https://doi.org/10.32762/eygec.2025.30

CASE STUDY ABOUT STABILIZING WORKS IN HIGH SENSIBLE QUICK CLAY AREA IN MOSS, NORWAY

Christoph JANUSKOVECZ[1]

ABSTRACT

Since railway traffic is constantly increasing, BANE NOR (national railway of Norway) is building, renewing and expanding it's railway network, especially in the greater area around Oslo. One of these projects is located in the city of Moss (appr. 60 km south of Oslo) that contains around 10 km of newly built double tracks north and south of the city (in tunnels and above ground) and a new railway station in the city center of Moss. During the first phase of the project it was discovered, that the underground in the center of Moss contains layers of quick clay making the area very sensitive for construction works. Following a redesign of the geotechnical works combined with a test field it was concluded that the soil stabilizing works can be done by installing jet grout columns to increase the slope stability. During execution of these jet grout works a lot of challenges were encountered such as reacting to the ground movements, adapt the jet grout works to the different soil layers or balancing the execution within aspects of economic terms while fulfilling highest quality requirements. Between September 2023 and October 2024 a majority of the stabilizing works in the city center of Moss could be finished preparing the ground for following geotechnical as well as construction works such as relocating streets, bored piles as a retaining wall or building the support walls for an excavation pit for the upcoming connection of the tunnels with the railway station.

Keywords: jet grouting, quick clay, soil stabilization, railway construction.

INTRODUCTION

Due to the men made global climate change societies and governments are trying to find ways and strategies to limit the global warming, mainly by reducing the CO_2 emissions. One out of many other approaches is to transform traffic. This transformation away from people's individual traffic towards public traffic requires - besides the will of people to change their behaviour - well working, modern infrastructure. Railway traffic plays a key role in this process by giving the opportunity of not only transporting people, but also quite big amounts of goods, while emitting much less CO_2. Like other countries, Norway also is modernizing, renewing, expanding and upgrading their railway network to make it fit for the future. One out of many other projects in Norway is the SMS2A project (Sandbukta - Moss - Såstad) in and around the city of Moss, which is located around 60 km south of Oslo. The SMS2A project contains approximately 10 km of newly built double tracks (from which around 5 km are located in tunnels) and a new railway station in the city centre of Moss.

SMS2A PROJECT

Figure 1 gives an overview over the SMS2A project that is part of the Intercity Development Project in Norway. Since population in and around Oslo is growing, the need for public transport in this area will increase, as well as this project is also part of the railway connection from Norway towards central Europe and further to Italy. Coming from the north, the new tracks split from the existing tracks (which follow the coastline) in Sandbukta heading into the Moss tunnel. The Moss tunnel tracks leave the existing tracks towards southeast bending towards south and southwest afterwards to enter the new station area in the middle of the city of Moss ("02 Pit Kransen" in Figure 1). The new station area ("03 Moss Station") is situated directly south of the existing Moss station in between the Fjordveien and the seaport. In this area the existing tracks are in use just nearby the construction area. The new tracks leave the Moss tunnel in the so called Kransen area entering directly into the new station. Following the line going southwards the tracks enter another tunnel - the Carlberg tunnel - south of the new station in the so called Kleberget area. The Carlberg tunnel follows a smooth bend towards southeast rising up to the surface again next to the Carlberg Gaard. After the tunnel portal the new tracks are heading towards southeast and draw closer to the existing lines, straightening an existing, small bend towards southeast while intersecting into the existing railway line in the so called Såstad area ("07 Farmers underpass" in Figure 1). All works described in this paper are part of the area "02 Pit Kransen" and "03 Moss Station" as shown in Figure 1.

1 Dipl. Ing., Keller Grundbau GmbH, Vienna, Austria, christoph.januskovecz@keller.com

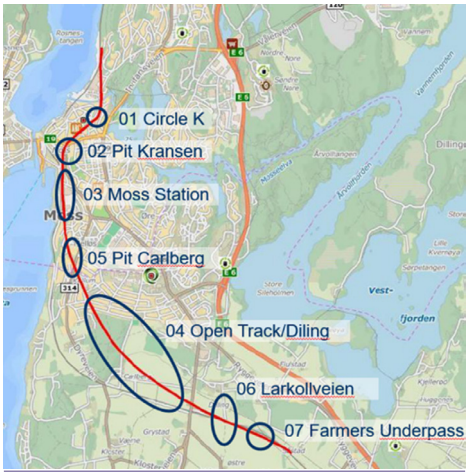

Figure 1 *Overview over SMS2A project*

Originally planned to be finished in 2024 the execution of the project delayed massively due to a geotechnical problem that occurred during soil stabilization works in 2020. In the city centre of Moss (near the future station area) a small slide occured during the execution of LCC (lime cement columns) works. Realizing, that the layers of quick clay in the project area are far more unstable than expected, the construction works were stopped due to safety reasons. The central part of the project, including the southern tunnel portal of Moss tunnel, the new station itself with all accompanying works, as well as the north portal of the Carlberg tunnel, were furthermore excluded from the general contractor project.

