USE OF EPS IN THE BJØRVIKA PROJECT IN OSLO, NORWAY

Ole Kristian Lied okl@geovita.no Geovita AS, Torbjørn Johansen tjo@geovita.no Geovita AS, Svein Røed svein.roed@vegvesen.no Norwegian Public Roads Administration Bjørvika Project

The Bjørvika project is a major infrastructure project in the city center of Oslo, Norway. The key element of the project is a submerged tunnel crossing the harbor front. The tunnel reduces the main traffic on the seafront and thus makes it possible for an urban development of the area.

EPS is used in several parts of the project. At both ends of the submerged tunnel, the contractors used EPS embankments for temporary access to construction sites. For the two bridges in the project EPS has been used to minimize loads on the bridge abutments and the adjoining embankments. The last part of the project is to construct new main streets in the new developed area. Due to soft ground conditions and deep rock face, EPS, in combination with other light fill aggregate, will be extensively used to keep settlements at an acceptable level.

THE BJØRVIKA PROJECT

The Norwegian Public Roads Administration (NPRA) is building the E18 Bjørvika project in Oslo. The project is a major infrastructure project in the eastern part of the city center of Oslo, Norway. The project connects the existing tunnel under the central part of the city (Festningstunnelen) with the Ekebergtunnelen for northbound traffic and Mosseveien for southbound traffic. The new tunnel will accommodate a traffic volume of 100,000 vehicles a day underground.

Figure 1: Bjørvika, the road project and the new development areas

The project will reduce the main traffic on the seafront and thus makes it possible for an urban development of the area. In this area the new Operahouse is already built and have attracted a large flow of interested locals and tourists. The opera is the first element in a large cultural, residential and commercial development of this part of the city.

The key element of the project is a submerged tunnel crossing the harbor front. At both ends, large open construction sites were necessary to connect the submerged tunnel with the existing road system.

After the main traffic is moved to the new main highway in the harbor, new boulevards and local roads will serve the new part of the town. This part 2 of the Bjørvika project has just started in 2011 and will be finished in 2016.

GROUND CONDITIONS

The ground conditions in the Bjørvika-area are characterized by relatively large depths to bedrock, soft normally consolidated marine clay and reclaimed land.

The depth to the bedrock varies typically (for the parts of the projects we deal with here) between 25 to 65 meters.

