

**Bentofix®**  
APPLIED KNOWLEDGE **IQ**

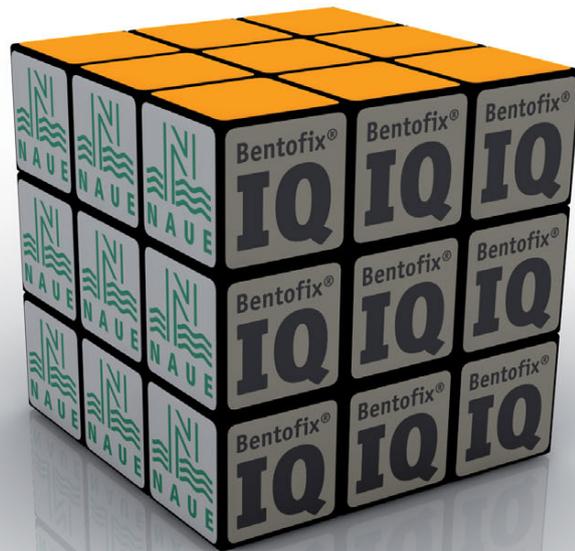


APPLICATION



The Inventor of  
Needle-punched Geosynthetic  
Clay Liners. Outstanding Quality  
and Longest Experience.  
**Bentofix® - The Original!**





Bentofix® IQ addresses four subjects key to understanding geosynthetic clay liners (GCLs): Technics, Quality, Application and Ecology. It describes the intelligence and importance of this product type, which was invented by NAUE in 1987, and highlights the intelligent use of needle-punched GCLs in sealing applications. Today, the Bentofix® IQ approach is guided by the classical elements of water, fire, earth and air as critical issues such as proper GCL production, design, application and installation. Bentofix® IQ encourages GCL users to utilize these classical elements to understand those four key GCL subjects: Technics (water), Application (earth), Quality (fire) and Ecology (air).



# Bentofix® IQ

## Hydraulic Applications

Bentofix® geosynthetic clay liners (GCLs) are produced in various types, which is especially important in hydraulic engineering applications. This allows Bentofix® to be installed in dry or wet conditions, and even underwater. With durable, robust geotextile outer layers and a uniform, high-swelling core of sodium bentonite, Bentofix® GCLs provide an ideal barrier for hydraulic installations. They prevent both water loss and water incursion, making them outstanding containment and protection solutions for canals, dykes, dam liners, flood embankments, water reservoirs and other situations requiring strong performance against hydraulic heads.

**Fig. 1**  
Permeability of Bentofix® GCLs in dependence of water head and confining stress.

conventional compacted clay. In general, the hydraulic head concern with a GCL-lined canal is lesser, because of a dependable, steady head. Also, desiccation or freeze/thaw concerns can be alleviated by the constant hydration of the GCL sealing system. Ensuring the true performance of the GCL, then, depends upon strong bentonite encapsulation. This protects the core from wave action. The uniform needle-punching of more than two million fibres per sqm in Bentofix® prevents lateral bentonite movement. With proper GCL selection and construction design, bentonite piping concerns are eliminated. A special version of Bentofix® (BZ13-B) enables underwater installation - something other liners are not capable of.

stallations must be guarded against seepage loss. Bentofix® GCLs are perfectly suited for this. Dam slopes typically are steep and internal shear strength and interface friction angles are often of concern. Scrim-reinforced Bentofix® GCLs with nonwoven geotextiles on both sides typically allow steeper designs than similar materials with woven components. The nonwoven element increases interface friction angles. For underwater installations Bentofix® BZ13-B allows installation even under faster currents. It features an integral sand ballast layer that is

