



Tunnelling Asia' 2023

International Conference on
Climate Change Resilience and Sustainability
in Tunnelling and Underground Space



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Sustainable Solutions for Safe TBM Operations

by

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Soil Conditioning – Where is it Required ?



EPB TBM for
Soft Grounds

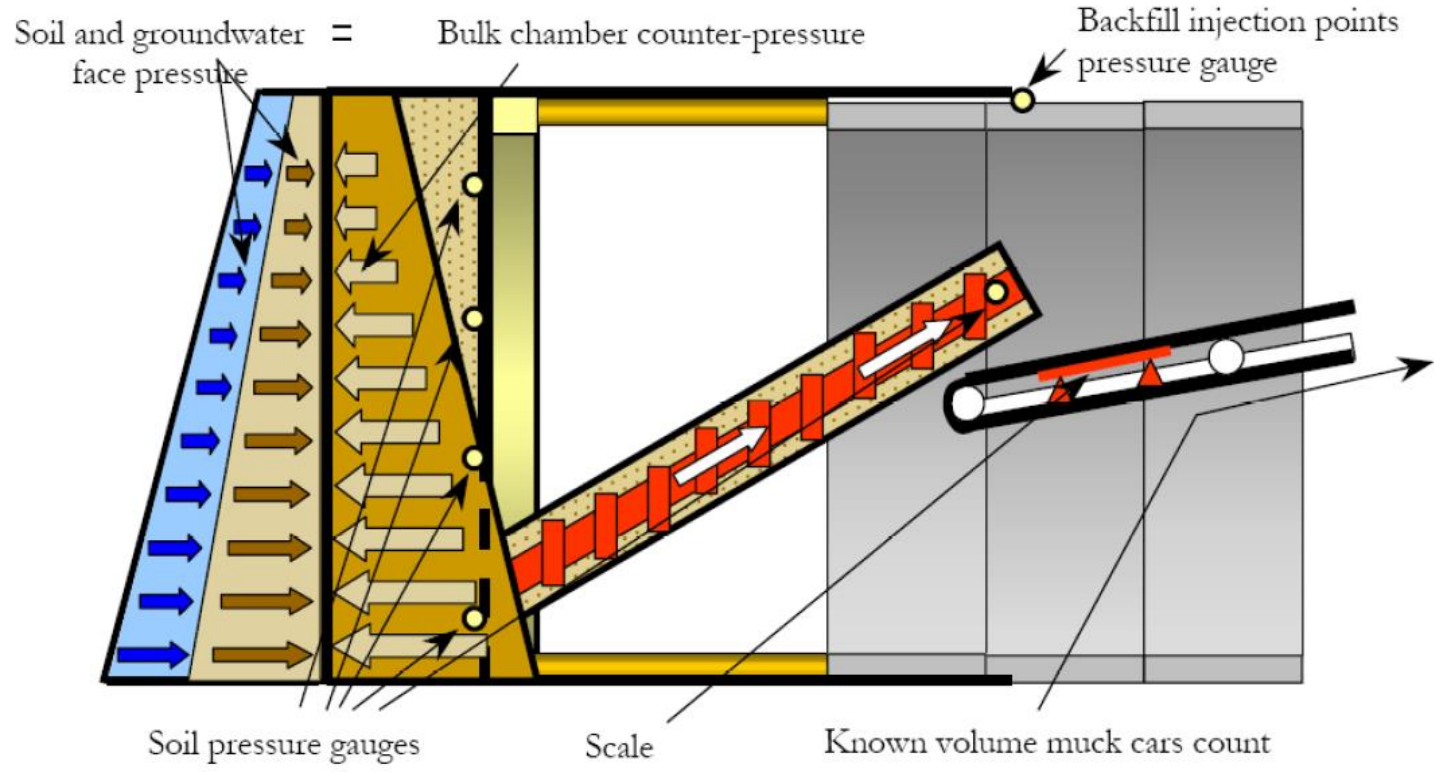


Figure 1 - Schematic representation of the tunnel face pressure control



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Tunnelling with EPB TBMs – Measures for a Good Soil Conditioning