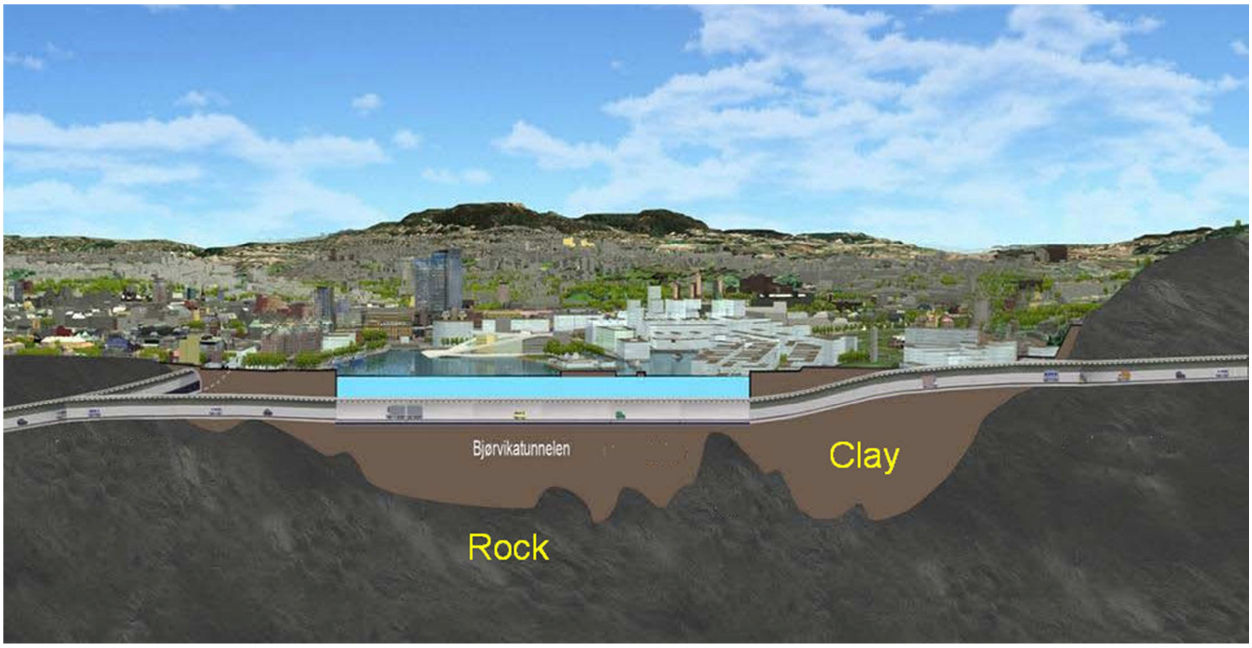

Figure 2: Cross section of the submerged tunnel

The soil deposits are marine clay from the last glaciation. The clay is normally consolidated and thus even relatively small loads will lead to settlements. The reclamation of the seafront have for a large part been done with soft material, either dredged clay and silt from the harbor or saw dust from the many old saw mills along the Akerselva river with its outlet in the middle of Bjørvika.

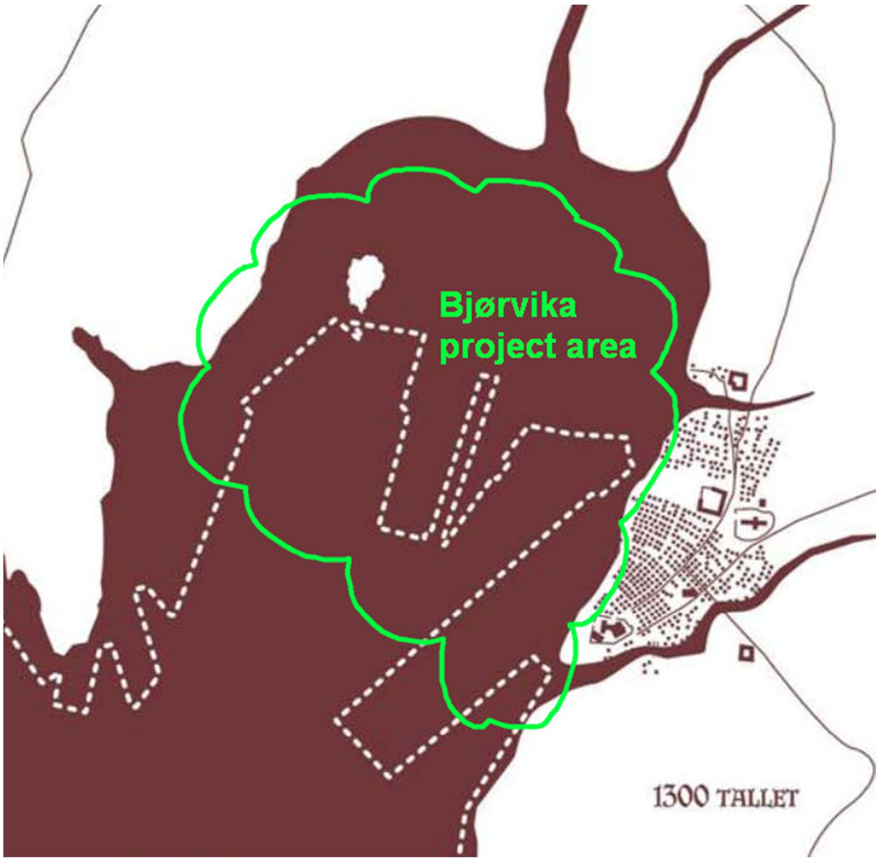

Figure 3: Reclaimed land at the Bjørvika area

As a consequence of the ground conditions many projects have suffered from large settlements shortly after completion repeatedly requiring maintenance and repair.

