Synopsis

In tunnelling, the logistic aspects associated with excavated rock and soil management (ERSM) significantly impact jobsite performances. Specifically, for Earth Pressure Balance Tunnel Boring Machines (EPB-TBM), ERSM must consider the temporal evolution of muck properties. This evolution arises from the gradual decay of the foam used for soil conditioning and the evaporation of water within the muck.

Through the conditioning process in the excavation chamber, the soil is transformed into a viscous liquid-like material with high compressibility, low shear resistance, and low specific bulk weight. These properties are crucial for effective excavation, managing counterpressure at the excavation face, reducing wear, and minimizing torque requirements for operating the TBM. It is desirable to maintain these properties as stable as possible while the material is in the plenum and screw conveyor.

On the other hand, as the muck is extracted from the screw conveyor, a quick transition to a solid-like behaviour is desirable for easier handling, storage, and reuse.

This research focuses on the time-dependent properties of conditioned soil. Using a morenic soil excavated using EPB in a construction site in Northern Italy, the stability of the foam used for conditioning was investigated, along with how its stability changes with the addition of particles. Additionally, the stability of conditioned soil was studied using different conditioning sets to understand how various parameters influence muck stability. Furthermore, the long-term effect of conditioning on the potential reuse of soil for civil applications, such as embankments and concrete production, was explored.

The aim of this study was to identify key mechanisms and contributions to conditioned soil stability, quantify them, and utilize this knowledge to optimize conditioning parameters at the jobsite. The findings provide valuable insights for designers and builders to consider the evolution of muck properties in their choices regarding jobsite logistics and management.

To address this aspect of soil conditioning, the research was divided into several steps, progressively studying simpler components and gradually incorporating elements to understand conditioned soil as a whole.

The first step involved testing and characterizing different liquid generators, measuring viscosity, electrical conductivity, surface tension, and determining the Critical Micellae Concentration (CMC). A comparison between liquid generators produced with distilled water and tap water revealed that the CMC reduced with tap water, resulting in more complex behaviour.

Subsequently, these liquid generators were used to produce foam across a wide range of Foam Expansion Ratios (FER), varying foaming agent concentration and flow rates during production. The stability of the foams was investigated through a modified half-life test on 460 foam samples, recording the drainage over time. It was observed that all foam samples exhibited decay following an asymmetric sigmoid law defined by five parameters. Two of these parameters were found to be correlated with FER, foaming agent concentration, and flow rate during generation, ultimately affecting the half-life time. Notably, the half-life time showed a logarithmic dependence on FER and an increment with the flow rate during generation. Also, was found a link with foaming agent concentration that was likely due to viscosity, as an increment in half-life time was observed only for products that increased the liquid generator's viscosity.

Building upon this point, the research focused on a single FER to investigate the role of soil particles in foam stability. Different quantities of soil fractions with varying grain sizes were added during foam production, and the resulting foams were tested for half-life time. Through 312 tests, it was determined that stability increased with the addition of soil fractions, and the half-life time followed a power law dependence on the quantity of soil present in the foam. Additionally, an exponential decrement of half-life time was observed with increasing particle dimensions. Furthermore, the presence of particles with different dimensions influenced the half-life time according to their proportion in the foam.

Subsequently, the investigation shifted towards studying the impact of conditioning parameters on muck stability. Using over 350 slump tests, more than 1000 modified vane tests, and 1000 specific bulk density measurements across 12 different combinations of water content and FER, it was observed that the evolution of muck properties mainly comprised primary and secondary decay. Primary decay exhibited a time-dependent gradient more sensitive to water content and less sensitive to FER. Consequently, achieving similar flowability could be accomplished through different water content-FER combinations, each displaying varying decay rates. Slower decay processes were associated with higher water contents. Additionally, the study explored the influence of muck remolding, revealing that mixing the soil impacted the speed at which the muck recovered its original properties.

Lastly, the research investigated whether soil conditioning affected its performance as a secondary raw material for civil applications. Ten different conditioning sets were tested to assess the soil's ability to regain its original compactability using a modified Proctor test. The findings indicated a relationship between the days required for the soil to recover its compactability and the initial water content present in the conditioned soil. Furthermore, the influence of surfactant residues resulting from conditioning on aggregates was examined concerning their suitability as concrete aggregate. It was observed that if not properly washed, the presence of surfactant residues in aggregates with a history of conditioning could lead to significant reductions in UCS, density, and stiffness of the resulting concrete.