



**Especialidades Químicas para Construcción de Túneles**  
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**BASF**  
The Chemical Company

**AATES**  
Asociación Argentina de Túneles y Espacios Subterráneos

3<sup>ra</sup> Jornadas de Túneles y Espacios Subterráneos  
4-5 Junio 2013-Buenos Aires-Argentina

### Soil conditioning agents



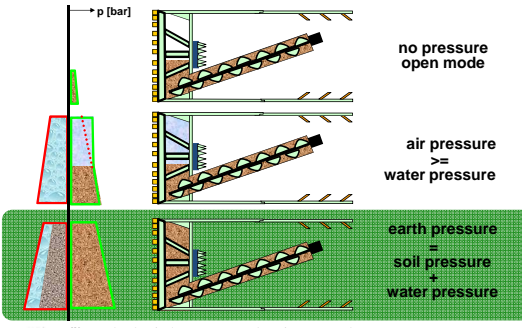
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### Earth Pressure Balance TBM (EPB)

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### 'EPB' driving modes in soft ground




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### Especialidades químicas para TBM

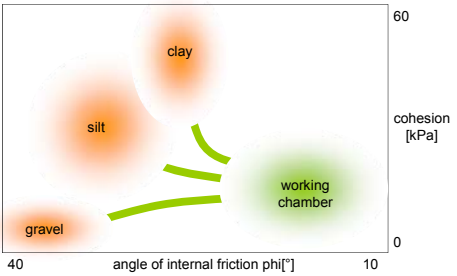
	Greases	Sealants	Soil conditioning	
Chemistry	Mineral & vegetable oil based	Oil & mineral fillers based	Surfactants anionic & nonionic	Thickeners, poly-meric & biopolymeric
Products	MEYCO EPB series MEYCO BSG series	MEYCO TSG series	RHEOSIL series MEYCO SLF series MEYCO ABR series	MEYCO SLF P series
In TBM used at	Main bearing	Tail shield	Tunnel face, cutter head, working chamber, screw conveyor	
Main purpose	Lubrication, sealing	Sealing	Soil: lubrication, liquefaction, dispersion, dust reduction, wear reduction	

**Image**







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### Soil conditioning and soil mechanics



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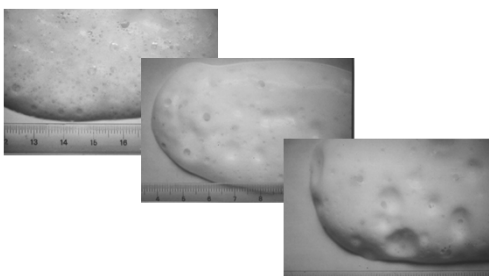
### Reasons for Soil Conditioning

Avoid surface settlement and/or collapse Enable proper EPB mode		Increase security
Reduce cutterhead torque (requirements)		Save energy Decrease costs
Increase TBM speed Decrease clogging & adhesion effects		Save energy & time Decrease costs
Reduce dust, ventilation, wear		Save energy Increase security

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### Tunnel Foam Appearance

MEYCO SLF Group



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### Soil conditioning agents

1. Foams
  - Allow filling of the working chamber
  - Increase the TBM speed
  - Decrease abrasion, torque
2. Anti-clay-additives
  - Decrease clogging, adhesion, transport problems
  - Increase the TBM speed
3. Polymers
  - Increase soil adhesion, impermeability
  - Decrease liquid soil consistency
  - Decrease settlements

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### Why use different foams?

Foams have different properties:


- air incorporation properties
- half life time
- anti-clay behaviour
- ion-sensibility (Ca, Na, ...)
- rheological behaviour
- soil draining behaviour

**Lab tests have to be carried out prior to site use!**

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### Soil Changes

with MEYCO Fix SLF soil conditioning agents




dry soil      + water      + soil conditioning

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### Soil Rheology Change

with MEYCO SLF Foam



Sandy Gravel      Sandy Gravel with Foam

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### Torque Reduction with MEYCO SLF foam in clay soil

The photograph shows the cutterhead of a tunnel boring machine (TBM) in a laboratory setting. The graph, titled 'London Clay (19.6.00)', plots torque in bar against time. Two lines are shown: 'Torque Mixer (bar)' and 'Foam liquid (l/min)'. The torque peaks at approximately 250 bar, and the foam liquid flow is indicated by a shaded area during the peak torque period.