Consequently all new structures, excluding the submerged tunnel, are founded on piles to bedrock. However, large road areas will be constructed on the existing terrain.

TYPICAL USE OF EPS IN THE PROJECT

The use of EPS has not been the major recognized technical aspect in the project, but still a part in several aspects of the project:

- Access ramps to excavations
- Reduce loads on structures founded on piles
- Reduce terrain loads from road embankments

Access ramps to excavations

The deep excavations for the end parts of the submerged tunnel are naturally located close to the sea front. The sheetpiles supporting the excavations had a top elevation of 1.85 meters corresponding to a 50 year storm surge in the harbor. The excavations were completely enclosed with sheetpile walls. The access ramps had to be constructed inside of the sheetpile walls. In previous projects the access ramp had been constructed as a steel formwork welded to the sheetpiles.

In Bjørvika, both the contractors preferred to build the ramps of EPS blocks. The designs of the ramps were undertaken by the contractors with their consultants and were paid as a lump sum.

At the city-side (Havnelageret) the contractor NCC Construction AS designed the access ramp with EPS fill combined with a concrete ramp outside thus minimizing the ramp inside the excavation. The EPS-fill was secured with ordinary fill material on the side slopes. Two pictures during construction of the ramp are shown below.

Figure 4: EPS-fill at Havnelageret excavation

Figure 5: Combination of EPS-fill and concrete ramp at Havnelageret.

At the opposite side of the harbor, the Sørenga excavation is much larger. The first part is secured with diaphragm walls. As the depth of the bedrock decreases, the excavation is secured with heavy steel sheetpile walls to bedrock. The access ramp was situated at the sheetpile wall part of the excavation. This access ramp would both be used for transport out of excavated material and transport in of reinforcement and concrete. The ramp would also serve as the main access for all the technical equipment for the tunnel system. The access ramp was therefore made both wider and with a gentle slope.

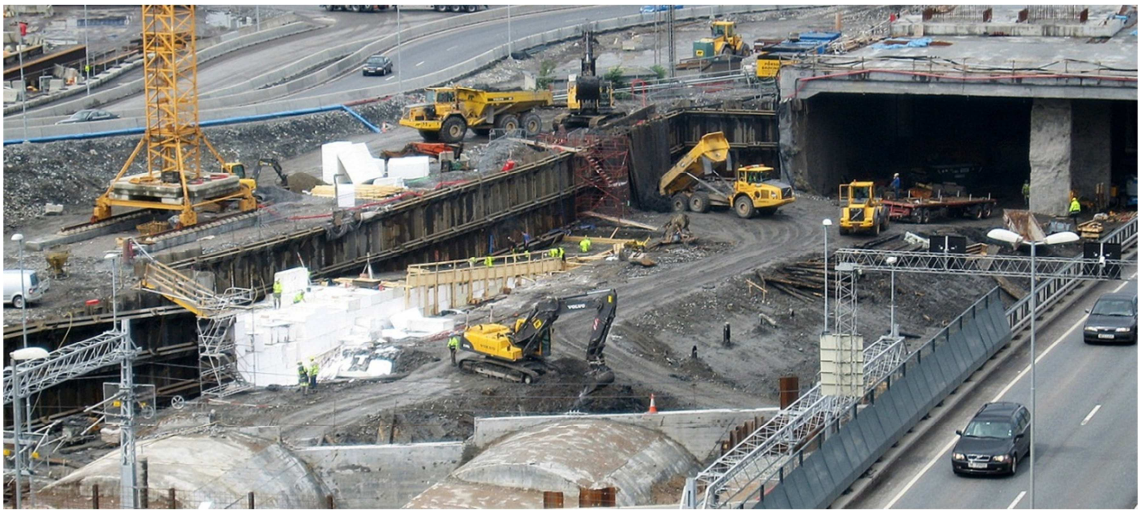

Figure 6: Construction of the EPS ramp at Sørenga

The design of the ramp was undertaken by Norconsult AS on behalf of the contractor AF Spesialprosjekt AS.

