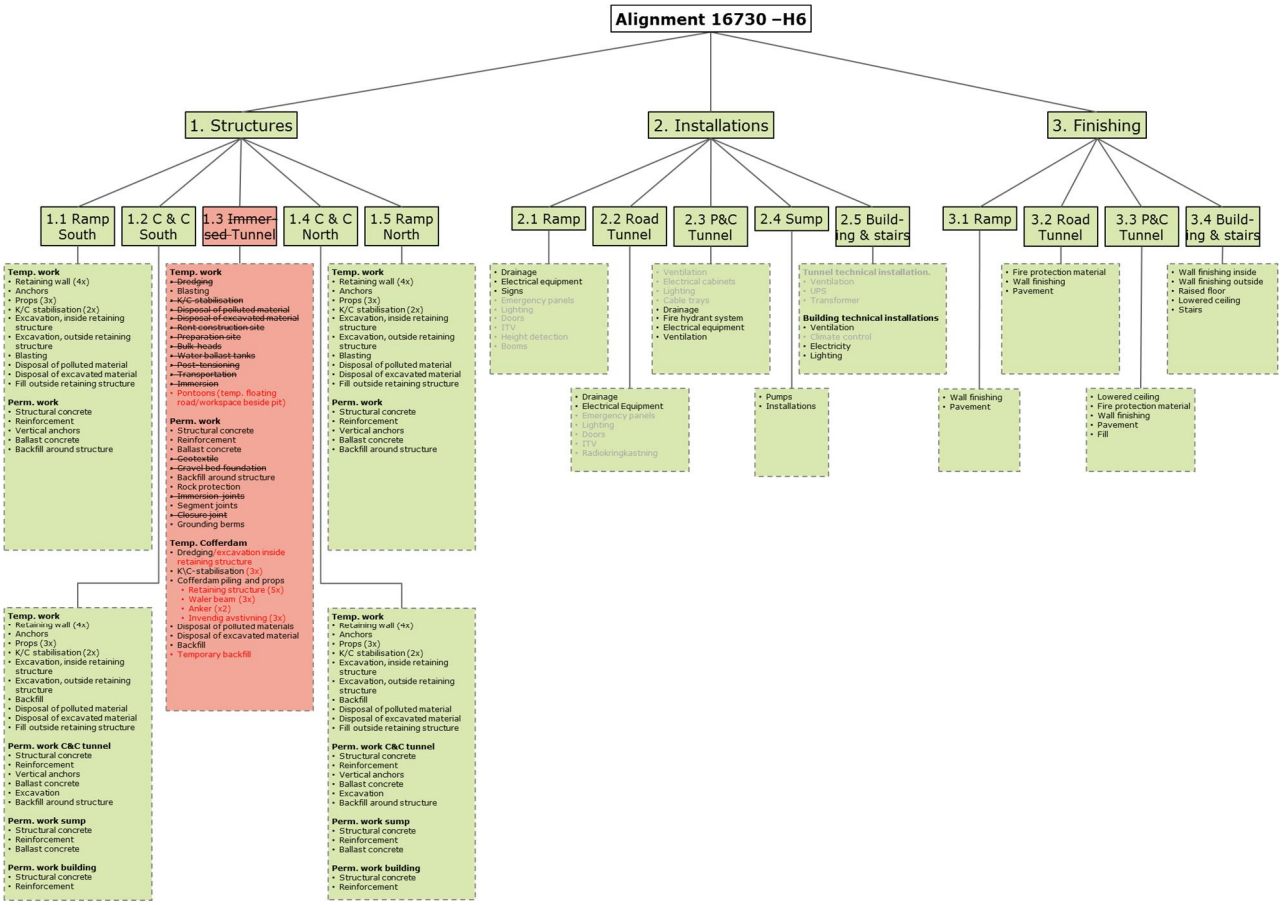

Figure 7. WBS for the open construction pit alternative for tunnel.

The figure above shows the WBS. The items that are unchanged in relation to the sketch design for alternative H6 on alignment 16730 are coloured in green. The WBS for the tunnel part (coloured in red) has been adjusted for the open construction pit alternative to reflect the considered solution. Items not applicable for the alternative have been taken out (marked ~~strike trough~~) and new introduced items are marked in red in the WBS.

An overview of the estimated cost for the tunnel part are shown in the table below where the cost for the open construction pit alternative are estimated to be 400 to 450 mill. NOK extra compared to the immersed tunnel alternative which equals to approximately 25% to 30% of the total price (before adding on 30% for “rigg”).

	Immersed tunnel Alternative, 16730, H6	Open construction pit Alternative, 16730, H6
1.3 Tunnel		
Temporary works, mill. NOK	531	935
Permanent works mill. NOK	346	375
Total, mill. NOK	877	1,310
Total for the project, including ramps, Installations, add on for "rigg" (25%)etc. mill. NOK	*1,952*	*2,516*

5. Other consequences/aspects

For the considered open construction pit method, a single sheet retaining structure placed in the water, important aspect to consider are the potential consequences when a vessel collides with the retaining structure. Under a collision the retaining structure could get severely damaged with potentially catastrophic consequences for the construction pit. The vessel colliding with the retaining structure could be a passing vessel or a vessel involved in the construction activities.

The period for the construction pit being present in the water can be expected to be longer than one year. This results in that the construction pit is potentially exposed to loads from drifting ice during the winter period. Drifting ice could potentially damage the single sheet retaining structure with potentially catastrophic consequences for the construction pit.

In the estimated costs for the open construction pit no provisions have been priced to deal with the two above mentioned aspects.

6. Conclusion

- The estimated cost increase for an open construction method with in-situ cast tunnel, for constructing the 580 meter tunnel on alignment 16730 (cross section H6) compared with an immersed tunnel construction method, is 25% to 30%.

- The risks during construction, due to the assumption that ships must be allowed passing and the risk of considerable load from the formation of ice on the fjord, are evaluated as being higher compared to the immersed tube tunnel alternative.