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### Soil conditioning system Schematic view

The schematic diagram illustrates the soil conditioning system. It shows a cross-section of the soil being conditioned. Air (air) and water (water) are pumped into the system. The air is supplied by a pump labeled 'P1', and the water is supplied by a pump labeled 'SLF'. The diagram shows the distribution of air and water into the soil through various pipes and nozzles.

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### Torque Reduction with MEYCO SLF Foam in Clay Soil, Herrenknecht test rig

The graph, titled 'London Clay (19.5.00)', plots torque in bar against time. Two lines are shown: 'Torque Mixer [bar]' and 'Foam liquid [l/min]'. The torque peaks at approximately 250 bar, and the foam liquid flow is indicated by a shaded area during the peak torque period.

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### Dosing of soil conditioning agents

The photograph shows a water booster pump and a dosing pump. The water booster pump is a large blue motor with a pump head. The dosing pump is a smaller blue motor with a pump head. The dosing pump is connected to a large blue tank.

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### Injection Points at the TBM cutterhead

The diagram shows a circular cutterhead with numerous injection points. A red arrow points to one of the injection points. The diagram is labeled 'Foam injection points on cutter head'.

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### Foam generator

The photograph shows a foam generator in a laboratory setting. The foam generator is a large blue motor with a pump head. It is connected to a large blue tank. The foam generator is used to generate foam for soil conditioning.


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## Anti-clay

MEYCO® RHEOSOIL

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### Toulouse Metro Line B



**Without Rheosoil 211:**

- empty working chamber
- air pressure support
- impossible to manage water ingress using sand lenses
- plugging of the cutterhead

**With Rheosoil 211:**

- full working chamber
- 1.5-2.5 bar EPB
- soft material
- no clogging
- increase of speed
- decrease of torque

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### Anti-clay additives

**Use in clay and clayey soils**

**Problem**

- adhesion on metal surfaces
- agglomeration (cohesion) of soil chips to big blocks

**Consequence**


- clogging of the cutterhead
- clogging in the working chamber

**Result**

- low TBM speed
- high maintenance & revision costs

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### The M30 project, Spain




twin tunnel M30 ring road connection south of Madrid, the project being worth 740 million Euro.


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### Change of soil behaviour

with Rheosoil anti-clay additives



Bologna clay +  
water & foam



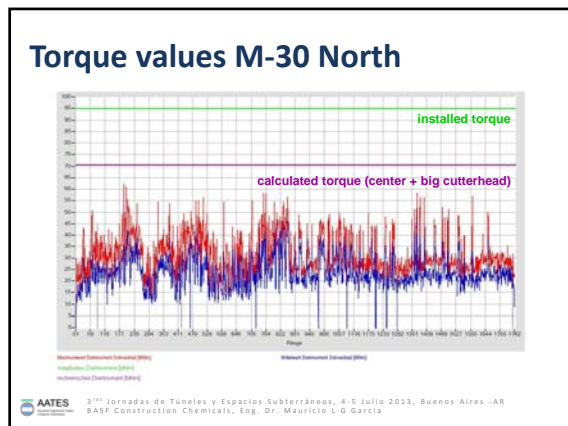
Bologna clay +  
foam & Rheosoil

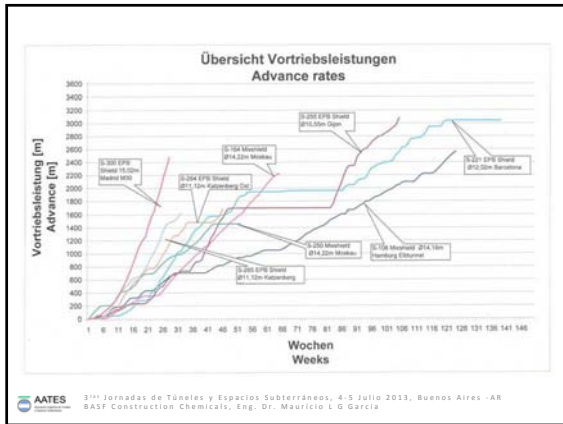
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### Mitsubishi Heavy Industries TBM



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### What can polymers do ?