The ramp was constructed as an EPS-embankment with vertical side. The embankment was anchored horizontally to the sheetpiles. The EPS fill was protected with shotcrete.

Figure 7: Finished ramp at Sørenga

Reduce loads on piles

As part of the Bjørvika project, a new bridge is built crossing the rail tracks of the central station in Oslo, The Nordenga bridge. The bridge is founded on piles to bedrock. The steel structure for the bridge was produced in sections in the Netherlands and welded together at the side of the rail tracks and finally pulled over the entire station.

Figure 8: Nordenga bru

The bridge abutments on both sides are also placed on piles, but due to large depth to bedrock the most economical solution was to use EPS in the abutments to reduce the loads on the piles. A typical cross section is shown below.

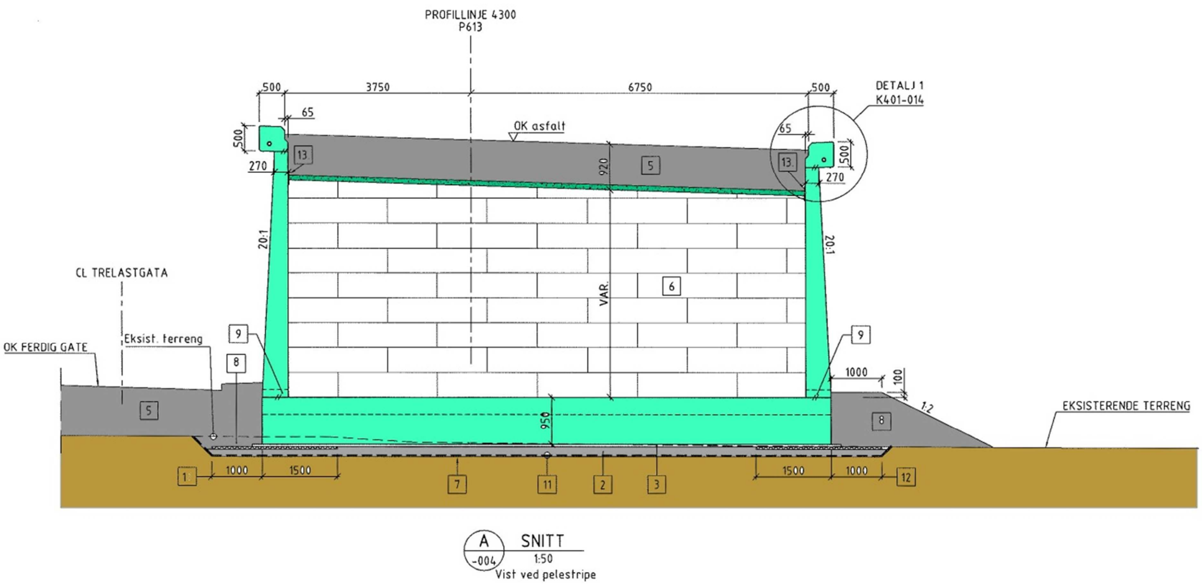

Figure 9: Cross section of bridge abutments for Nordenga bridge (piles not shown)

The bridge is at present under construction by the contractor Betongmast AS. In April 2011 the concrete structure was finished and the work on the EPS embankment was under way. A total volume of approximately 4.000 m^3 is used in the different EPS embankments.

Figure 10: EPS fill for the Nordenga bridge

Reduce terrain loads from road embankments

The main street from south and east to the Bjørvika area (Kong Håkon 5's gate) is to be built along an artificial lake. The lake represents the sea shore 800 years ago when Oslo was one of the main cities for the Vikings. The street is separated from the lake with a concrete retaining wall.