As a first assessment, the soil features required for good EPB operations are:

- » A certain degree of **PLASTICITY** that makes the treated soil suitable for the **PRESSURE TRANSMISSION** in the excavation chamber and the **PRESSURE DECAY** control along the screw conveyor, as well as for the controlled extraction through the screw conveyor itself
- » The **PERSISTENCE** of the above-mentioned characteristics over the time, to allow a safe control of the face stability during the whole excavation step and when the machine has to be stopped due to any reason
- » A **LOW INNER FRICTION** of the bulk material that allows to reduce both the power requirement of the cutting head (**TORQUE**), as well as the **WEARING** of the machine parts that are in contact with the soil

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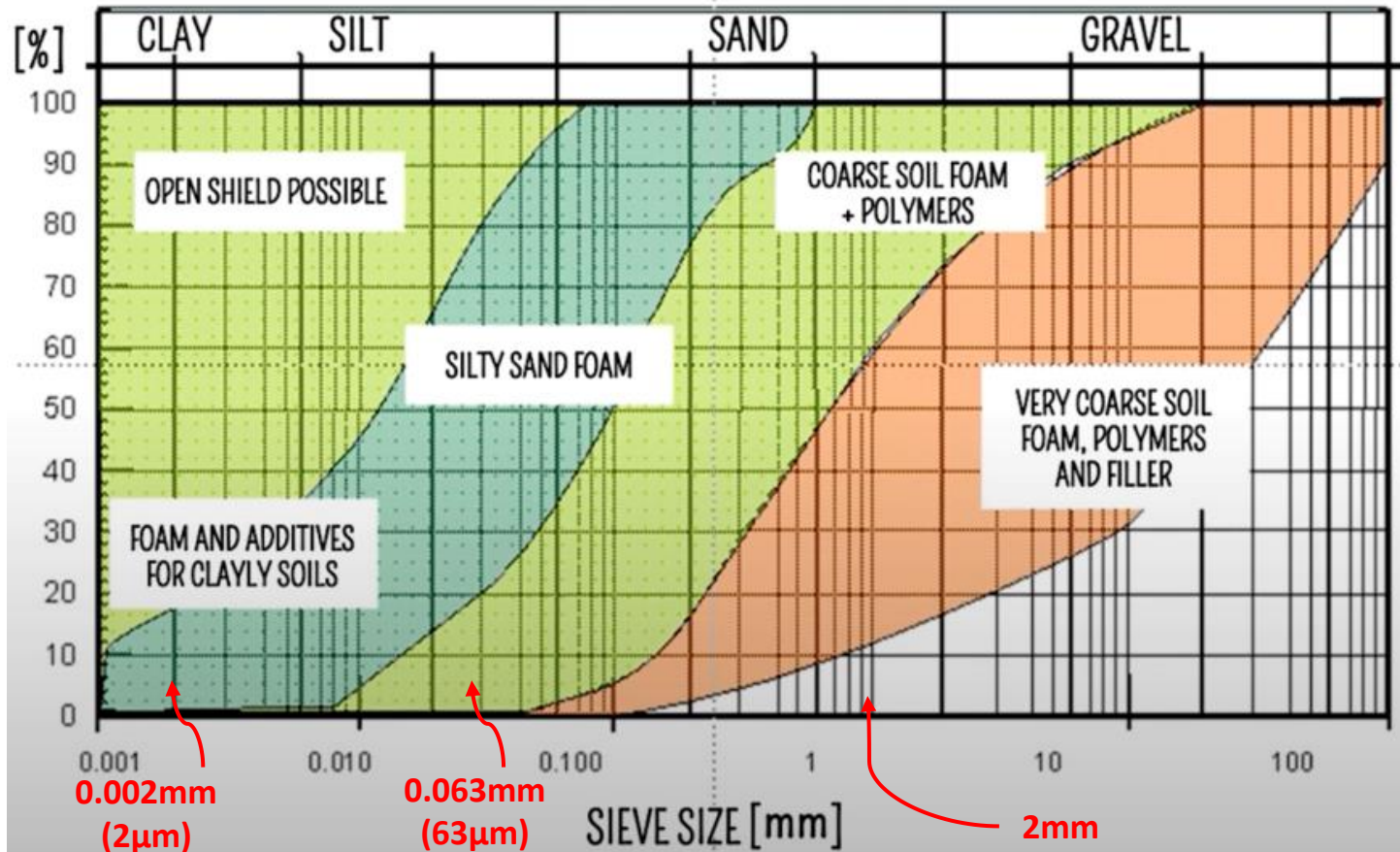