Hartgesteins-Chips, Stöhlen Bodlo  
Feinkornanteil-reduziert  
Überschuß an Wasser

MEYCO Fix SLF P1      MEYCO Fix SLF P2

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### The Metro TorontoTTC project, CAN

**Without Rheosol:**

- empty working chamber
- air pressure support
- impossible to manage water ingress by sand lenses
- plugging of the cutterhead

**With Rheosol:**

- full working chamber
- 1.5-2.5 bar EPB
- soft material
- no clogging
- increase of speed
- decrease of torque

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### Singapore Metro - Polymer P1

only foam used  
water content too high

foam with 5% SLF P1  
too much Polymer  
big blocks

foam with 3.5% SLF P1  
improved situation  
2-3% polymer would be excellent

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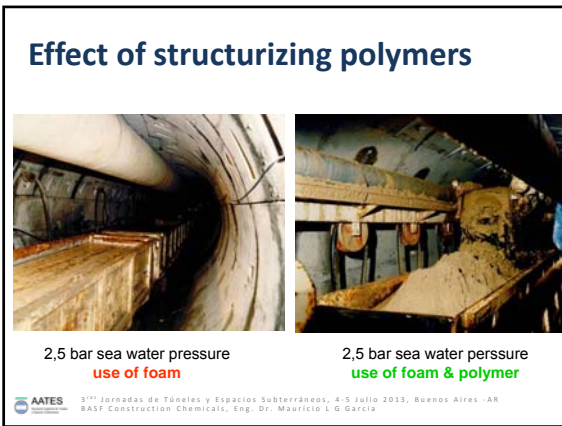
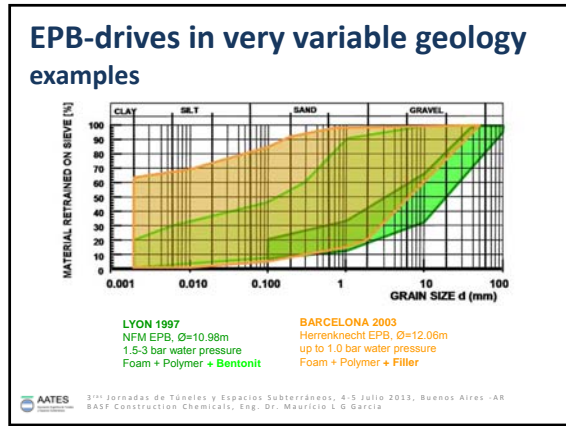
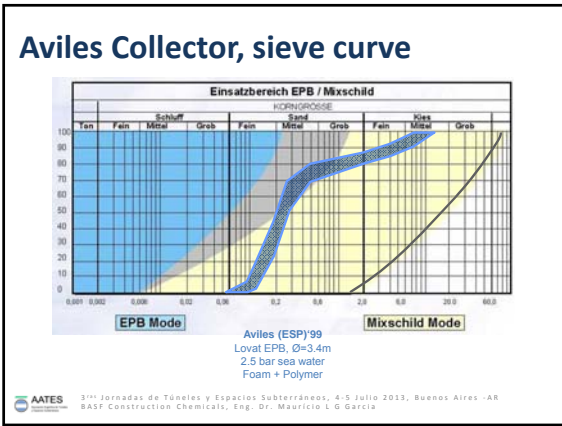
## Polymers

MEYCO® SLF P1 Medium liquid soils  
MEYCO® SLF P2 Water binding, increasing soil adhesion, stabiliser

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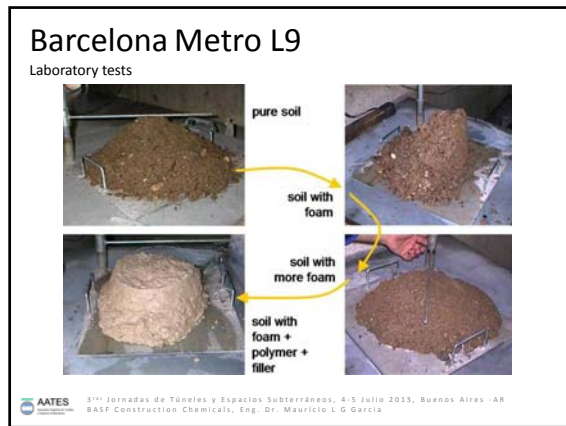
### Aviles Collector, Spain