The pedestrian lanes and the traffic lanes are separated by three rows of trees, see the cross section in figure 12.

Behind the wall, the old main highway with up to eleven lanes was built in the early 90's. The highway was entirely constructed on an embankment placed on the existing terrain to avoid excavation in cultural layers from the middle age.

The ground conditions consist typically of silt embankments placed on top of normally consolidated clay. The depth to bedrock exceeds 50 meters. The soils are exposed to large settlements when loaded.

From the opening of the highway in the early 90's to 2010, parts of the highway with concrete retaining walls have experienced settlements up to nearly 1 meter.

Figure 11: Kong Håkon 5s gate

The new street has to have an elevation up to 1 meter above the old highway thus increasing the net load on the soft subsoils.

The design was therefore to make the new road embankment totally load compensated. This is achieved with the use of EPS and lightweight foamglass aggregate.

The EPS embankment is placed on the existing terrain from the '90's. Before the new embankment is placed, the old road embankment is removed. It is further important not to excavate deeper than the previous terrain level to avoid the need for archeological excavations and investigations.

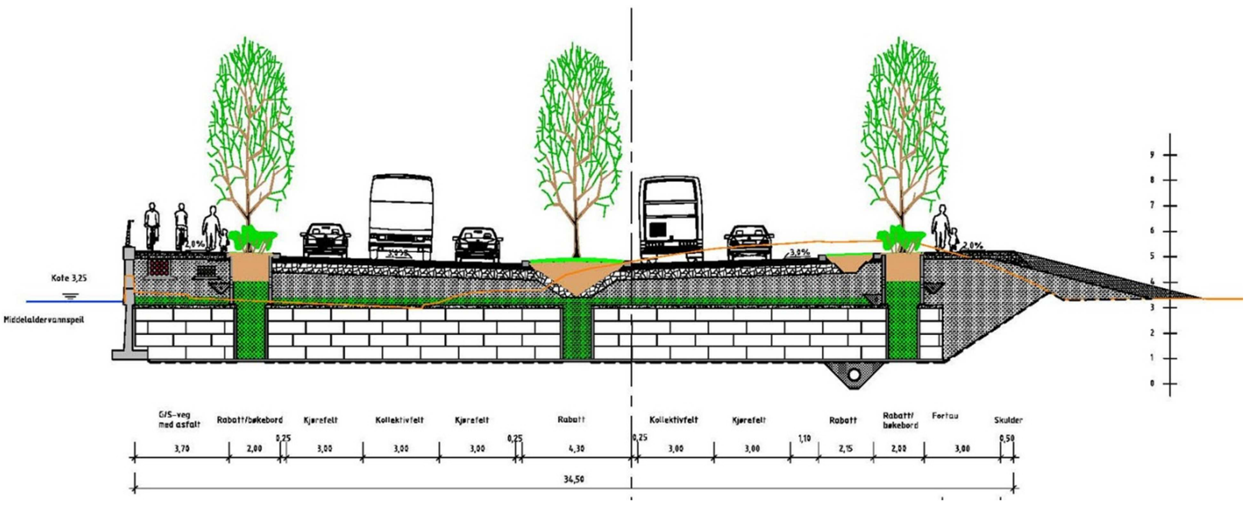

Figure 12: Cross section of Håkon Vs gate with EPS and foamglass

The cross section above shows the main principle for the road structure. The EPS embankment is horizontal and is covered with a concrete slab. The volume of EPS is approximately 15.000 m^3. The area of the EPS embankment is approximately 11.000 m^2.

On top of the concrete slab a layer of foamglass is placed. This layer takes up the geometry variances across the section. Foamglass has also good load bearing characteristics thus allowing it to be used higher up in the road construction than EPS normally used in road embankments. A total volume of approximately 22.000 m^3 of foamglass will be used.