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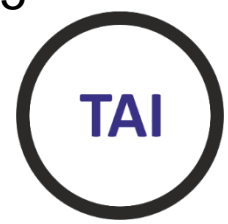
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Permeability of Soils – What happens without a proper soil conditioning



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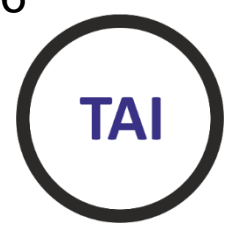
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Sika Stabilizer® TBM Technologies

Type of ground	Treatment	Sika Stabilizer® trade name	Technical name
Permeable soft grounds with presence of water.	Soil conditioning	Sika Stabilizer® SLF	Soil liquefying foams
	Anti-clogging	Sika Stabilizer® ACP	Anti-clogging polymers
Heterogeneous and plastic grounds.	Water Ingress Management	Sika Stabilizer® SLP Sika Stabilizer® SWA	Soil Liquefying & Super Water Absorbers polymers
Hard Rock	Lubrication	Sika Stabilizer® ABR	Anti Abrasion Foaming agents

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Sika Stabilizer® TBM Technologies – Foam Control Parameters



FER
Foam Expansion
Rate

1

FER REGULATES QUALITY

2

LOW FER → WET FOAM

3

HIGH FER → DRY FOAM

FIR
Foam Injection
Ratio

1

FIR REPRESENTS THE **VOLUME OF FOAM**
ADDED TO THE **VOLUME OF SOIL**

2

FIR CORRELATES WITH PORE VOLUME



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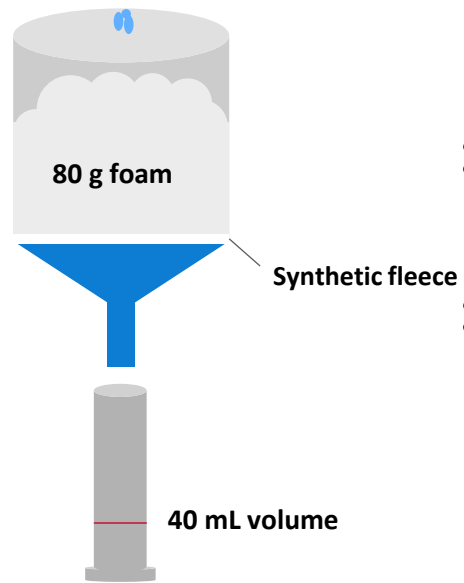


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Sika Stabilizer® SLF Technology – Half Life Drainage Time (HLT) & Mechanical Resistance Test

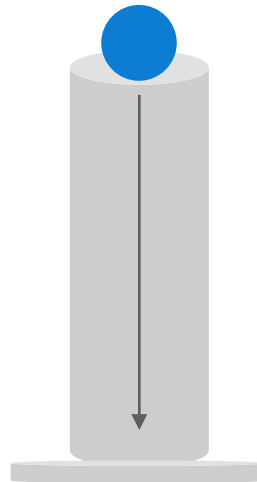


HLT is the time required by a foam to drain 50% of its weight

- » The test measures the time a foam needs to lose half of its liquid content.
- » When 80g of foam are filled into a funnel, we measure the time until the liquid in the cylinder, located under the funnel, has reached 40 ml (which equals to 50% of the liquid content of the foam).
- » The test determines the “drainage stability” of the foam, as half-life time.