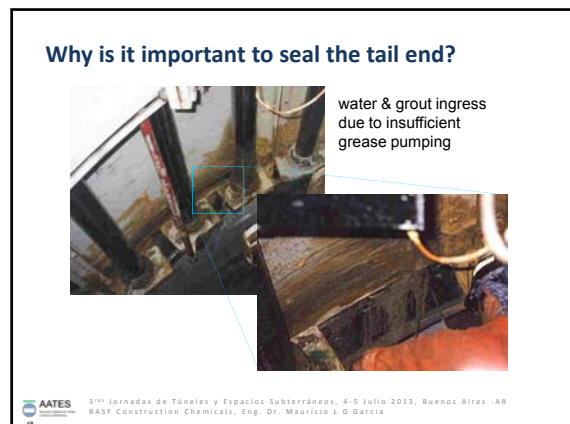
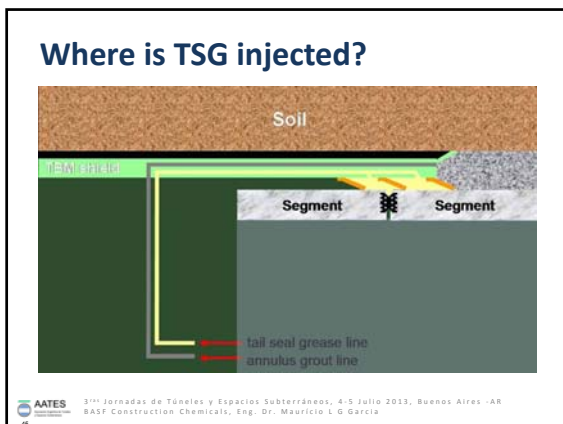
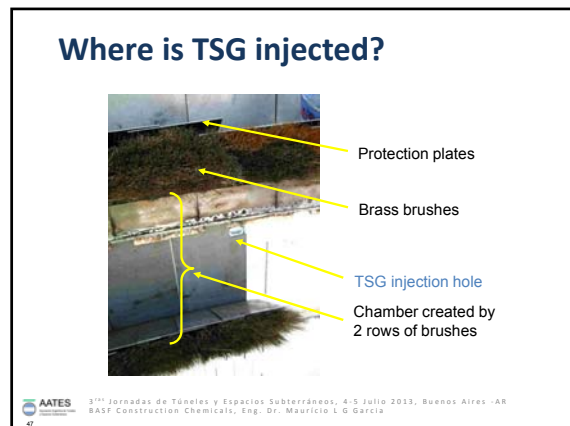
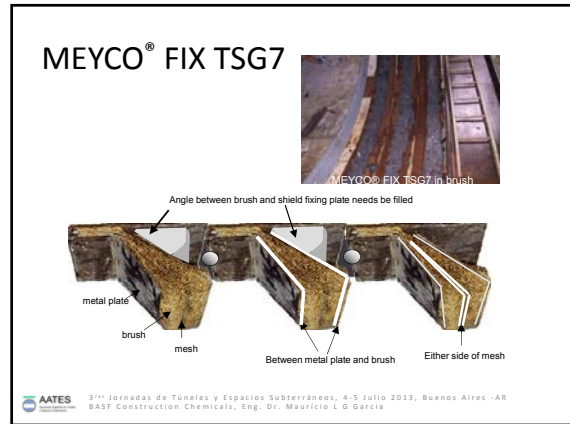
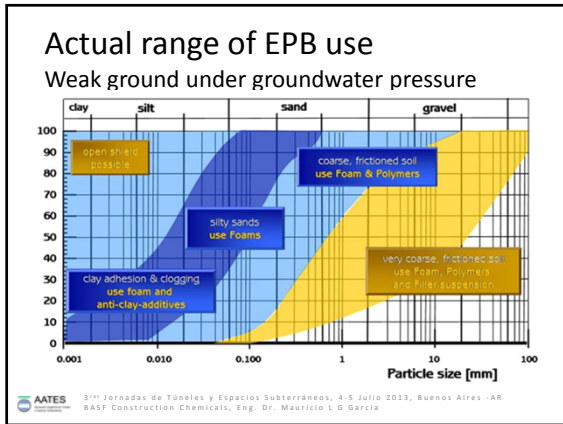
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### EPB mode in heterogeneous geology


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### Different BASF tail sealant types