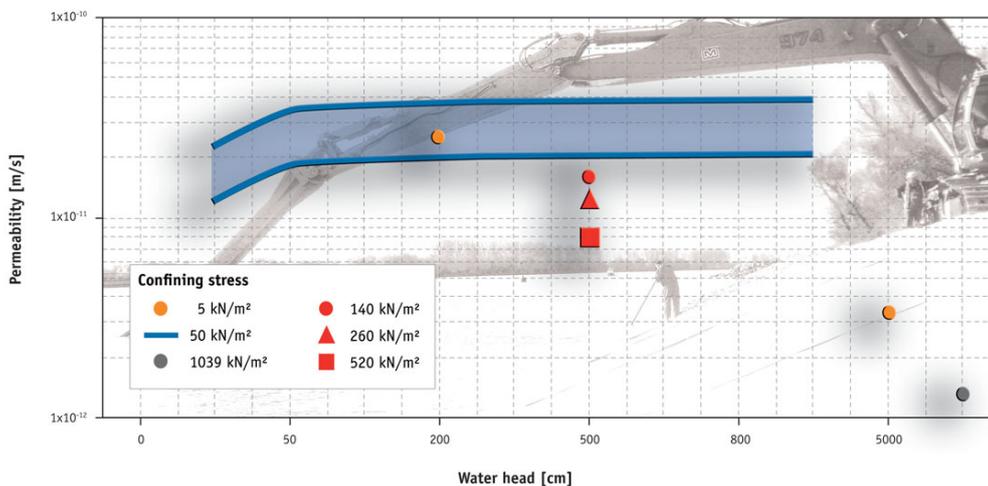
potential overtopping. Both scenarios impact flood defenses. Bentofix® GCLs provide the essential seal to protect against erosion and failure-inducing seepage. An approx. 10 mm-thick layer of hydrated Bentofix® outperforms a 60 cm-thick compacted clay liner on cost and long-term performance. When installed on the upstream surface, high-swelling powdered sodium bentonite offers an excellent low permeability seal. Slope angles of 2.5:1 (H:V) or greater are possible with Bentofix® GCLs due to the needle-punched surface structure of the cover and carrier nonwovens,

*»Water runs down the hill, not through Bentofix®«*

as well as the large internal and external shear strength. The more robust Bentofix® BFG 5000 features a cover nonwoven geotextile that has been uniformly impregnated with a second layer of sodium bentonite powder, which can help an installation proceed more efficiently versus installations where the overlaps must be sealed with additional bentonite.

### Testing confirms:

Independent testing of in-service Bentofix® GCLs by the German Federal Waterways Engineering and Research Institute (BAW) has confirmed their durability and performance. Even after years of service, Bentofix® continues to meet stringent material specifications and performance criteria. Outstanding historical performance in flood defenses is even helping to write new levee construction codes.



### Canals:

The sealing of canals has become much more important. Water loss due to seepage limits agricultural productivity. Erosion threatens the safety of shipping and recreational canals. Bentofix® GCLs are more economical to install and more stable against internal erosion than

### Dams:

Like canals, dams (e.g. in water reservoirs) generally require designs with permanent hydraulic heads. Bentofix® GCLs have been utilized in a number of dam installations, such as for inland shipping routes with an elevation higher than the natural groundwater. These in-

encapsulated by a nonwoven geotextile. Once installed, Bentofix® BZ13-B stays put and withstands the placement of heavy armor rock.

### Levees and coastal dykes:

Levees and dykes present interesting challenges. Levees must withstand temporary loads. Coastal dykes are subjected to waves and

# Bentofix® IQ Landfill Applications



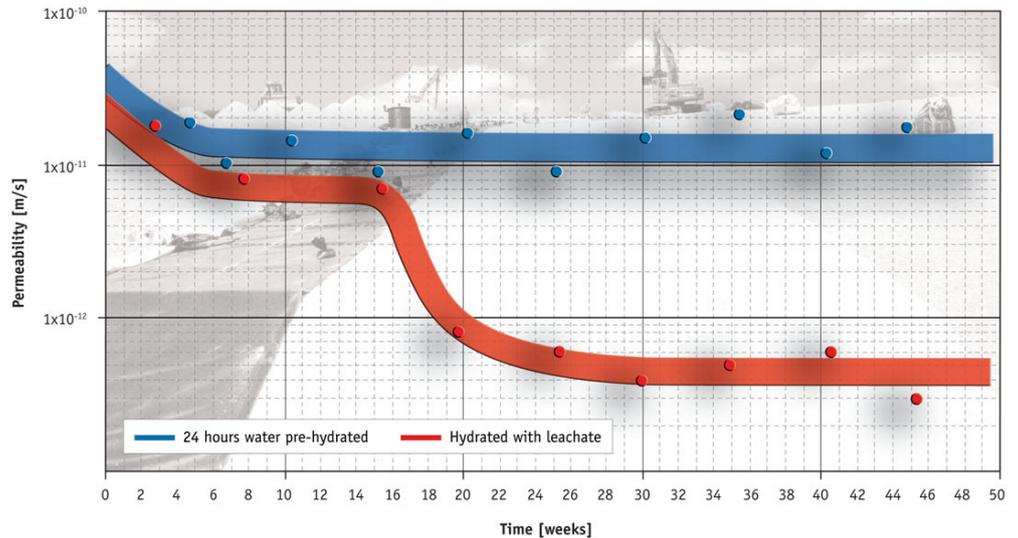
NAUE's 1987 invention of the needle-punched method of manufacturing geosynthetic clay liners (GCLs) changed the field. The advance enabled not only the rapid, safe production of GCLs but the efficient shipping of GCLs in rolls. These moves lowered cost while maintaining the high level of product quality, thus expanding the available applications for GCLs. Also, the previously low friction coefficient of the bentonite used in GCL cores ceased to be of concern. The needle-punching of a nonwoven geotextile outer layer transferred the shear stress from the clay to the highly engineered geotextile to which the sodium bentonite was

## »The feather in your (landfill) cap«

bonded. Bolstered by this technology, Bentofix® geosynthetic clay liners (GCLs) established themselves quickly in landfill applications.