Bane Nor, as the owner of the project, took over the central part, started to redesign and evaluated how to proceed with soil stabilizing works. Part of this evaluation was a test field in 2021 where Bane Nor and Keller Geoteknikk, in close collaboration, evaluated the possibility of carrying out the soil stabilization works by installing jet grout columns. Based on the outcome of this test field the redesign could be done and finally the execution of the works were commissioned in 2023.

EXECUTION OF JET GROUT WORKS

Execution of the jet grout columns started in September 2023 with another test field. Since stabilizing the ground using jet grout columns was evaluated and approved at the first test field in 2021, the goal of the second test field in 2023 was to optimize the design in a final step. It was tested to produce columns with diameters of 1,6 m and 1,8 m with a close look on the reaction of the surrounding ground (pore pressure, movements and signs on surface like cracks, surface uplifts, etc..). The trial of the 2,0 m diameter columns was cancelled during execution of the first test columns. Moreover it was tested to produce columns with different strenghts (2,5 - 5 MPa) and how these different strenghts influence execution parameters like production time, amount of used material and amount of backflow. After finishing the test field with appr. 40 test columns the design could be finalized by the client.

In the two so called areas of Kransen South and Station Area the soil stabilizing jet grout ribs contain of 1,6 m diamter columns with a compression strenght of 5 MPa. In the so called area of Kransen North the ribs that support the ground for the production of the excavation pit's retaining walls were designed with columns with 1,5 m diameter and 4 Mpa. In the most sensible area of Kransen East (where the slide in 2020 happend) two different types of columns with diameters of 1,4 and 1,6 m and strenghts of 2,5 and 4 MPa had to be executed. In Figure 2 an overview of the jet grout soil stabilizing works can be seen (with jet grout columns that build the rips in red)

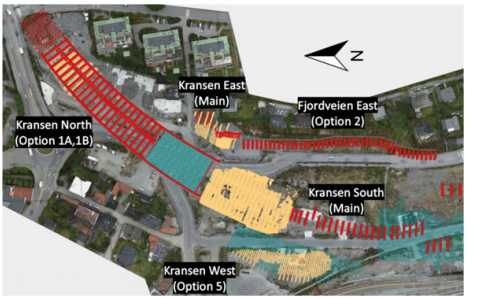

Figure 2 *Overview over jet grout works in center part of SMS 2A project*

SUBSOIL CONDITIONS

In most of the Moss-center project area, the bottom layer over the bedrock is a kind of moraine, followed upwards by silty clayey layers with embeddings of quick clay and furthermore menmade backfillings near the surface. In some areas the layers are stiffer, in others softer, as well as they vary in their granular content. Quick clay is a former submarine clay sedimentation, that was saturated with salt. Nowadays, since the salt content in quick clay is decreasing slowly, quick clay has a poor stability and is very sensible in regards of construction activities. When quick clay gets loaded too much or treated in the wrong way (vibrations, etc...), it can end up in liquefication and landslides. In the last decades landslides happened in all over Scandinavia due to quick clay problems.

CHALLENGES

One of the main challenges of the execution of the jet grout works were to achieve the required strenghts in the silty clayey subsoil conditions. Due to the stabilizing function of these columns, it was also necessary to have a good bedrock connection. This two requirements and the big project area spreading over 600 m in north-

south direction, made it necessary to adapt the execution paramters like pumping pressure, drill string rotation or withdrawal speed continouisly in refference of the local soil conditions. These parameters were determined as base values during the test field 2023 and had to be adjusted slightly througout the execution. The geometry as well as the strength requirements were controlled by two different methodes. For adjusting the parameters to the local subsoil conditions and controlling the diameter, so called ACI-tests were conducted. ACI test (Acoustic Column Inspector) is an invention of Keller Grundbau GmbH (Austrian parent company of Keller Geoteknikk AS). By using ACI tests the diameter of a jet grout column can be determined with the help of two acoustic rods that are set into the ground in a specific distance of the drilling rod. With acoustic sensors it can be measured, when the jet stream touches the rod, making it possible to determine the achieved diameter in certain depths. The strenghts were controlled by doing core drillings and UCS (uniaxial compression tests) testing. In the beginning of the works also the backflow (the eroded soil that is spilled out at the borehole) was controlled with UCS tests, which was concluded not to be done anymore, since test results varied too much due to inhomogenous backflow samples.

