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Pressurised TBM tunnelling in mixed face conditions resulting from tropical weathering of igneous rock

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ABSTRACT

Weathering is a process that turns rock into soil. Deep weathering is prevalent in tropical and sub-tropical areas. The resulting sub-surface conditions can be very onerous for tunnelling, with tunnel drives commonly encountering a significant proportion of mixed face conditions, comprising partly rock and partly soil. Problems that have been encountered have included: inability to maintain the face pressure, ground loss, sinkholes, slow rates of tunnelling, rapid tool wear, damage to tools, mixing arms and other parts of the TBM, very frequent and long interventions, clogging and blow-outs. The nature and extent of the problems on any particular tunnel have depended on the type and design of the TBM, the nature of the rock and the proportion of the tunnel in mixed ground. In Singapore this has resulted in a change from mainly EPB to mainly slurry tunnelling in weathered igneous rock; however, predominantly EPB TBMs have been used in weathered sedimentary rock. Information from EPB and slurry TBM drives is used to illustrate the issues involved.

1. Introduction

In tropical regions, weathering can affect rock to a depth of 60 m or more below ground surface. Tunnelling in these conditions can be particularly challenging because of the potential for encountering abrasive, mixed face, conditions and/or swelling clay minerals. Over the last 20 years, there has been a significant amount of pressurised TBM tunnelling in weathered rock. Much of the tunnelling has been for infrastructure construction, in cities including Hong Kong, Singapore, Kuala Lumpur, Bangalore, Shenzhen and Guangzhou. The ground conditions resulting from tropical weathering are challenging for tunnelling, and there have been various problems during tunnelling. Some of the problems that have been experienced include:

- Inability to maintain the face pressure.
- Ground loss.
- Sinkholes or local areas with large settlement over the tunnel.
- Slow rates of tunnelling.
- Rapid tool wear, damage to tools, mixing arms and other parts of the TBM.
- Very frequent and long interventions.
- Clogging, either by sticky clay or by coarse grained particles.

Some of these problems are illustrated in Figs. 1–6. All of these examples are from tunnelling in mixed face conditions resulting from the weathering of granite in Singapore. Examples are provided from both slurry and EPB TBM drives.

The degree to which these problems may affect a particular drive depends on many factors, including: the extent of the mixed ground and type of rock encountered, the type and design of the TBM and cutting tools, and the operation of the TBM. Improvements in the design and operation of the TBMs have mitigated many of these problems, but the ground conditions remain inherently challenging, particularly when the rock is strong and abrasive. Selected experience from tunnelling in weathered igneous rock will be used to illustrate the challenges. Much of the experience discussed comes from tunnelling in Singapore, although use is also made of information from other locations with deep tropical weathering.

2. Ground conditions resulting from tropical weathering

2.1. General

Shirlaw et al. (2000) provided a review of the ground conditions that can result from deep tropical weathering, with a focus on the conditions encountered during underground construction in Hong Kong and Singapore.

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Fig. 1. Abraded screw conveyor from an EPB TBM.

Fig. 2. Damaged (bent and abraded) mixing arm, slurry TBM.

Fig. 3. Sinkhole over an EPB TBM drive.

Rocks close to the earth's surface are typically weathered to some degree, due to the effects of stress relief, the passage of groundwater and changes in temperature. Weathering involves physical disintegration or chemical attack. The chemical attack causes minerals break down to more stable forms, particularly to clays and oxides. Selby (1993) provides a review of weathering processes.

Fig. 4. Sinkhole over a slurry TBM drive.

Fig. 5. Damaged disc tyre.

Fig. 6. 'Flat' discs.

In tropical climates, chemical decomposition is generally the main factor in the weathering of the rock. The rock is often altered so severely that it is disintegrated or chemically altered to the state