Mechanical Resistance is the time a water-filled ping-pong ball needs to penetrate through the foam

- » The test measures the time when a ping pong ball 18g weight vertically crosses a foam placed into a plastic cylinder, from top to bottom
- » The measure of time gives the indication of the mechanical resistance the foam applies to the vertical scroll of the ball, at a certain FER → it's the indication of the **MECHANICAL STRUCTURE & STRENGTH OF THE FOAM**





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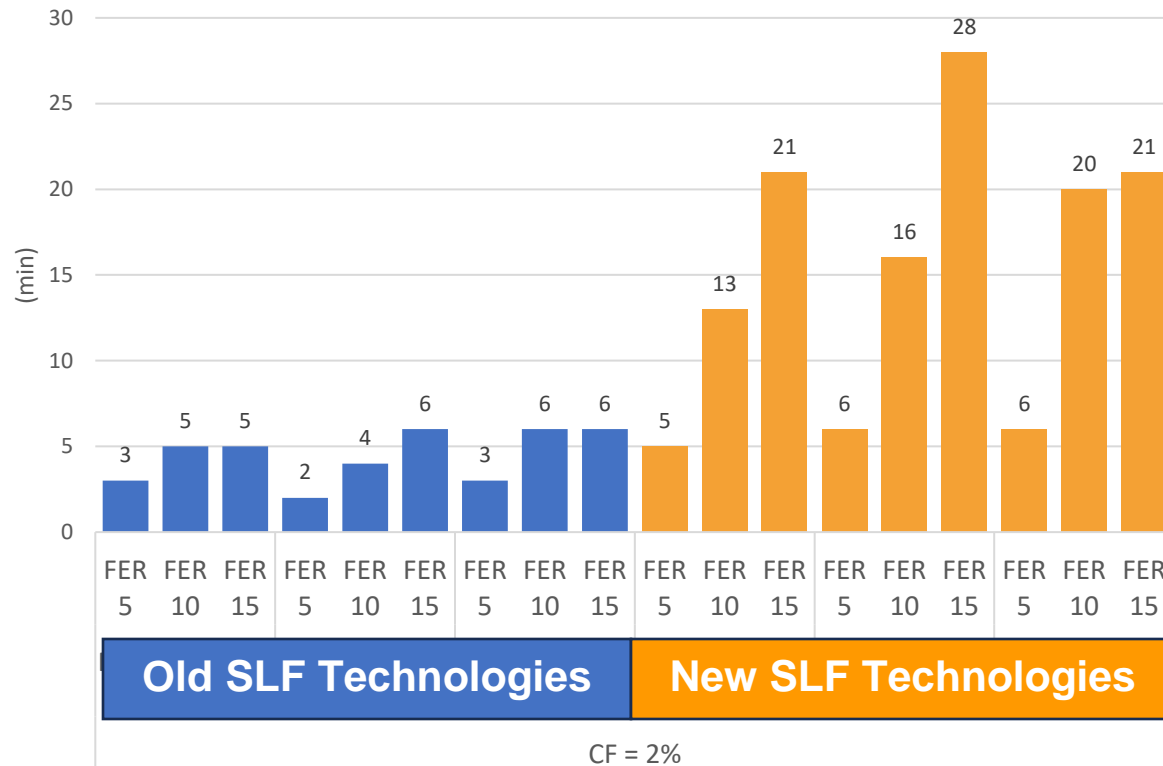
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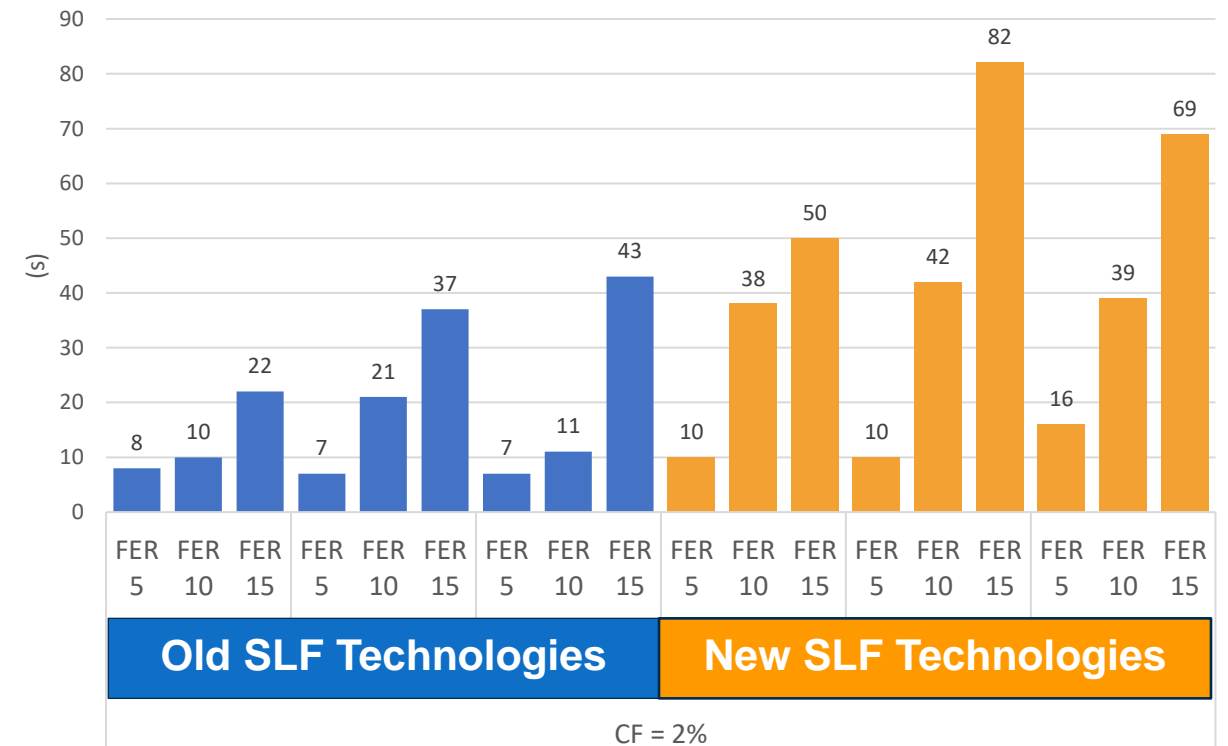
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Sika Stabilizer® SLF Technology– HLT @Cf 2%, FER 5-10-15

