BULLFLEX® Structural Sealings
Introduction

BULLFLEX® Structural Sealings have been developed as a special solution for underground excavation. The main application of this system are O-ring Sealing Systems used in combination with tunnel boring machines (TBMs).

BULLFLEX® Structural Sealings consist of patented textile groutable hoses made of high-strength fabric, which are subsequently filled with concrete, featuring an excellent sealing and load-bearing capacity. The hoses are available in different dimensions, allowing an optimum alignment to the excavation dimensions or support perimeter. All system components are light-weight as well as easy to transport and install.

DSI has long-time experience in the application of BULLFLEX® Structural Sealings. With the engineering and on-site support of DSI, this system solution has been successfully used for various global infrastructure projects.
System Description

The BULLFLEX® system provides an immediate load transfer and form fit between the passive support lining and the ground or rock mass. Thanks to the special filter effect of the BULLFLEX® fabric, the surplus water in the grout fill is immediately drained out, providing an accelerated curing procedure. Hence, the pressure inside the BULLFLEX® system is maintained, inducing an active pre-load into the excavation perimeter which leads to an immediate sealing action. The BULLFLEX® system can easily be adapted to on-site conditions using different diameters or filling media.

Due to the product characteristics of the BULLFLEX® textile, this system can be used for various different sealing applications. The endless, patented BULLFLEX® hose enhances the application as reliable and easy-to-use O-ring sealings for tunnel boring machines, featuring a special hose-in-hose system. The first BULLFLEX® hose seals the start and launching platforms of shield TBMs (sealing of the annular gap between sealholder and the TBM shield skin). Subsequently, the second BULLFLEX® hose secures the sealing between the excavation line and segment ring. Further applications are so-called bedding hoses for flotation control of process tubes, or O-ring sealings for pipe jacking and structural repair works.

The use of BULLFLEX® structural sealing ensures the protection of machinery and civil structures against flushing media, compressed air, water, and building materials. Each BULLFLEX® structural sealing is customized for its application, backed up with extensive global experience and engineering solutions.

Fields of Application
- O-ring sealing membrane, installed in the annulus between lining segment rings and outer shell or ground
- Sealing against water (liquids) and compressed air
- Launch and receptions of TBMs
- Sealing or re-lining of existing tunnels
- Sealing of annular gaps in civil structures
- Protection and stabilization of the cutterhead during a TBM repair process

Main Advantages
- Quick and easy to install
- Pressure rating up to 4 [bar] (58 [psi])
- Easy compensation of eccentric and uneven excavation surfaces
- Application possible even in confined spaces
- Proven safety against failure of the sealing function in all working phases during passing-by of the TBM
- Special hose-in-hose system for TBM launching applications
- Easy handling on-site due to light-weight components
- Shrink free, UV resistant material
- High resistance against tearing; no longitudinal seams
- Inflation can be achieved using various filling media
System Components

- **BULLFLEX® hoses**
  - Patented endless round woven fabric
  - Default outer diameter range: 230 [mm] (9.1 [in]) to 800 [mm] (31.5 [in])
  - Off-size diameters and special designs are available on request
  - Permeable to air and water
  - Fabric made of Polyamide 6.6
  - Anti-static, flame resistant, and self-extinguishing
  - Fabric treated with inverse salt-pairs which cool down the flames thanks to an endo-thermal reaction under the flame-point of the fabric
  - Working pressure up to 4 [bar] (58 [psi])
  - Retention of the grout mineral content while draining due to the special filter effect of the BULLFLEX® system

- **BULLFLEX® filling ports**
  - With check valve
  - Inner diameter 32 [mm] (1¼ [in]) or 50 [mm] (2 [in])

