Ground improvement and Injection technology in underground construction

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- **Soil stabilization** is the process which is used to **improve the engineering properties** of the soil and thus **making it more stable.**
- Soil stabilization is required when the soil available **for construction is not suitable.**
- It includes compaction, pre consolidation with injection, drainage and many other such processes.

Why do we inject into underground structures?

- **Environmental protection**
  - Contaminated water has to be managed
  - Lowering of groundwater has to be prevented in most areas
  - Surface subsidence has to be avoided

What Is Injection Or Grouting? Why Do We Inject Into Underground Structures?

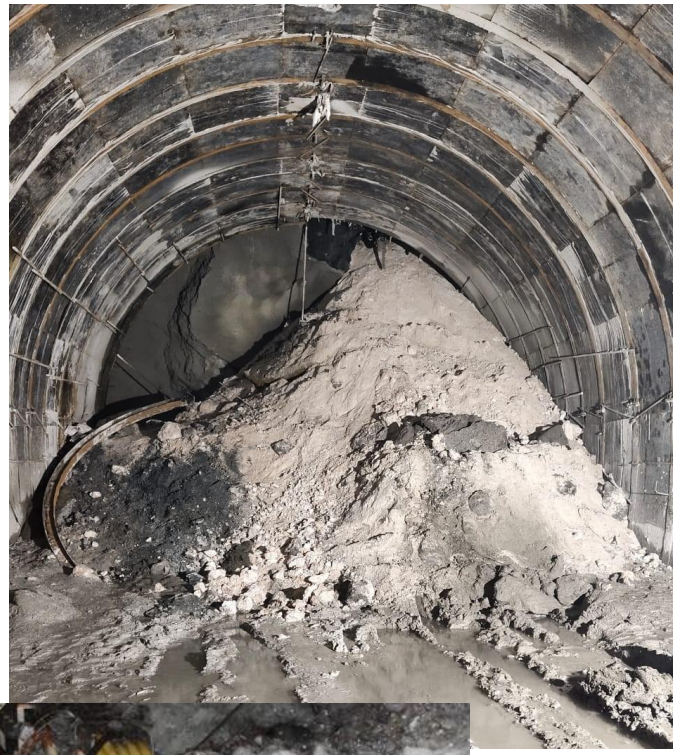
- **Definition:**
  - Injection is “the introduction of a material with **pressure** into the ground or a structure with the goal of **water stopping, consolidating, repair** and filling of voids, cracks and porosity”

Safety

- Dangerous situations in tunnels and mines are uncontrolled water ingress, rockfalls or total collapses.

Risks are:

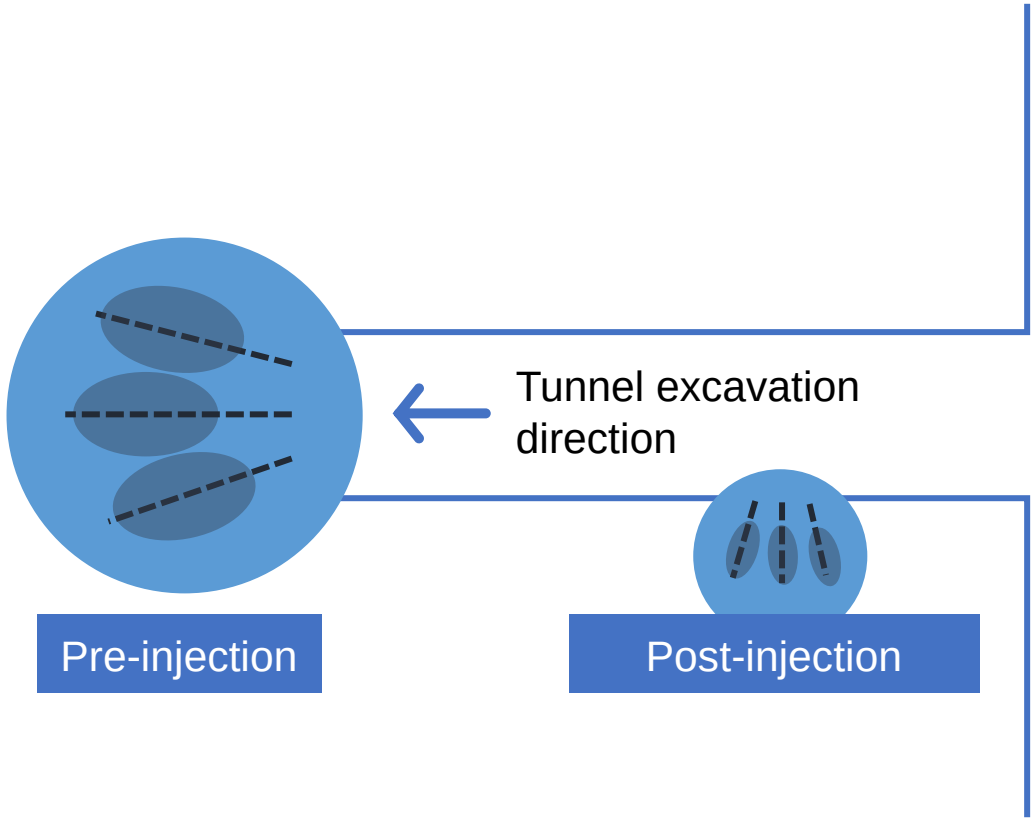
- Ground collapse associated with or without water ingress
- Immediate flooding
- Injuries of tunnel/mine workers
- Damage underground structures and equipment