Half-life Drainage Time



Mechanical Resistance



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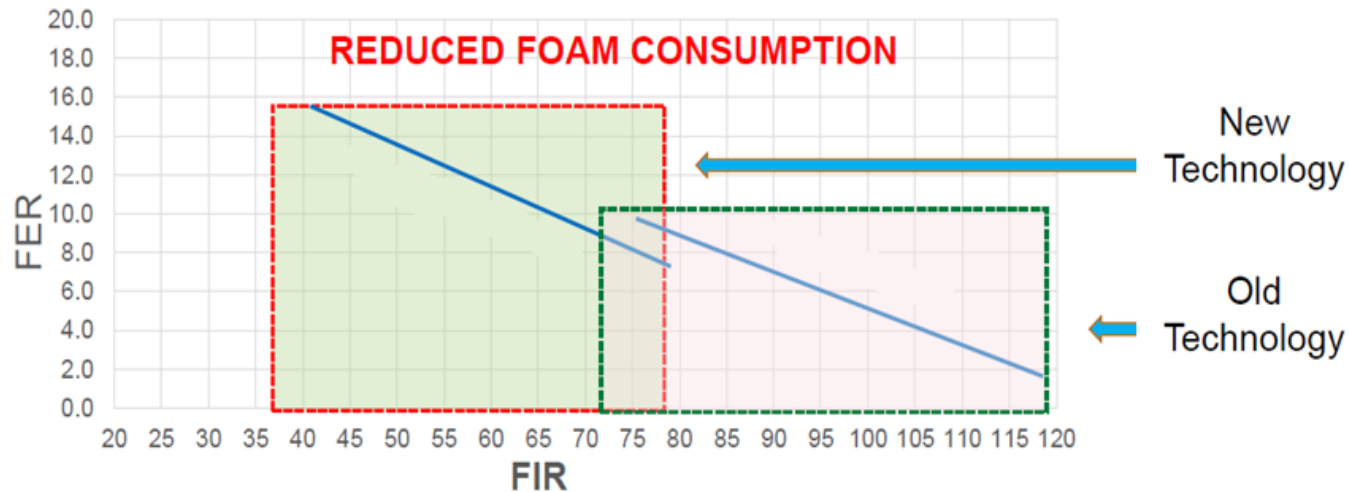
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Sika Stabilizer® SLF Technology – Benefits