### Capping systems:

The most common use for Bentofix® GCLs in landfill construction is for the creation of long-term capping systems. Whether it is a municipal solid waste facility, a construction and demolition cell, or something more industrial (such as a fly ash landfill), an impermeable cover barrier is essential for successful closure, landfill stability, and potential site reuse. The exceptional swelling properties of sodium bentonite and the needle-punched nonwoven geotextile strength of Bentofix® provide outstanding containment and durabi-



lity. Rainwater incursion is prevented and the GCL panels possess enough flexibility to adjust to dif-

ferential settlement without losing their uniform thickness and performance quality. In addition to their stronger performance versus traditional compacted clay-only systems, Bentofix® provides economical and environmental benefits that traditional mineral seals cannot. The thinner profile of Bentofix® means that waste installations have greater volume. In waste management, air space equals profitability. But GCL rolls are also more economical from a shipping and installation standpoint. Fewer deliveries and faster installation reduce cost. And significantly fewer truckloads of GCL rolls are needed to cap a landfill, whereas compacted clay requires many truckloads. The use of Bentofix®, then, reduces transportation pollution and minimizes the mining of clay from elsewhere. Combined with other geosynthetics (e.g. NAUE Secudrain® drainage composites) a Bentofix® capping system manages leachate strongly, keeps out rainwater, and enables other beneficial closure activities, such as methane harvesting below the cap and vegetation establishment above.

### Base sealing:

Waste management professionals must comply with some of the strictest environmental regulations. These codes call for strong sealing systems beneath landfills to protect groundwater during active landfill operations and long-after final closure. Bentofix® GCLs have played an important role in these critical base sealing systems, most often in composite liner systems such as with Carbofol® HDPE geomembranes for primary barriers and geocomposites for leachate and gas management. Sodium bentonite-based Bentofix® GCLs provide essential security in

base sealing systems. In the event of a breach in the primary barrier, Bentofix® provides the same impermeable, self-sealing protection it does for landfill cover systems, hydraulic barriers, and other installations where soil and groundwater must be protected.

### Slopes:

One of the biggest challenges to any waste cell's containment system is the integrity of the sealed slopes. This applies to both cover systems and primary base liners. The weight of waste and soil coverage can be tremendous. But geosynthetic clay liners perform just as well on slopes in sealing systems as they do on flat portions of the installation, such as in composite base lining systems beneath the landfill. The strength of Bentofix® GCLs along landfill cap and bottom liner slopes is the result of the needle-punched nonwoven outer layer, which provides the necessary internal reinforcement to manage shear stress benefit.

Fig. 2  
Effect of permeability once permeated with leachate.

# Bentofix® IQ

## Infrastructure Applications



Roads and railways commonly use geosynthetic technologies for applications such as sub-grade reinforcement, separation of fines, drainage and erosion control. But Bentofix® geosynthetic clay liners are also utilised in infrastructure. Containment, in fact, is a growing need for environmental protection in transportation applications.

### Roads:

Stormwater retention ponds collect rainwater runoff. With its easy-to-delivery, easy-to-install rolls, Bentofix® provides the essential seal for runoff ponds so that the underlying

can provide a base liner beneath roads and slopes for exceptional environmental protection. In applications where friction angle is a concern, e.g. on steep slopes Bentofix® GCLs with nonwoven geotextiles on both side are the solution. They increase the interface friction angle, which enables secure slope installations; and their robustness provides exceptional durability. Freeze/thaw effects and dry/wet cycles are generally not a concern in these applications, so long as a standard cover material thickness (e.g., greater than 800 mm) is used.