Why do we inject into underground structures?

- **Cost**
- Pumping water is costly:
  - During tunnel/mine development
  - During the live time of the tunnel/mine
- Reduced development rate
- Refurbishment work in tunnels and shafts is labor intensive and dangerous
- Right focus: Not price per kg, total project cost

Methods of Injection



Pre-Injection

- In front of the tunnel face
- Planned and executed before excavation
- Creates a protective bulkhead between the workers and the water zone

Post-Injection

- Behind the tunnel face
- Carried out after excavation when the need arises
- A reaction to rock and strata conditions

The Four Main MBA UGC Injection Technologies

Cementitious grouting systems

Ordinary Portland cement, the most commonly used material which is mostly supplied locally.
Microcement systems consist of much smaller particles for deeper crack penetration.

Mineral grout

Colloidal silica, a suspension of nanometric particles for penetrating the finest cracks

Polyurethanes & Polyurea silicates

Single component polyurethane systems are hydrophilic and use moisture as a curing agent for mainly waterstopping applications.
Two component polyurethane systems with tailored properties achieved by controlled curing systems are used to solve more complex challenges.
Polyurea silicate resins are fast setting, two component systems with excellent adhesion properties.

Acrylates

Acrylic resins are hydrogel systems which are very flexible for use in concrete repair and water sealing applications.

The Four Main MBA UGC Injection Technologies

Cementitious Grouts

Cementitious grouting systems

MasterRoc® MP 600S

Fast-setting Microcement for injection in tunneling and mining;
Fineness (Blaine) > 600 m^2/kg
d95: 16 microns
Water/Cement ratio 1.0
Mud balance 1.50 - 1.52 kg/l
Flow cone 40 – 42 s
Bleeding maximum 2 %

The Four Main MBA UGC Injection Technologies

Mineral Grouts

Mineral grout

MasterRoc® MP 324

Mineral grout system based on colloidal silica

Mixed material (values given are dependent on mix)

Color Whitish/clear

Viscosity (20ºC, AP-014) ~5 mPa.s

Density (20ºC, AP-005) ~1.25 kg/l

pH (20ºC, AP-009) ~9 dependent on ratio

The Four Main MBA UGC Injection Technologies

Polyurethanes

Polyurethanes

MasterRoc® MP 350
1-component permanent flexible water sealing polyurethane injection grout for fine cracks and fissures in concrete and rock

MasterRoc® MP 354
Flexible 2-component CE certified Polyurethane resin for concrete repair

MasterRoc® MP 355 1K
Watertight 1-component polyurethane injection foam for filling holes and jointed rock, as well as cutting off running water

MasterRoc® MP 355 1K DW
Watertight 1-component polyurethane injection foam for filling voids and jointed rock, as well as cutting off leaking potable water

MasterRoc® MP 355
Highly reactive, 2-component polyurethane injection resin

MasterRoc® MP 355 THIX
Highly reactive, two component polyurethane injection resin / foam to stop very high-volume water ingress

MasterRoc® MP 355 MR0
Slowly reacting, 2-component polyurethane injection resin

MasterRoc® MP 358 GS
Highly reactive, 2-component nearly compact hydrophobic polyurethane injection resin for ground stabilization

MasterRoc® MP 358 SC
Highly reactive, 2-component hydrophobic polyurethane injection foam for ground stabilization

The Four Main MBA UGC Injection Technologies

Polyurea Silicates

Polyurea silicates

MasterRoc® MP 368
Highly reactive 2-component polyurea silicate resin for consolidation of concrete and rock