On top of the foamglass a traditional road pavement is placed.

A challenge to the project has been the large number of trees which are to be placed in three rows along the street. How to get trees to grow in an EPS-embankment?

Together with the landscape architects Dronninga AS we have developed a method where we install concrete boxes for each tree. The box is placed directly on the ground and the EPS-fill is constructed around the box. The boxes are to be filled with a mixture of foamglass, organic soil and mineral soil. The boxes have also openings on the sides to allow the root system to spread on top of the concrete slab. Therefor the lower layer of foamglass is also mixed with organic soil. The trees will have an automatic watering system. A detailed cross section is shown below.

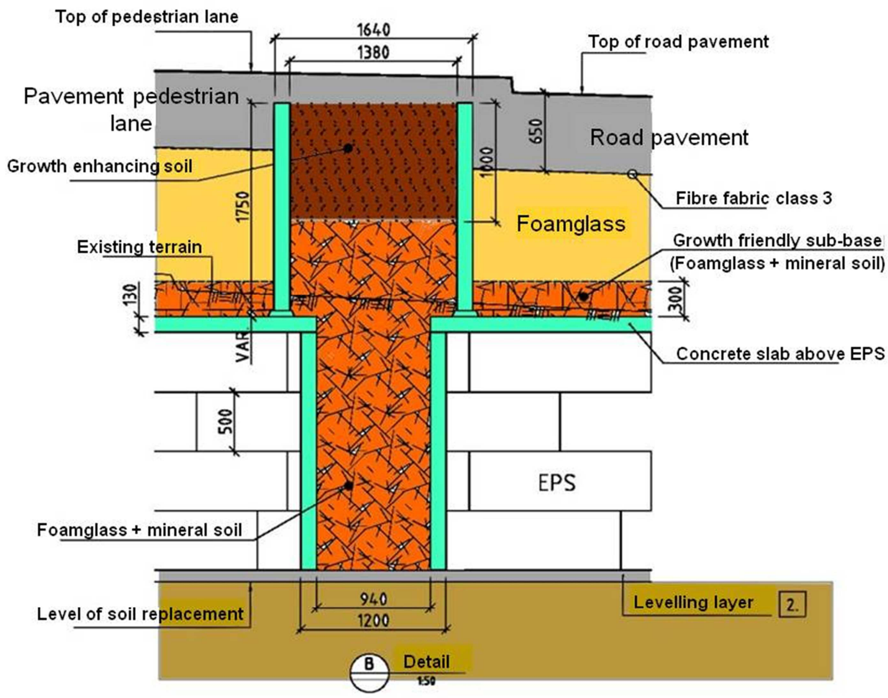

Figure 13: Concrete box for growing trees in EPS embankment

The construction of the street will start in 2012 and it will be interesting to see if this approach will work in real life.

The plan for the new street demands that the concrete retaining wall must be elevated further to support a higher elevation of the street due to new plans for the city planning.

The retaining wall is not designed for the increased earth pressures. The redesign of the wall had therefore to allow for a higher wall without increased earth pressure. This is achieved by anchoring the wall to the concrete slab which is placed over the EPS-fill together with allowing a gap between the EPS fill and the wall. The EPS fill in Kong Håkon 5s gate will therefore serve two technical purposes.

The EPS-works are specified in the standard specification from the Manual 025 General Specifications 1 Standard specification texts for highway construction from the Norwegian Public Roads Administration.

CONSULTANTS AND CONTACTORS IN THE BJØRVIKA PROJECT

The main consultant for the Bjørvika project is Aas-Jakobsen AS. A consortium of 18 consultants makes up the project team. Geotechnical design is provided by Geovita AS and the Norwegian Geotechnical Institute in cooperation. Vianova Plan og Trafikk is responsible for the road planning. Dronninga Landskap is the landscaping architects for part 2 of the project.

The Bjørvika project is planned and supervised by the Norwegian Public Roads Administration.