The handling and treating of the backflow was also a big challenge, especially in the first months of execution. Since jet grout columns with strenghts of 4 or 5 MPa in silty clayey conditions are very special to produce - and in general not very common - the amount and especially the consistency of backflow that contains quick clay made it hard to deal with. It was a requirement, that all backflow masses need to be treated in chamberfilterpresses due to economic reasons (reducing volumes and avoiding expensive liquid masses to be brought to landfills). The water, which was pressed out, was treated in a water treatment station to be used again as process water or to be drained into the sea. The pressed masses of backflow with approximately 30 % rest humidity were stored temporarly on site before beeing removed to landfills. It was found out, that one chamberfilterpress did not reach the capacity to filter the backflow of one jet grouting rig within one day. Therefore backflow treatment was limiting the jet grout production in the beginning. In the end 6 chamberfilterpresses were needed to treat the backflow that was produced by 4 operating jet grout rigs. The ratio of 1,5 operating filterpresses for 1 jet grout rig was experienced for the first time, resulting from the special execution requirements in combination with the local subsoil conditions. In tests it was also found out, that backflow, that containes quick clay, will not dry and get hard like usually - even after weeks of storing.

Besides these execution challenges mentioned above, the overall sensible subsoil conditions represented the major challenge for the project as a whole. With hundreds of sensores, measuring pore pressures and inclinations, in addition to geodetic surveyance and orthofotografic observations, the project area was monitored in a dense grid securing to reduce any kind of risk of soil failure to a minimum. Therefore execution had to be stopped several times for some days up to weeks due to slight movements. These interruptions in execution were necessary to guarantee a safe way to continue with the works, but also represented big challenges regarding the construction schedule, the overall organization as well as the on-site coordination.

Other challenges, even if not that impacting like the ones mentioned above, were to deal with the problems that occur due to the location of the construction site in the city center of Moss. The aim to reduce the impacts on the neighbouring residential areas resulted in some special solutions, like pumping backflow with densities of up to 1,65 kg/L over a distance of 700 m or limitations regarding execution hours. Weather conditions in Norway, especially the winter of 2023/2024 with temperatures between -10° C to -20° C for several weeks and (for the coastal areas) untypically amounts of snow, challenged people as well as material and equipment.

CONCLUSION

Despite all challenges and requirements, in the first year between October 2023 and October 2024 all soil stabilizing jet grout works in the areas of Station Area, Kransen South and high sensible Kransen East could be finished. These stabilizing works build the base for upcoming construction in these areas like relocating streets or other preparation works for the later starting construction of the railway station. In the area of Kransen North approximately 50 % of the needed soil stabilizing jet grout ribs were executed. These jet grout executions in Kransen North were continued after October 2024, besides starting up other stabilizing works by installing bored piles as retaining wall or doing deep soil mixing works.

In summary it can be said, that - after redesigning the Moss center part of SMS2A project - in the first year of executing soil stabilizing works, between September 2023 and October 2024, a lot of challenges had to be faced, ending up in finishing most parts of the works successfully in regards of economic terms whilst also fulfilling all quality requirements.

REFERENCES

Bane Nor, (2020). Kapittel D1 Oppdragebeskrivelse til NS 8405, Bane Nor, Oslo, Norway.

Besler, O. (Year). Large scale geotechnical works on Norways largest infrastructure project, Keller Geoteknikk AS, Oslo, Norway.

Keller Group Plc., Acoustic column inspector ® - ACI ® Online diameter control for jet grouting elements, Keller Group Plc, London, UK.

NGI (2023). What is quick clay?, Available at: https://www.ngi.no/en/research-and-consulting/natural-hazards-container/avalanches-and-slides/quick-clay-landslides/what-is-quick-clay/, accessed: 01/05/2025.

Rosenquvist, I.Th. (1966) Norwegian research into the properties of quick clay - a review, Engineering Geology, Volume 1, Issue 6, pp. 445-450, https://doi.org/10.1016/0013-7952(66)90020-2.

Schaden Hans Jürgen, SH, Keller Holding GmbH (2015). Verfahren und Anordnung zum Ermitteln des Radius eines mittels Düsenstrahlverfahren herstellbaren Bodenelements, AT, EP 2 843 137 A1.

07

DEEP EXCAVATION AND UNDERGROUND STRUCTURES