MasterRoc® MP 367 Foam
Highly reactive, 2-component polyurea silicate foam for void filling and ground consolidation

MasterRoc® MP 368 TIX
Highly reactive, thixotropic 2-component polyurea silicate resin for consolidation of rock and repair of concrete

The Four Main MBA UGC Injection Technologies

Acrylates

Acrylates

MasterRoc® MP 303 CE
Low viscosity, fast reacting acrylic resin for permanent water sealing and layer curtaining of concrete and masonry

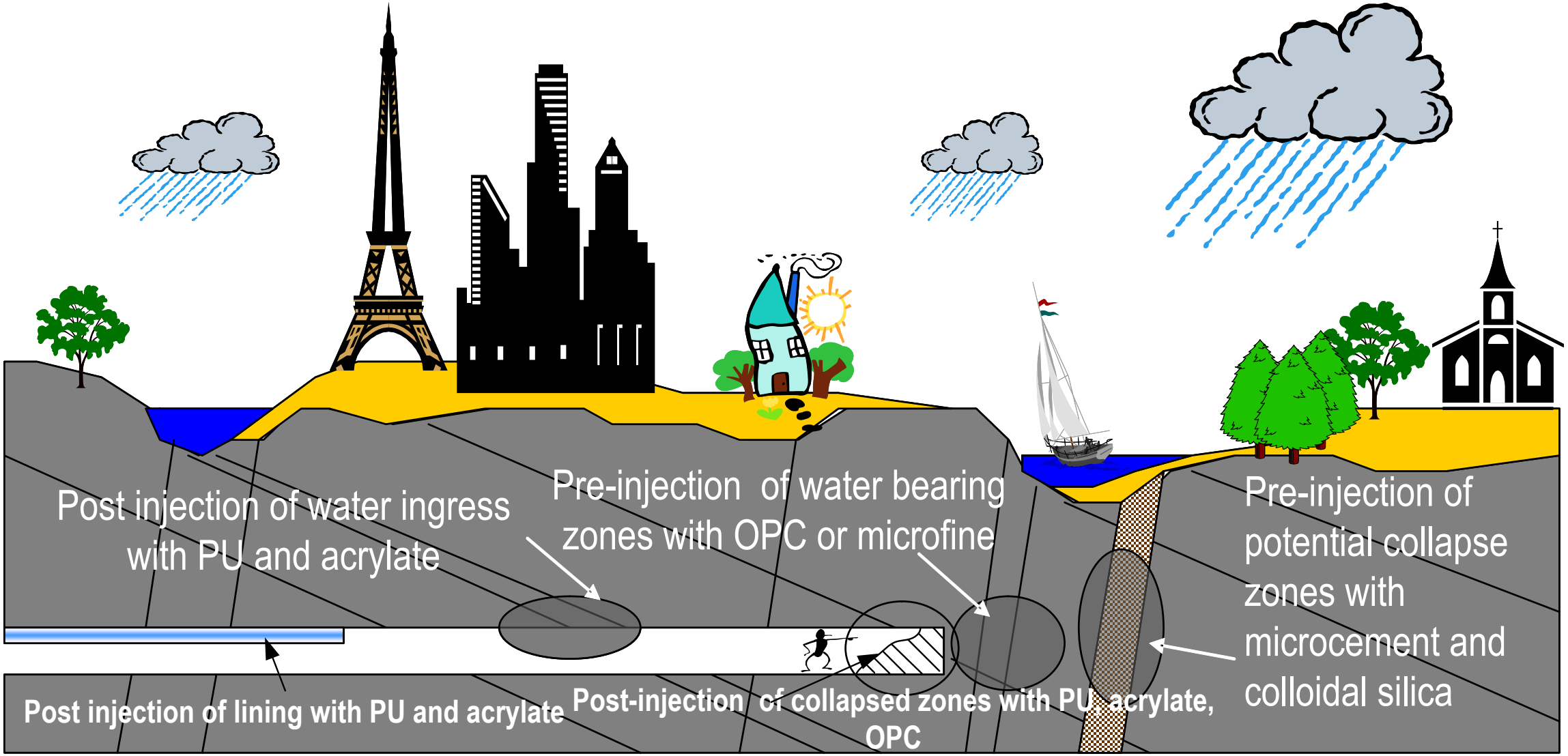
MasterRoc® MP 304
Low viscosity, fast reacting and highly flexible acrylic resin with adjustable reaction speed for permanent water sealing, joint repair and layer curtaining of concrete and masonry

