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Assessment of clay soils and clay-rich rock for clogging of TBMs

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ABSTRACT

Shield tunnel drives in both, overconsolidated clays soils and sedimentary rock with clay minerals, frequently suffer extremely from hindrance due to clogging. The problem of clogging can have varying degrees, from locally blocked disk cutter housings to completely clogged excavation chambers with a blocked cutterhead. The clogging risk depends on multiple mineralogical and soil-mechanical parameters. The authors have more than 15 years of experience in practice and scientific research with the problem of clay clogging of TBMs. The paper shows the occurrence and risk for clogging in varying ground types and for different machine components, summarizes the available characterization methods for the stickiness of the ground, discusses a variety of laboratory tests for the assessment of clogging potential, explains a recently developed diagram for the assessment of clogging risks for all types of tunnelling machines, and introduces a new testing scheme for the evaluation of sedimentary rocks regarding clogging.

1. Introduction

The clogging of shield machines, as it is encountered in clay-containing ground has extensive consequences for the construction process and can severely affect performance. To address the clogging potential of the ground, therefore, is an important aspect of geological reports for tunnel projects. Here, we summarise the influences relevant to the tendency of soils to cause clogging and we present a new classification diagram according to Hollmann and Thewes (2013). Clogging can also occur in rock under certain conditions. Systematic methods of clogging assessment of rock, using parameters analogous to the procedure for soft ground, have not been available until recently. A new test to estimate the clogging risk of rock containing clay minerals is be presented.

Geotechnical standards differentiate between soil (=soft ground) and rock (=solid). The individual grains of solid rock are minerally bonded to each other or cemented. The strength and the amount of this grain bond determine parameters such as the rock strength and the brittle fracture behaviour of rock. In cohesive soils, on the other hand, the individual grains are only bonded to each other cohesively. The cohesive bond of soil is weaker than the mineral bond of rock and determines parameters such as the shear strength and consistency of the soil. The cohesive bond is susceptible to water and decreases in strength with an increase of the water content. This results in a reduction of the consistency of the soil, which in turn may cause sticky plastic behaviour.

In clay soil or very soft rock, during tunnelling, the cutter rings of the disks are pressed into the tunnel face, pushing the plastically deformable soil to both sides where it is cut by the drag picks in the form of 'lumps'. Water can transform the consistency of the cut lumps and the soil at the face into a sticky consistency, unless the soil is already sticky owing to its natural moisture content. In this case, if water is available, uncritical soils can turn into sticky material. Parts of the fine grains contained in the lumps or the soil at the face may disintegrate and accumulate in the inflowing groundwater or support liquid. Therefore, lumps with sticky outer layers may occur (Fig. 1) besides dry soil lumps, sticky material and sludge with accumulated fines.

In this context, clogging poses a higher risk to the tunnelling process than disintegrated fine contents in suspensions. While negative impacts induced by disintegrated fine contents only occur at the final stage of the process (separation plant, water treatment, disposal), clogging occurs throughout process from the excavation at the tunnel face up to separation and transport for disposal. In these cases, one and the same sticky material may create clogging of the tunnelling system at different process stages. Primary clogging may occur at the cutting wheel and will later cause secondary clogging at sieves of the separation or at transfer points of conveyor belts (Fig. 2).