MEYCO TSG 7	MEYCO TSG 6	MEYCO TSG 16	MEYCO TSG 26
<ul style="list-style-type: none"> <li>1<sup>st</sup> fill grease</li> <li>stiff but pumpable</li> <li>not mixable with annulus grout</li> </ul>	<ul style="list-style-type: none"> <li>driving grade</li> <li>highly resistant against water</li> <li>allrounder</li> </ul>	<ul style="list-style-type: none"> <li>driving grade</li> <li>highly resistant against water</li> <li>different rheology</li> </ul>	<ul style="list-style-type: none"> <li>fire resistant</li> <li>eco-friendly because 100% oil-free</li> <li>passes waterpressure tests</li> </ul>

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### Why is an annulus grout important

- To give early stability as construction occurs
- To prevent heave / flotation of the lining
- To take early load in the build area
- To reduce settlement, especially in non-cohesive soils
- To prevent segmental misalignment and the rupturing of gaskets
- To eliminate / reduce water ingress to avoid secondary injection (costly)



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### Grout mixing test with TSG7

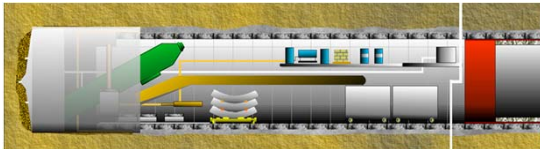


**MEYCO TSG7:**  
grout is not mixable with tail sealant, brushes are well protected in case of grout ingress

**competition:**  
grout is mixable with tail sealant, risk of brush hardening in case of grout ingress

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### Filling of the annulus gap



- For this purpose a pressurized mortar or grout is used which we call backfill grout or annulus grout. Generally the strength only needs to match or slightly exceed the shear strength of the surrounding soil.
- This allows the natural stress in the ground to be maintained. Less stress displacement causes less soil movement and surface settlement.

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### Annulus Grouts

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### ABR5 Anti-Abrasion and -Dust Technology

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### Typical situation in hard rock TBM excavation

**excessive wear is a direct cost issue**

- cutter cost
- maintenance cost (cutter changes are time consuming)
- damaged cutters can lead to cutter head damages

**down time**

- the more frequent cutters have to be changed, the more down time it means for the TBM
- during down time the tunnel does not make any progress


**dust & temperature**

- not good for the worker's health
- reduce life-time of equipment
- expensive exhausting

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### Site Example: Guadarrama High Speed Rail Tunnel

- 4 hard rock TBM machines diameter: 9.5m  
2 x Herrenknecht  
2 x Wirth
- 2 TBMs drive from the north, the other two drive from the south
- total length: 56 km
- geology: mainly granite, high quartz content, 100-200 MPa very high abrasivity




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### The Guadarrama project, Spain





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### Situation only using water




number of cutters changed typically varied from 5-28 per day



high maintenance cost, lot of down time


high temperature and high dust level time consuming disc cutter change



due to the high temperature, cutters can get blocked (failure of bearing seal)

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### Guadarrama Rock



CAI=5,66

0	not very abrasive
1	slightly abrasive
2	medium abrasive to abrasive
3	very abrasive
4	
5	extremely abrasive
6	quarzitic
7	

CAI  
(Cercher Abrasivity Index)

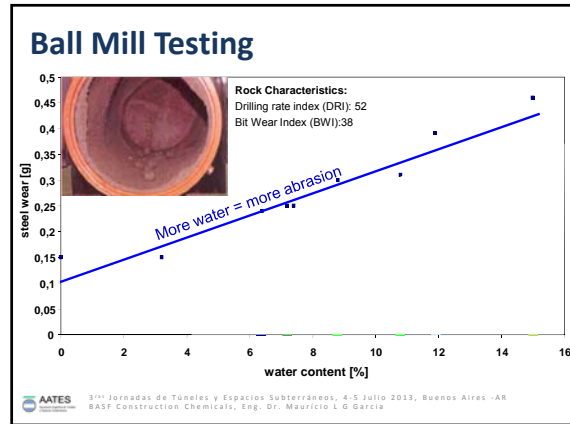
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### Results wear - dust - temperature

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### Why using ABR5?

**current practice: injecting water**

- lots of dust is not cached by the water
- the cutter temperature can still be higher than 100°C
- the use of water contributes to higher cutter wear.