MasterRoc® MP 307 CE
Low viscosity, highly flexible, fast reacting acrylic resin for permanent water sealing and layer curtaining of concrete and masonry

MasterRoc® MP 308
Low viscosity, single component acrylic resin for permanent water sealing in underground structures

MasterRoc® MP 309
Low viscosity, fast reacting acrylic resin with high compressive strength for consolidation of sand and silt strata

Pre-Injection And Post Injection



Pre-Injection Versus Post-Injection

- Experience shows very clearly that in potentially wet / water bearing ground
  - Post-injection alone is costly and challenging
  - Pre-injection can solve ***almost*** all problems
  - Pre-injection target of 100% sealing (not realistic)
  - Post-injection as a supplement is effective
- Optimised use of pre- and post-injection together is the recommended procedure to follow
- Most important is to plan for one or the other approach to injection
- Pre-Injection is a lower risk than dealing with the problem after it arises using post injection

Pre injection

Size Does Matter!

Limit for Injection into cracks = 4 x cement particle size

MasterRoc MP320/325 0.015μm

Silica fume* 0.2μm

MasterRoc MP 900

9μm

MasterRoc MP 800

12μm

16μm

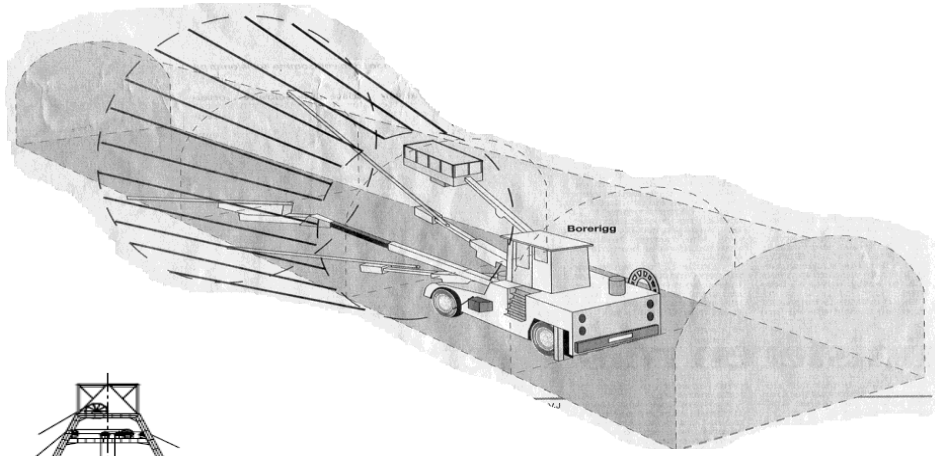
MasterRoc MP 650

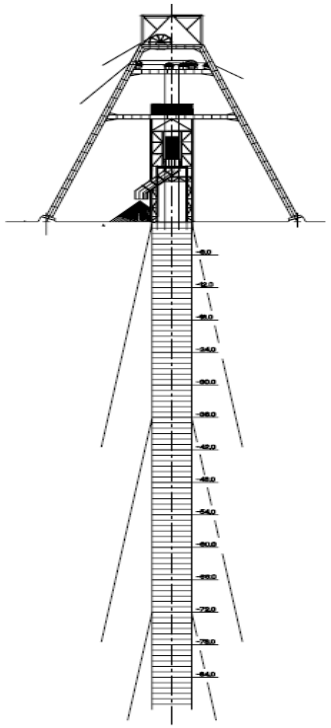
Ordinary Portland Cement **50μm**

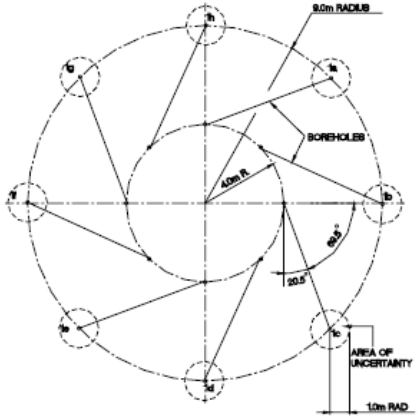
*Silica Fume is n*ot a stand alone injection material – used as a stability aid in OP cement injection

Fast Setting Micro-cement – MasterRoc MP 600S

- Low viscosity ✓
- w/c-ratio = 1.0 – 0.8 ✓
- Marsh cone time 40- 42 sec ✓
- Bleeding < 2% ✓
- Final set 500 to 600 min. ✓
- Open time in equipment, about 1 hour when agitated ✓
- Good stability under pressure ✓







plan on shaft bottom
showing cover round

What If We Need More Penetration Or Lower Pressure?