Half - Life Time Cf 2%



Substantial savings on:

- » Water as a natural resource.
- » Reducing TBM torque which reduces energy consumption.
- » Controlled and efficient excavated soil disposal.
- » Safer and faster TBM advance rates
- » Reduced chemical consumption

Biodegradability

- All three components are readily biodegradable.
- The entire product passes the criteria for biodegradability.
- The leachable fraction of the product is readily biodegradable.

Disposal of Conditioned Soil

Deposition of excavated material conditioned with MasterRoc SLF on a landfill for inert materials as per the Council Directive 1999/31/EC dated 26.04.1999 on the landfill of waste (OJ L 182, 16.07.1999) shall be possible in any case.

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TBM foam Generator Setup - The Influence of Foam Preparation I

The foam generation system influences the quality of generated foam and its properties. Periodic inspection and calibration is highly recommended for generating a good quality foam intended to be used for a proper soil conditioning.

- » Surfactant dilution percentage (Cf)
- » Air proportion & Regulation (related to FER)
- » Homogenization (Air + liquid)
- » Turbulence efficiency (shape of the material)
- » Duct section and termination (inlet size, length, outlet size, drill retainer)
- » Pressurized environment
- » Temperature



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TBM foam Generator Setup - The Influence of Foam Preparation II



➔ *Success comes from Teamwork !*

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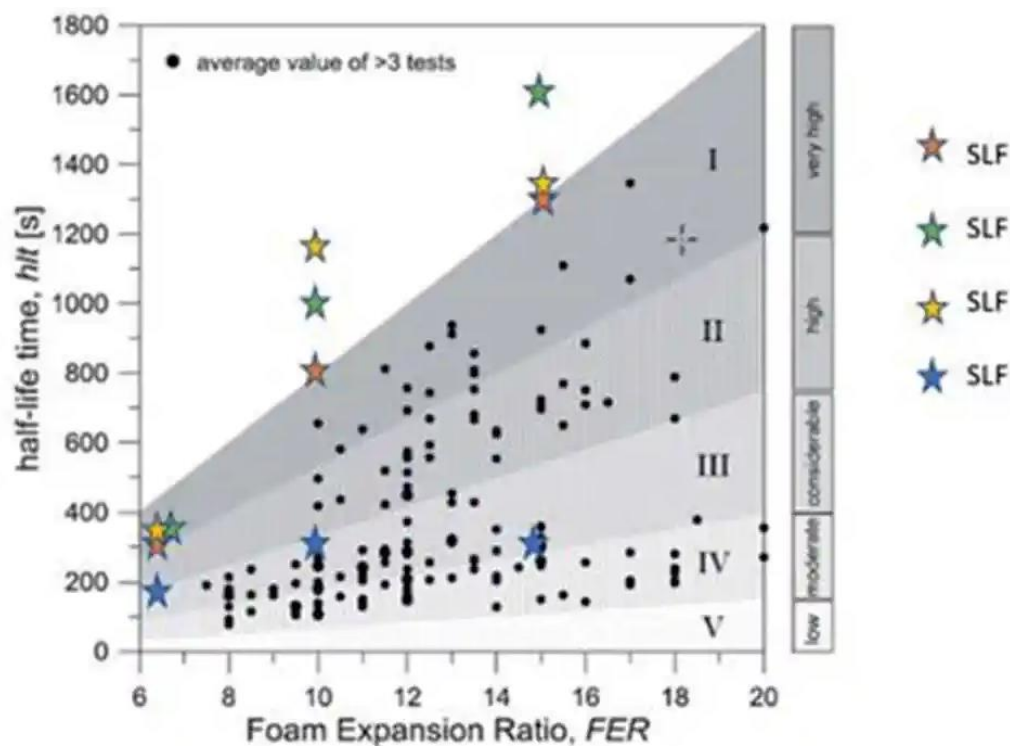
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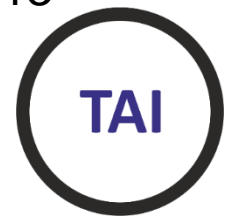
Sika Stabilizer® TBM Technology– New Classification of Foaming Agents



