GEOTHERMAL TUNNEL LINING
TURNING INFRASTRUCTURE INTO GREEN ENERGY SOURCES
We generate continuous growth through our expertise and innovative capabilities in materials development, systems design and surface technology. More than 15,000 employees at more than 170 locations around the world ensure the continued success of our independent, privately owned company.

Geothermal Energy
REHAU are experts in the use of Geothermal Technology to utilise the abundance of Ground-source energy, a renewable and sustainable source of energy that can be used for heating and cooling a variety of different construction projects. Over the past few years, architects, consultants and clients have realised that renewable energy is the future.

At 1.5m deep, the ground temperature is around 8-12°C and below 15m deep it is a constant 10°C. Ground-source energy can be exploited the whole year around and provides significant reductions in carbon dioxide emissions and energy costs.

Geothermal Tunnel Lining
Geothermal Tunnel Lining is a great example of REHAU’s ability to apply the benefits of its various intelligent solution concepts and products to enhance an existing engineering application. REHAU has successfully installed its Geothermal Tunnel Lining technology on projects across Europe, ensuring that contractors make the most of both the Geothermal Energy available at such depths and the heat generated by tunnel traffic.

By using REHAU’s Geothermal Tunnel Lining as part of the tunnel construction, the tunnels themselves generate a source of renewable energy for the surrounding commercial and domestic needs.

When included at the very first stages of tunnel project development, Geothermal Tunnel Lining is both simple and cost effective.

REHAU’s complete solution has been designed to fit within the existing tunnel fabrication rather than be an addition to what are already complex, precision projects. REHAU offers complete project solutions that ensure the desired result is achieved economically both in time and cost.
REHAU RAUWAY is a multi-layer PE-Xa pipe comprising of high-pressure cross-linked polyethylene (RAU PE-Xa) according to DIN 16892/16893 and EN ISO 15875 with a ratio of cross-linking of > 80% and additional layers for extra protection and oxygen barrier.

The high-pressure cross-linking of the polyethylene upgrades the material to high resistance against notches, grooves and puncture loads as demonstrated in the Notch Test or Full Notch Creep Test (FNCT) according to ISO 16770.

REHAU RAUWAY pipes also offer a service life of a minimum of 100 years even at higher temperatures (see table below), which is of particular concern for infrastructure projects with similar construction design life and the need for higher fluid temperatures to future proof the construction.

### Performance Improvement through Cross-Linking

<table>
<thead>
<tr>
<th></th>
<th>PE 100</th>
<th>PE RC</th>
<th>PE-Xa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Notch-Test</td>
<td>&gt; 1.000</td>
<td>&gt; 5.000</td>
<td>&gt; 40.000</td>
</tr>
<tr>
<td>FNC-Test</td>
<td>≥ 2.000</td>
<td>&gt; 5.000</td>
<td>&gt; 14.000</td>
</tr>
</tbody>
</table>

Test Results of Notch Tests & Full Notch Creep Tests (FNCT) in Hours

### Service Life and Temperature Resistance

<table>
<thead>
<tr>
<th>Temp.</th>
<th>DIN 16892/3 PE-Xa</th>
<th>DIN 8074/5 PE 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>20°C</td>
<td>100 years / 15 bar</td>
<td>100 years / 15.7 bar</td>
</tr>
<tr>
<td>30°C</td>
<td>100 years / 13.3 bar</td>
<td>50 years / 13.5 bar</td>
</tr>
<tr>
<td>40°C</td>
<td>100 years / 11.8 bar</td>
<td>50 years / 11.6 bar</td>
</tr>
<tr>
<td>50°C</td>
<td>100 years / 10.5 bar</td>
<td>15 years / 10.4 bar</td>
</tr>
<tr>
<td>60°C</td>
<td>50 years / 9.5 bar</td>
<td>5 years / 7.7 bar</td>
</tr>
<tr>
<td>70°C</td>
<td>50 years / 8.5 bar</td>
<td>2 years / 6.2 bar</td>
</tr>
<tr>
<td>80°C</td>
<td>25 years / 7.6 bar</td>
<td>-</td>
</tr>
<tr>
<td>90°C</td>
<td>15 years / 6.9 bar</td>
<td>-</td>
</tr>
</tbody>
</table>

Service Life (Safety Factor SF=1.25) SDR 11

### Comparison PE-Xa Vs PE 100

<table>
<thead>
<tr>
<th>Temp.</th>
<th>PE-Xa</th>
<th>PE 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Operation Temperature</td>
<td>95°C</td>
<td>40°C</td>
</tr>
<tr>
<td>Max. Scratch Depth</td>
<td>20%</td>
<td>10%</td>
</tr>
<tr>
<td>Robustness</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Point Load Resistance</td>
<td>+++</td>
<td>-</td>
</tr>
<tr>
<td>Resistance to Slow Crack Propagation</td>
<td>+++</td>
<td>-</td>
</tr>
<tr>
<td>Tight Bending Rules</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td>Pipe Roughness (Pressure Loss)</td>
<td>0.04mm</td>
<td>0.007mm</td>
</tr>
</tbody>
</table>

Molecular Structure of PE-Xa Pipe showing Cross-Linked Bonds between Carbon Atoms
REHAU EVERLOC™
PIPE CONNECTIONS AND FITTINGS

REHAU EVERLOC™ Fitting
REHAU EVERLOC™ is a unique fitting patented by REHAU. Comprising of a DZR brass internal fitting and compression sleeve the joint is completely watertight and permanently sealed. In high pressure tests up to 60 bar the pipework would fail rather than the joint. Over 50 million fittings have been completed in REHAU EVERLOC™ without one single failure.