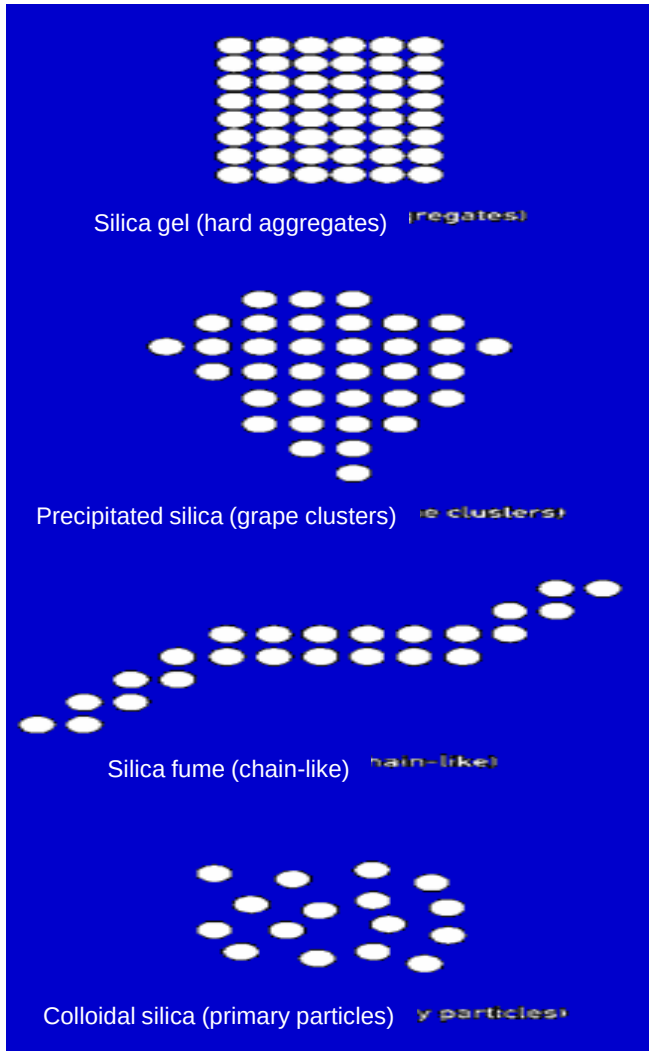
Solution here is MasterRoc MP 320/324. This product is ideal for use in the following situations:

- Consolidation of sand, silt and weak rock where micro-cement cannot penetrate
- As “fine” injection after the first injection with micro-cement to take the last drops of water
- Cross passages in TBM tunnels
- TBM breakthrough into a shaft or breakout from a shaft
- Slope stabilisation
- Open pit excavation, preventing groundwater lowering

Colloidal Silica Technology

- A base component + accelerator
- Controllable gel time from 10 minutes to 2.5hours
- Very low viscosity = excellent penetration
- Approximately 5 mPas ready to use
- High penetration in narrow cracks due to size of particles (0.015 micron) and low viscosity
- No solvents or toxic products. Approximately pH 9
- Workable between +5°C and +45°C
- Excellent for consolidation of sedimentary strata or soils
- When the gel is moisture saturated, shrinkage is negligible
- Low leaching of sodium, about 1500 PPM
- Very cost effective compared to chemical injection systems