**use of MEYCO® Fix ABR5 makes the difference**

- effective dust suppression makes the working environment healthier and increases the life time of the electronic equipment
- cutter temperature can be reduced down to 60-80°C (depending on the conditions) due to better heat transfer and mucking out
- increase of life time of the cutter sealing
- decrease of wear due to lubrication effect and reduced water injection
- decrease of TBM downtime due to reduced maintenance needs

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### ABR Benefits

**without**

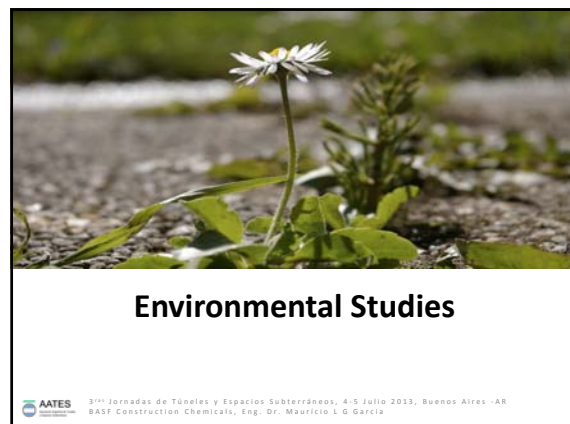
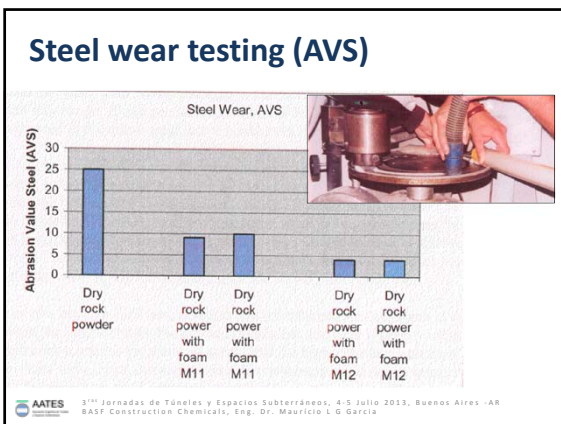
disappearance of dust  
longer life time of electronics,  
healthier working conditions

clean & cool cutters  
easy & quick to change  
no muck clogging

drastic reduction of cutter  
temperature (150→70°C)  
no cutter blockage any more  
around 15% wear reduction  
reduced downtime

**with**

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### Construction & Sustainability

- Consumes up to 40 % of the world's energy
- Contribute to 30 % of the global greenhouse gas emissions
- Causes 10 % of the world's emission of fine dust
- Displaces the most productive land
- Consumes half of the world's resources
- Contributes to loss of biodiversity and ecosystems
- Chemicals are the key to transform the construction industry towards sustainability

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### Landfill with excavated soil

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### Emission possibilities

ground water      landfill      working environment

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### Surface water collection

Lixiviation data (24h, DIN 38-414 4)  
Acute toxicity tests (Daphnids, NF EN ISO 6341)

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### Aquatic Toxicity

what do LC<sub>50</sub>/EC<sub>50</sub> data mean?

algues      daphnia magna      rainbow trout

additives [mg/l water]

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### General Risk Characteristics

important factors of eco-compatibility

(mammal) toxicity

Persistence (biodegradation)

Bioaccumulation

Aquatic toxicity

Risk to surface water

Risk to air

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# 3ras Jornadas de Túneles y Espacios Subterráneos 4-5 Junio 2013-Buenos Aires-Argentina

## Environmental Risk Assessments !

<p style="font-size: small;">MBT International Underground Construction Group</p> <h3 style="text-align: center;">Environmental Risk Assessment</h3> <p style="font-size: x-small; text-align: center;">Use of Megapack F16 T.F. in tunnel constructions</p> <p style="font-size: x-small; text-align: center;">May 2011</p> <p style="font-size: x-small;">BNG Construction Chemicals</p>	<p style="font-size: small;">MBT International Underground Construction Group</p> <h3 style="text-align: center;">Environmental Risk Assessment</h3> <p style="font-size: x-small; text-align: center;">Use of Rheosol® in tunnel constructions</p> <p style="font-size: x-small; text-align: center;">October 2011</p> <p style="font-size: x-small;">BNG Construction Chemicals</p>	<p style="font-size: small;">MBT International Underground Construction Group</p> <h3 style="text-align: center;">Environmental Risk Assessment</h3> <p style="font-size: x-small; text-align: center;">Use of MEYCO® F16 TSG in tunnel constructions</p> <p style="font-size: x-small; text-align: center;">December 2012</p> <p style="font-size: x-small;">BNG Construction Chemicals</p>
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