- **Fixing devices**
  - Webbings
  - Hook-and-loop tapes
  - Clip systems

- **Cement grout**
  - Portland cement
  - High early strength

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### Specifications

<table>
<thead>
<tr>
<th>Characteristics ¹</th>
<th>Unit</th>
<th>Value</th>
<th>Notes</th>
</tr>
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<tbody>
<tr>
<td>Material</td>
<td>[-]</td>
<td>Polyamide 6.6</td>
<td>Nylon</td>
</tr>
<tr>
<td>Weight</td>
<td>[g/m²] / [oz/yd²]</td>
<td>Approx. 660 / 19.44</td>
<td></td>
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<tr>
<td>Fabric thickness</td>
<td>[mm] / [in]</td>
<td>Approx. 1 / 0.04</td>
<td></td>
</tr>
<tr>
<td>Minimum tensile strength</td>
<td>L ² / T ³</td>
<td>[N] / [lbf]</td>
<td>12,000 / 2,698</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>24,000 / 5,395</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100 [mm] / 3.94 [in] width</td>
<td>According to EN ISO 10319</td>
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<tr>
<td>Corresponding maximum elongation</td>
<td>L ² / T ³</td>
<td>[%]</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>20</td>
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<tr>
<td>Elastic elongation</td>
<td>L ² / T ³</td>
<td>[%]</td>
<td>15</td>
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<td></td>
<td></td>
<td></td>
<td>15</td>
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<tr>
<td>Minimum seam strength</td>
<td>L ² / T ³</td>
<td>[kN/m] / [lbf/ft]</td>
<td>155 / 113</td>
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<tr>
<td>Airflow through fabric at pressure</td>
<td>[mbar] (psi)</td>
<td>[l/min] / [gal/min]</td>
<td>6.5 / 1.7</td>
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<tr>
<td></td>
<td>10 (0.15)</td>
<td>13 / 3.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20 (0.30)</td>
<td>19 / 5.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30 (0.45)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residual tensile strength</td>
<td>[%]</td>
<td>20 - 30</td>
<td>After 1 year and under light exposure in Florida</td>
</tr>
</tbody>
</table>

¹) The indicated values are laboratory values and may deviate on-site
²) Longitudinal
³) Transversal
Theoretical max. Pressure Resistance depending on the Lining Gap and the BULLFLEX® Diameter


- Ø = 230 [mm]
- Ø = 320 [mm]
- Ø = 400 [mm]
- Ø = 500 [mm]
- Ø = 630 [mm]
- Ø = 800 [mm]
Installation Procedure O-ring Sealing for Microtunneling

Mounting of the BULLFLEX® O-ring Sealing for marking the welding spots

Fixation of filling pipes into the BULLFLEX® filling valves
Note: to be able to ensure a proper grouting sequence, the filling pipes must be marked with different colors

Welding of screws to the sealing holder
Note: BULLFLEX® hoses must be protected against sparks & melted steel

Stepwise grouting process of the three sections

Fixation of the BULLFLEX® O-Ring Sealing in the lower area

Increase of the filling pressure up to 4 [bar] (58 [psi]) to achieve active pre-loading

Note: during inflation (cement injection), all default and recommended personal protective equipment must be used. BULLFLEX® Structural Sealings are resistant against mine water inflow; the fabric itself is only soluble in concentrated inorganic acids and phenol.
Mounting of two hose-in-hose BULLFLEX® O-ring Sealings for marking of the welding spots

- Welding of screws to the sealing holder
  Note: BULLFLEX® hoses must be protected against sparks & melted steel

- Fixation of the BULLFLEX® O-ring Sealing in the lower area

- Fixation of filling pipes into the BULLFLEX® filling valves
  Note: it is required to mark the filling pipes with different colors (see above)

- Phase 1: stepwise grouting of the inner sections of the first and the second hose-in-hose BULLFLEX® O-ring Sealings - sealing of the annular gap between the excavation line (sealholder) and the TBM shield skin

- TBM advance until the tail has reached the second BULLFLEX® O-ring Sealing (view against driving direction)

- Phase 2: grouting of the outer hose section of the first BULLFLEX® O-ring Sealing – sealing of the annulus between the TBM shield skin and segment ring.