Colloidal Silica Technology



5 to 15 μm

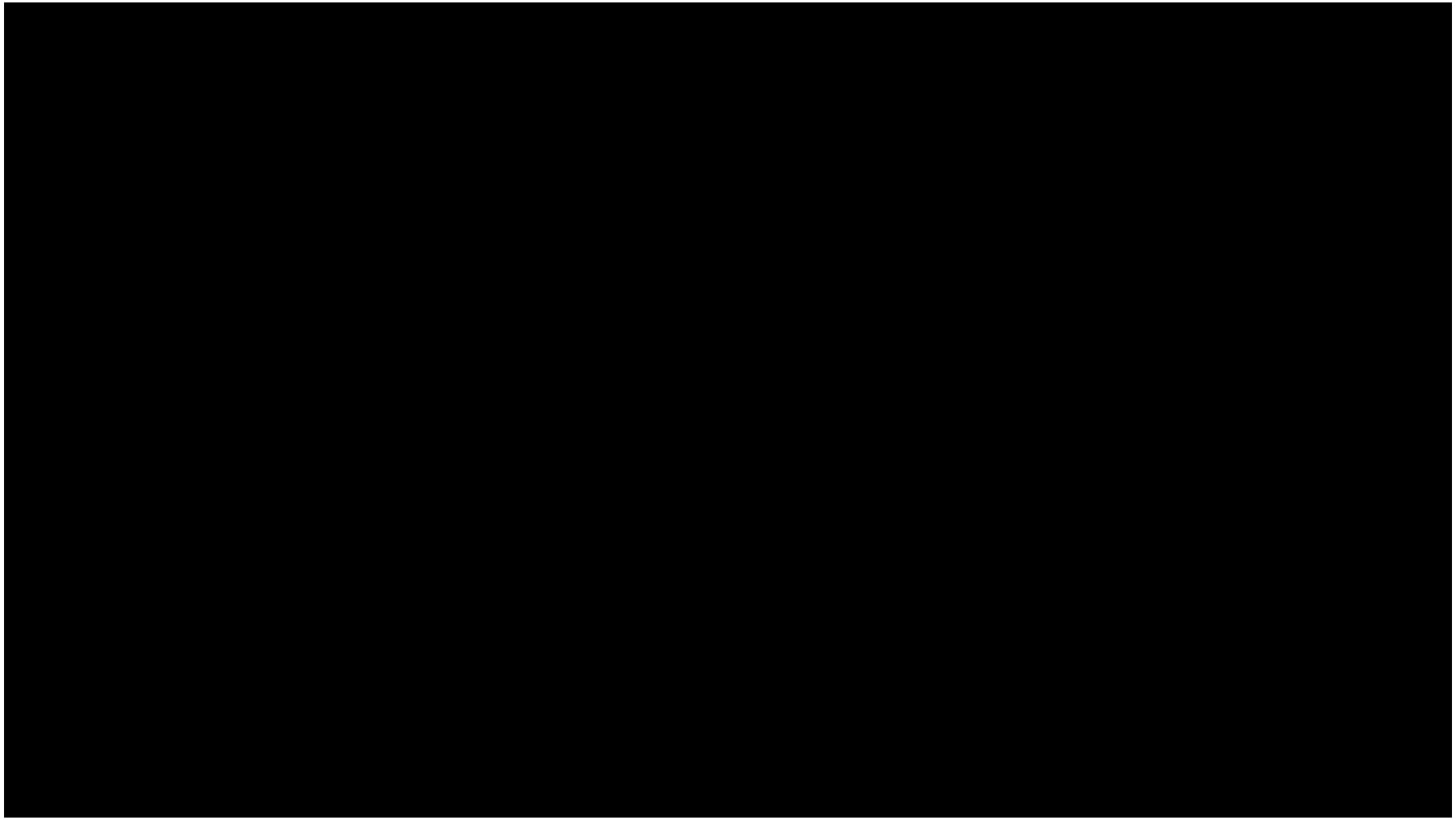
5 μm

0.2 μm

0.015 μm

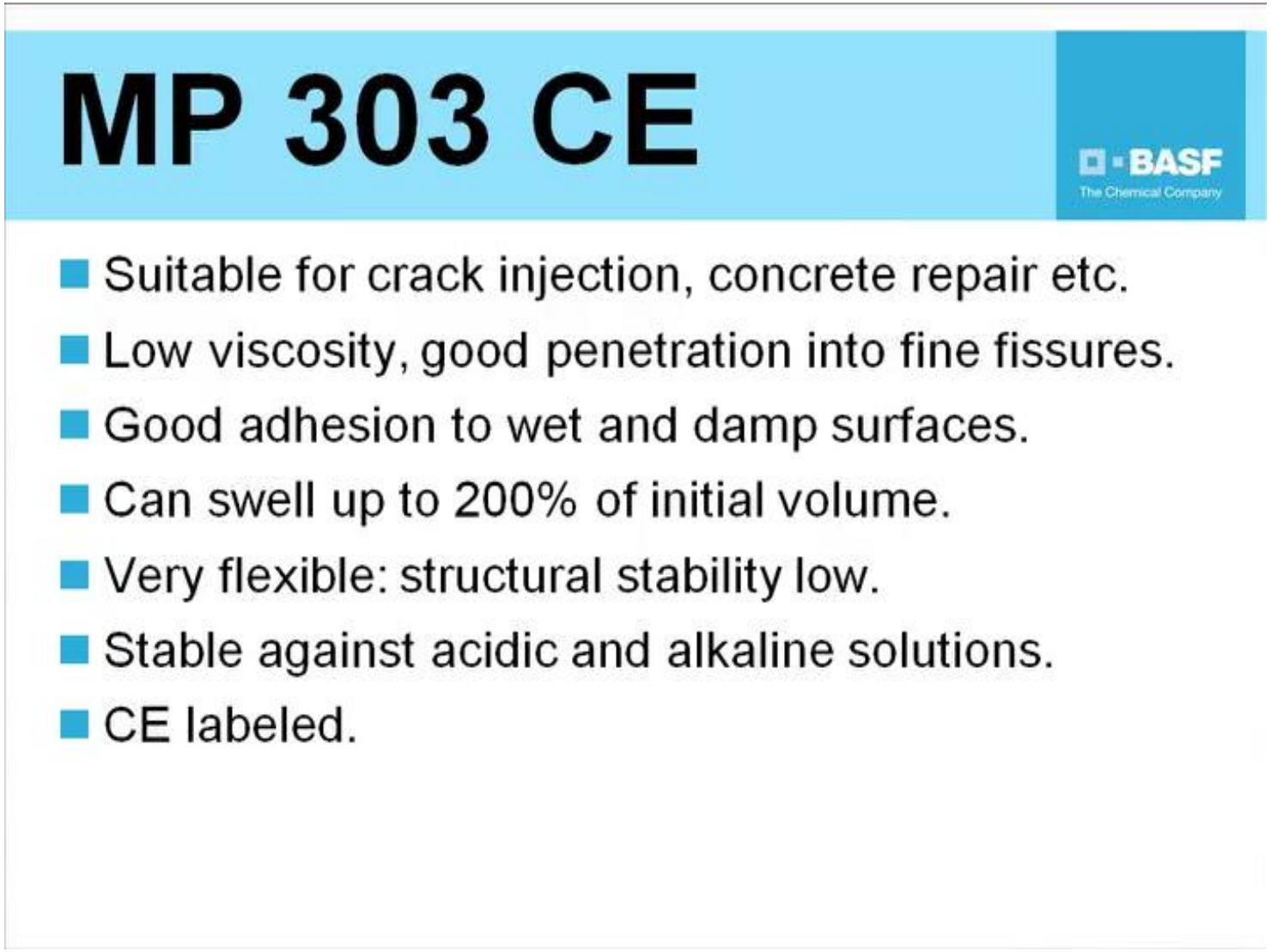
- A stable dispersion of discrete, sub-microscopic particles
- Particles are spherical and are composed of 100% amorphous silicon dioxide (non-crystalline)
- Colloidal silica production process creates specific particle size of a few nanometers for a tailor made, consistent product for specialist applications