» In 2020, the new classification has arisen five classes of foaming agents, where Class I is the strongest (more stable, more performing and durable over time) and Class V is the weakest. In this scientific work, they have plotted all the Old Technology of foaming agents available on the market by displaying HLT (at Cf 2% - Y axis) vs FER (FER 10 – X axis), as shown in Figure 8 with dark dots.

The Department of Structural and Geotechnical Engineering and
the Department of Chemical Engineering Materials Environment, La Sapienza University of Rome (Italy),

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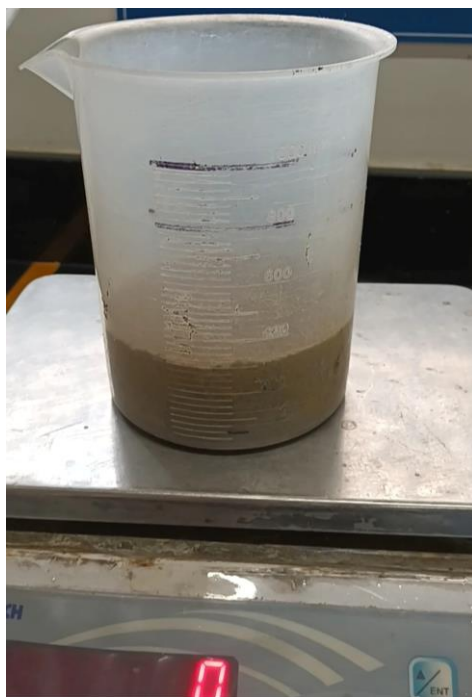
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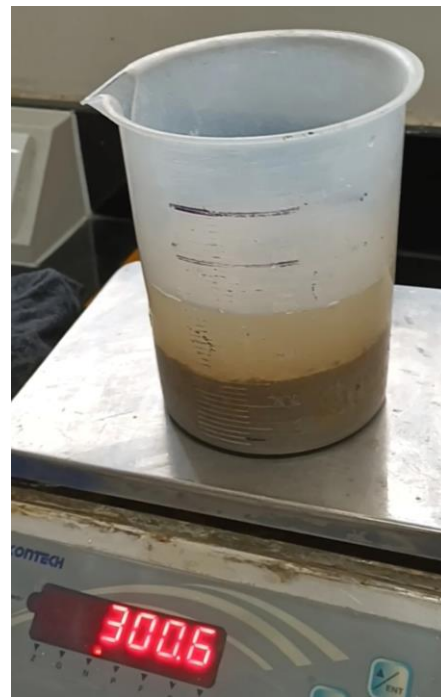
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Sika Stabilizer® TBM Technologies – Water Ingress Management

