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Rock Grouting In Copenhagen Limestone – The Cityringen Experience

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Abstract

Extensive rock grouting has been carried out during the construction phase of the Cityringen Metro Project. The main goal of the rock grouting has been to reduce the permeability in the rock by filling joints, cracks and fissures, in order to minimize the groundwater inflow during excavation of caverns, pump sumps and TBM break in/out through the stations/shafts. Both horizontal and vertical grouting has been performed above and below the water table, with unique challenges and advantages/disadvantages. The grouting has been performed as up-stage, where the grout hole is drilled to full depth and then grouted from the bottom and up in stages using a pneumatic packer. The split-spacing method has been used to expand the grouting pattern if needed after primary grouting campaign has been finished and tested. The article describes, through case histories, the achieved results, challenges and limits of the applied methods, including future recommendations. The rock characteristics of the Copenhagen limestone, in regards to the performed rock grouting, are also discussed.

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Keywords: Rock Grouting; Limestone; Copenhagen; Case Study

1. Introduction

The Cityringen Metro is expected to be running in 2019 and will consist of two single tracks in twin tunnels, each approximately 16.5 km in length. A total of 17 underground stations, 4 cross-over facilities and 3 construction and ventilation shafts have been made when the project is finished.

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The Cityringen is built entirely in the urban area of Copenhagen; most of the stations are located in congested areas, surrounded by historical building. One of the most sensitive activities during construction is the break-in/-out of the station/shafts. It is mandatory to ensure a dry or at least a controllable groundwater inflow during the break-in/out phases. Between various technical solutions, the contractor developed a grouting plug to reduce the inflow of water, which has proved efficient in the Copenhagen limestone.

2. Geology

The Geology of the Copenhagen area consists of Quaternary Deposit overlying the Paleogene Deposits, primarily consisting of Danian Limestone and Locally of Selandian Greensand [1]. The Copenhagen Limestone Formation is divided in 3 stratigraphically units: Upper Copenhagen Limestone (UCL), Middle Copenhagen Limestone (MCL) and Lower Copenhagen Limestone (LCL). The tunneling and excavation activities are entirely in UCL and MCL.

The Copenhagen limestone is a carbonate rock that can be generally described as a weak rock with very hard layers or nodules of flint. The Upper Copenhagen Limestone is horizontally bedded with layers of different indurations and flint beds with thickness ranging from a few centimeters, up to 1 m which in some cases can be followed continuously over long distances of up to 1 km. The Middle Copenhagen Limestone has a more nodular distribution of flint and more evenly distributed silicification. The unit is characterized by a lower frequency of strongly indurated limestone layers and flint bands compared to the Upper Copenhagen Limestone.

The upper part of the limestone is often disturbed or fractured by glacial processes. The disturbed zone is highly variable and ranges from a mixture of indurated limestone clasts in a less indurated, muddy limestone matrix, to a zone of higher fracture intensity than the limestone below.

In a few areas, no glacially disturbed limestone is observed, and the undisturbed limestone is directly overlain by Selandian Greensand.

Layer fracturing in the horizontal plane usually occurs along the surfaces between weakly indurated limestone and strongly indurated limestone beds or flint bands. Such fractures are probably caused by relaxation, due to unloading of the ice or by isostatic uplift. The intensity of the layer fracturing usually decreases with depth, but also reflects the differences in the constituent limestone units. Horizontal fractures are usually narrow with apertures sizes in the range of 20 μm to 2 mm, although openings locally up to 10-20 mm have been observed. The layer fractures are often associated with the peak flow zones registered in flow logged boreholes.

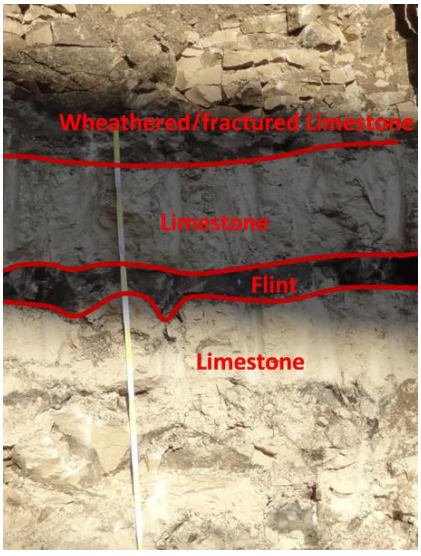

Fig. 1. Limestone geological profile.