- TBM advance until the tail has passed the first BULLFLEX®-O-ring Sealing

- Phase 3: grouting of the outer hose section of the first BULLFLEX®-O-ring Sealing – now both BULLFLEX® O-rings proof the annulus between excavation line and segment ring

Note: in principle, the sealing will work with one single BULLFLEX® O-ring hose-in-hose assembly as well. However, based on previous experience, a redundant sealing system is recommended.
**TBM O-ring Sealing Installation Procedure (Hose-in-Hose System)**

**Principle of the hose-in-hose system**

- Phase 1: 2 seals close the annulus between TBM skin and the excavation line
- Phase 2: The TBM’s tail is located under the second seal. The outer hose of the first seal has been filled and seals the annulus between inner lining and excavation line

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**General Health and Safety Regulations**

- Ensure that injection hoses are laid out without kinks
- Avoid contact with any sharp edges in order to prevent the fabric from being damaged
- Wherever there is a change of direction, the bending radius must not be less than six times the outside hose diameter
- Screw pumps are high-pressure pumps, therefore only steel-reinforced hoses may be used for grout transport
- Before starting the machine, ensure that easily workable grout is being used
- The intake hose must not leak anywhere (especially not at connections), and the inner side of the hoses must be sufficiently lubricated
- Before undoing the unions and the pump outlet flange, ensure that these components are de-pressurized by starting the main motor of the injection pump in REVERSE direction
- In order to prevent eye injuries, protective goggles must be worn, also when removing obstructions from the pump
- The person carrying out the task of pump operation must be at a safe distance from any material that may be discharged
- Accordingly, other people must be kept out of the immediate vicinity
- During inflation (cement injection), all default and recommended personal protective equipment must be used
- BULLFLEX® hoses are resistant against tunnel water inflow; the fabric itself is only soluble in concentrated inorganic acids and phenol
- Further information is included in the BULLFLEX® material data sheet
Accessories

- BULLFLEX® filling nozzle
- Attachments for BULLFLEX® filling nozzles
- Flexible functional sealing inserts and protective inserts for the improvement of sealing capabilities
- Watertight inlets for up to 8 [bar] (116 [psi]) for emergency sealings and adjustment of existing sealings
- Steel-reinforced grout pumping hoses or grout pipes, minimum diameter: 2 [in]
- Gunite pipes
- Valve extensions
- Repair kit
- Electric mortar-mixing pump type MP06
- Other injection pump types are available on request

<table>
<thead>
<tr>
<th>Characteristics 1)</th>
<th>Unit</th>
<th>Value</th>
<th>Notes</th>
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<tbody>
<tr>
<td>Nominal power</td>
<td>[kW]</td>
<td>5.5 - 7.5</td>
<td></td>
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<tr>
<td>Power supply</td>
<td>[V/Hz]</td>
<td>400/60</td>
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<tr>
<td>Pump capacity</td>
<td>[m³/hr] / [gph]</td>
<td>≥ 3.5 / 925</td>
<td>At 100 [bar] (1450 [psi]); spiral pump type required</td>
</tr>
<tr>
<td>Max. delivery pressure at the hose</td>
<td>[bar] / [psi]</td>
<td>4 / 58</td>
<td>Water transport pump or pressure control pump required</td>
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<tr>
<td>Required inlet pressure</td>
<td>[bar] / [psi]</td>
<td>2 - 5 / 29 - 72.5</td>
<td>Mixing liquid: water</td>
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<tr>
<td>W/C ratio</td>
<td>[1]</td>
<td>0.45</td>
<td>30% cement and 70% fly ash or equivalent filler material</td>
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<tr>
<td>Max. grain size filling material</td>
<td>[mm] / [in]</td>
<td>4 / 0.16</td>
<td></td>
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</tbody>
</table>

1) In combination with the BULLFLEX® system

Further References

- United States Patent No. 5,971,401
- Bigby, D.: Application Of RMT’s Remote Reading Telltale System To Monitor Roof Movement During Face Retreat At West Colliery, Germany. 22nd International Conference on Ground Control in Mining (ICGCM). Morgantown, 2003
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