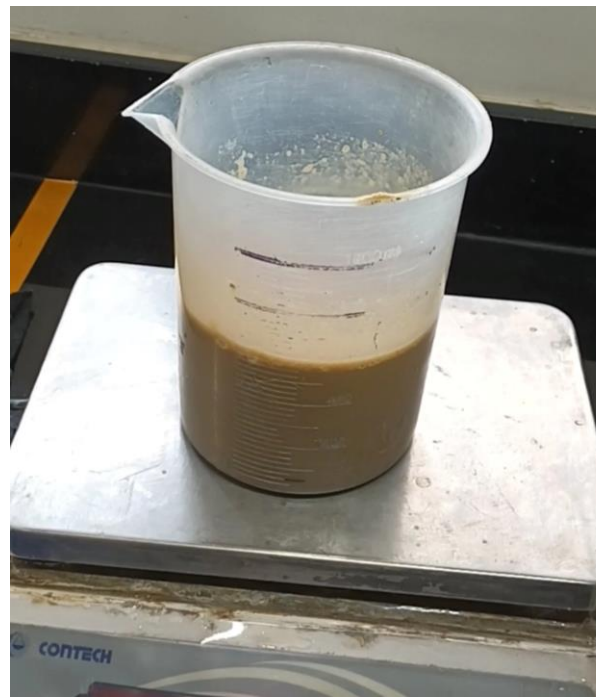
Strong Thickener acting as water absorbers (NOT water reducers). The water remains trapped inside the polymer chains so rheology of the spoil can be modified by increasing its viscosity.



300 mL Silty Sand



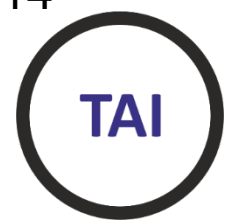
300 mL Water



Added % of MasterRoc Polymer



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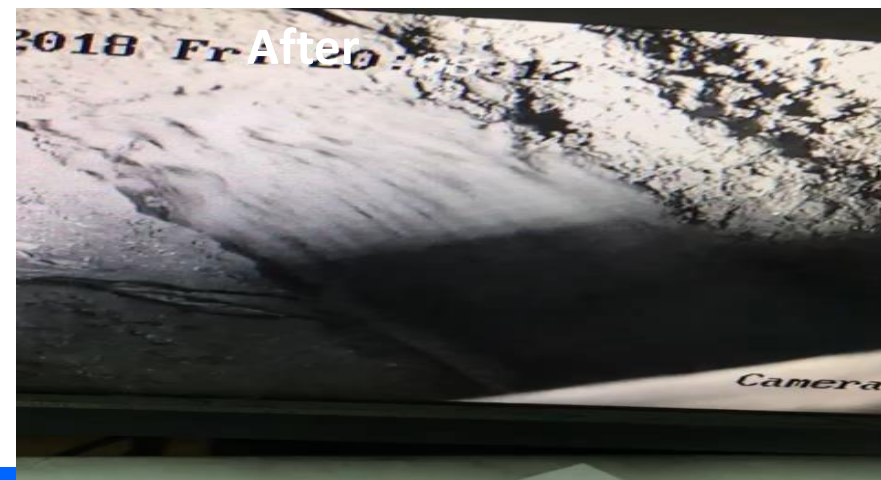
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Sika Stabilizer® TBM Technologies – Water Ingress Management

Environmental Impact :

- » Disturbance of natural water reserves/aquifers.
- » Danger of ground settlement
- » Lower TBM advance rates, leading to higher energy consumption
- » Longer downtime for cleaning and maintenance.
- » Additional vehicular movement for excessive muck disposal leads to more Carbon emission.



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Working Towards Sustainability >>

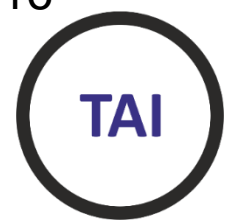
High performance soil conditioning foaming agents

- » Use new generation of foaming agents with higher drainage stability (able to work with higher FER)
- » Setup injection parameters depending on actual geology and TBM foaming system
- » Reduce the indiscriminate use of water

Benefits

- » Increased face support stabilization, less risk for tunnel collapse
- » Ensured stable TBM advance
- » Reduce TBM torque and the overall energy to build the tunnel
- » Reduce the volumes of muck for disposal
- » Reduce the chemical agents in the soil for disposal
- » **Huge budget savings**

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Thank you



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