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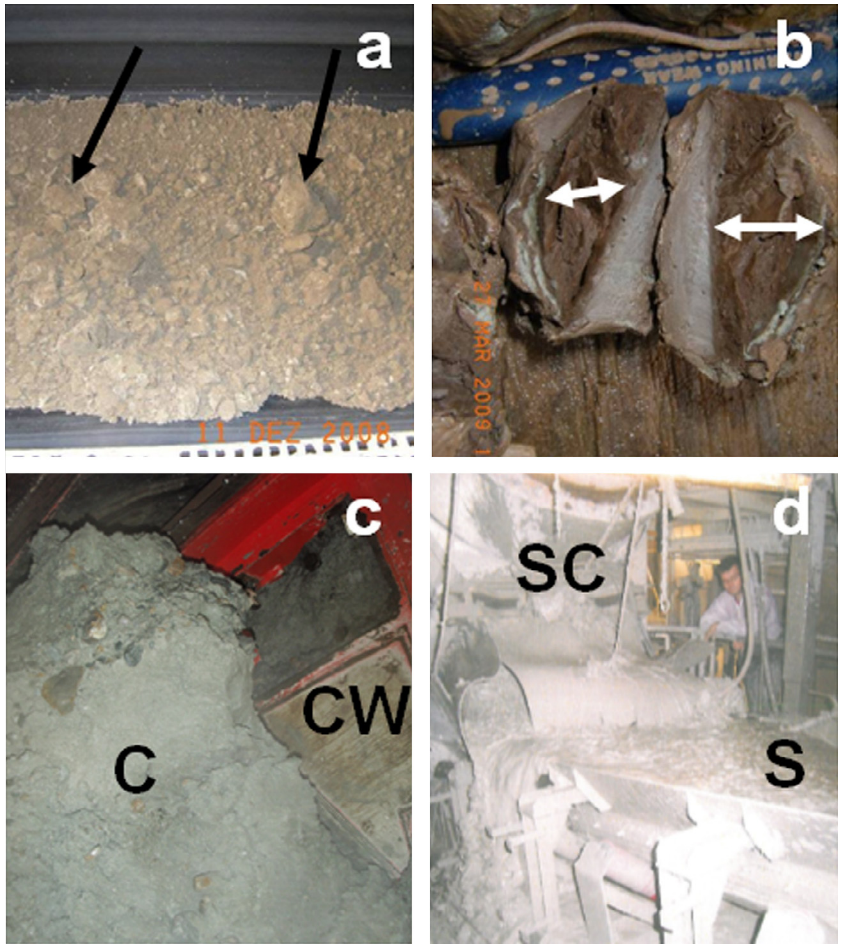

Fig. 1. Clay in shield tunnelling: (a) Dry clay on conveyor belt, (b) sliced clay lump with natural core and sticky surface, (c) clogging (C) between submerged wall and cutting wheel (CW) and (d) clay sludge (S) with high fine contents below discharge opening of a screw conveyor (SC).

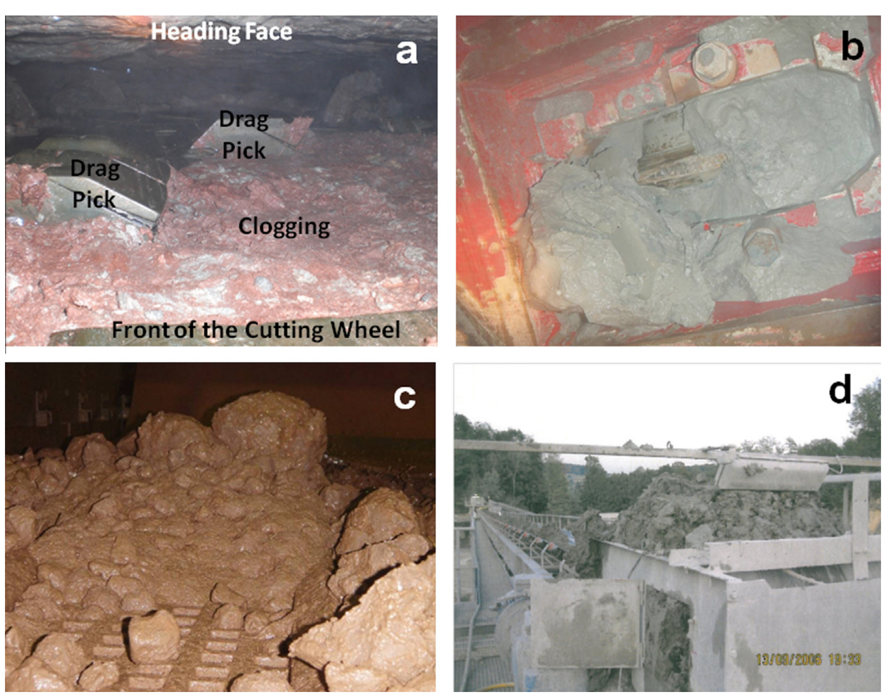

Fig. 2. (a) Clogged front side of a cutting wheel, (b) clogged disc cutter housing, (c) clogging of a separation plant and (d) clogging at the transfer point of a conveyor belt.