Using a simple pipe cutter, expansion pliers and jointing tool the joint can be performed quickly, efficiently and safely on site in under 25 seconds. The pipe is simply cut to length and the compression sleeve slid onto the pipe.

The end of the pipe is then expanded and the fitting inserted. The joint is completed by bringing the compression sleeve into place with the clamping tool.

The combination of speed and efficiency with reliability makes REHAU EVERLOC™ the perfect choice for tunnel applications. Not only can the fittings be completed during tunnel construction but the reliability gives piece of mind once the sections are completed.
**GEOTHERMAL TUNNEL LINING**

**SEGMENT CONSTRUCTION AND INSTALLATION**

1. **Segment Construction**
   REHAU RAUWAY pipe assembled to a steel mesh or cage forms a module. These modules are inserted into the segment moulds before concrete is poured. Once a segment has been constructed it forms part of a ring.

2. **Tunnel Lining Construction**
   From the tunnel boring machine (TBM) the pre-fabricated concrete segments are installed. Typically 7 segments and a keystone complete a ring. The absorber pipes in each segment are connected at radial and circumferential joints to create a continuous loop using REHAU EVERLOC™ fittings. Robustness and speed of installation is ideal for tunnel construction applications.
Ever changing legislation and support for the climate debate is increasing the pressure on major construction project developers to future proof their projects, not only for 20-30 years but for much further into the future. REHAU Geothermal Tunnel Lining Solutions present just the option to do so through a number of unique features and benefits.

By installing absorber pipes inside pre-fabricated tunnel segments it is possible to upgrade the tunnel lining to extract energy out of the surrounding soil and surplus heat inside the tunnel (e.g. rail, sewer or service tunnel). Typical energy extraction ranges from 10-30 W per m² tunnel surface. This extracted energy can be used to heat buildings above ground. By incorporating this technology early on in the tunnel design stage it is more cost effective than traditional ground-source energy such as ground-source probes or energy piles. Using Ground-source Heat Pumps to extract the energy out of the tunnel construction enables the client to apply for grants and incentives (i.e. Renewable Heat Incentive for the UK). It can also play a significant benefit for tunnel cooling. Overall, embracing this technology in the tunnel design is helping to future proof the infrastructure.

**Hot Tunnel Applications:**
- Deep/long rail and road tunnels or service tunnels (power, sewer)
- Tunnel air temperature higher than ground temperature
- Extracted energy mainly from the tunnel
- Energy used for space heating and hot water demand above ground
- Significant cooling effect for the tunnel

**Cold Tunnel Applications:**
- Short rail and road tunnels
- Tunnel air temperature similar to ground temperature
- Extracted energy mainly from soil mass around the tunnel (ground-source application)
- Provides heating and cooling for buildings above ground

The introduction of Geothermal Tunnel Lining into tunnel projects provides the developer with a unique opportunity to contribute positively to the Green debate whilst improving the financial performance of the project. The extraction of heat energy from the tunnel allows efficient energy supply and reduces the energy needed to provide adequate cooling. The revenue potential from the sale of such energy and the cost reductions possible through lower cooling requirements impact significantly on investment calculations.

Furthermore, tunnel projects are usually by definition a significant disruptive influence on life on the surface. The positive impact Geothermal Tunnel Lining can deliver offers developers strong arguments in the political arena.
In this case a 54m section of the new twin-track high-speed railway tunnel was identified for the installation of Geothermal Tunnel Lining to generate c. 40kW of heat for a municipal building on the surface. The tunnel is 12m in diameter and situated 27m below the surface. Each concrete segment that forms the tunnel lining is 2m wide and 500mm thick. The ring is formed with seven segments and a keystone. Each segment is connected using REHAU EVERLOC™ pipe connections. 27 activated segment rings formed the system each connected through header pipes back to a central manifold and into the building shaft less than 150m from the access point to the tunnel.

In this particular project the decision to include Geothermal Tunnel Lining was made retrospectively to the design of the concrete segments. This meant adaptations to the design. However, REHAU will work closely with concrete segment manufacturers to optimise the design from an early stage ensuring reduced cost and lower risk.

The length of tunnel required to provide the heat requirement for a building will depend on a number of factors namely:

- Heat requirement of the building
- Tunnel geometry
- Thermal ground conditions
- Hydro geological conditions

The amount of CO₂ emissions saved over a conventional heating system will also depend on a variety of factors and whether or not the impact of cooling is taken into account.
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