- Very stable and environmentally friendly product
- Content: water, SiO_2 and $Na_2O < 0,7$. (Sodium Silicate or Water-glass is well over 7)

MasterRoc MP 355 1K (Single component PU)



MasterRoc MP 355 (Two component PU)

MasterRoc MP 303,307 and 309 (Acrylate)

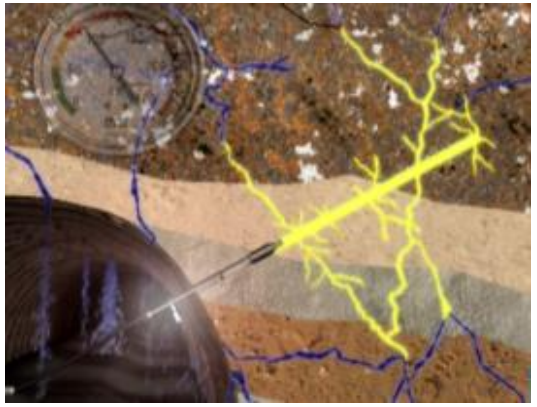


Injection Systems For Tunnel Lining Rehabilitations

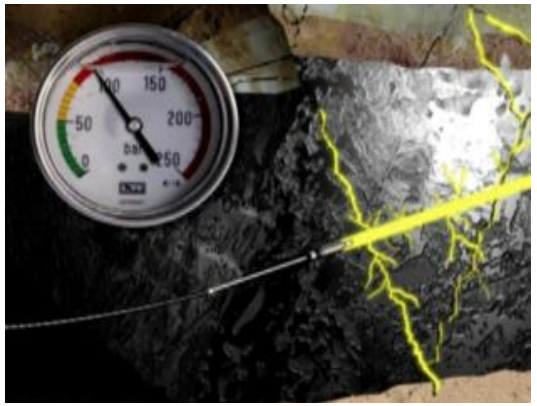
MBS MasterRoc® MP injection product families:

- MP 355 1K- Polyurethane (PU)
  - MasterRoc **MP 355 1K** – system
    - one-component **hydro reactive** organic polyurethane
    - waterproofing
- MP 303/ 307 CE- Acrylic
  - Two-component system
  - waterproofing
- MP 368- Polyurea Silicate (PUS)
  - Two-component system
  - Concrete repair and consolidation
  - Watertight solution

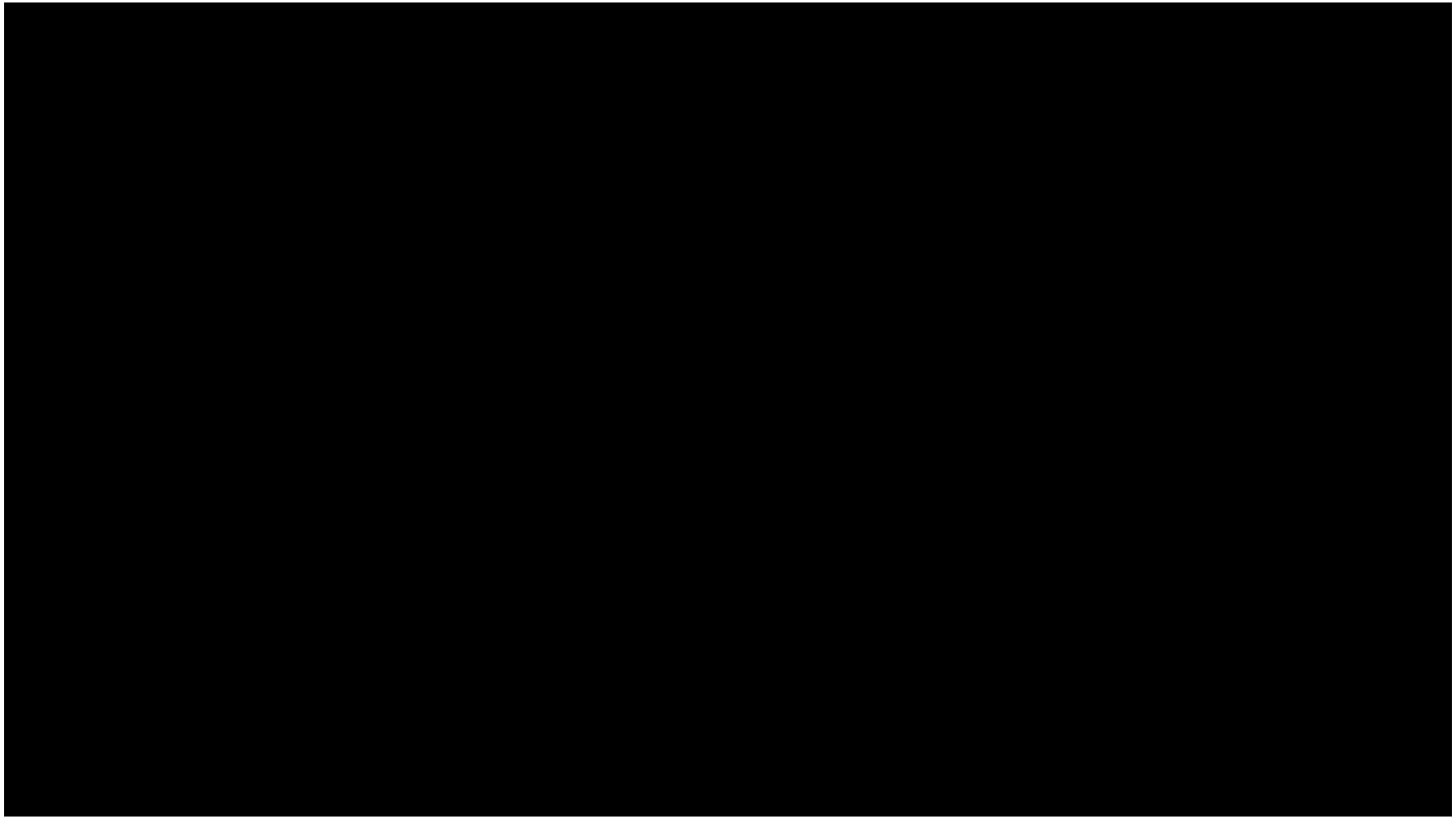
Water stopping / Sealing



Consolidation



Polyurea silicate



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