The high-swelling sodium bentonite in Bentofix® provides an effective, long-term barrier against unwanted seepage, including for track drainage systems and protection of adjacent land. Bentofix® GCLs

by providing both a safety and stress-relieving barrier between residents and important transit corridors. But barriers are more complicated than many realize. They often must use steep slopes, because the space

»All roads lead to Bentofix®«

are uniformly needle-punched through all three layers (outer geotextile layers and intermediate bentonite core). This needle-punching creates a uniform encapsulation of the sodium bentonite by over 2 million

in which they are constructed is limited. (Most of the space is reserved for roads or rails.) Drainage and erosion concerns must also be addressed so that the barrier does not negatively impact the road or railway. And if local soils cannot be used, the cost of the barrier will more than likely be too high for approval. Geosynthetics resolve these issues. Geogrids provide reinforcement. Geocomposites provide drainage support. And Bentofix® geosynthetic clay liners provide internal sealing to protect the noise barrier core. Not only does this enable the use of most local materials, it can be used to encapsulate contaminated soil (e.g., arsenic contaminated soils) while putting it to a beneficial use in infrastructure. The bentonite core of Bentofix® provides that environmental protection, and the durable geotextile outer layers secure the seal even on steeper barrier slopes.

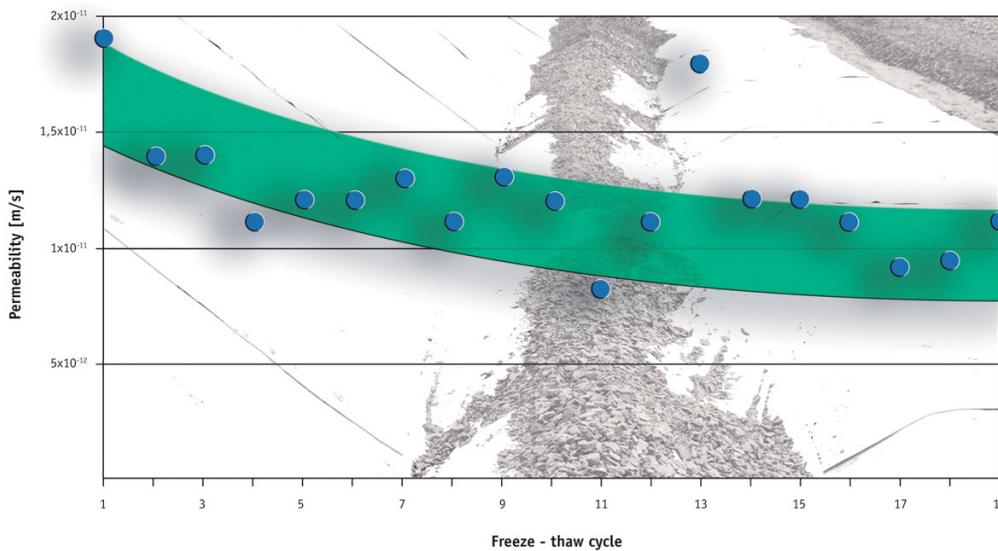


Fig. 3 Freeze-thaw effects on Bentofix® permeability.

soils are not overtaxed. Sensitive locations, such as roads built adjacent to wetlands, increasingly call for protection like this, especially to prevent the seepage of automotive-related liquid contaminants into the soil. Also, Bentofix®

### Railways:

As in road design, environmental protection is of growing importance in rail applications to prevent contaminated liquids from migrating into soils, threatening wells, impairing water catchment zones, etc.

fibres per square metre which also withstands dynamic forces during the service life.

### Noise Barriers:

The installation of noise barriers along roads and railways can help gain project approval

# Bentofix® IQ

## Other Applications

Geosynthetics are established in every sector of civil engineering. The composite construction of geosynthetic clay liners (GCL) reflects how geosynthetics perform best: by interacting with natural elements to create something stronger or more secure. In the case of Bentofix® GCLs, the needle-punching of the three layers – outer encapsulating geotextiles and intermediate sodium bentonite core - leads to excellent internal and external shear strength for durability while the uniform layer of sodium bentonite provides the containment. Together, these components outperform significantly thicker compacted clay layers.

bentonite impregnation on the outer surface of the nonwoven geotextile (Bentofix® BFG 5000), leads to efficient construction and a permanent, water-tight seal for floors, slopes, and vertical walls. Installed against concrete, Bentofix® seals micro-racks and other flaws found

against the structure, provides an intimate seal that will swell quickly and effectively in the event of water incursion. And the extra polymer-coating on the woven side protects against the high water pressure.

### Secondary containment:

Tank farms, such as fuel depots, commonly require secondary

compatibility against a wide range of liquids being stored.

### Mining:

Few industries are as intensive and environmentally injurious as mining. When sites are closed, capping systems prevent rainwater incursion into and upward migration of potentially harmful

»Never change a winning strategy«

in conventional hard materials so that, sealed and protected, the service life of those materials is extended.

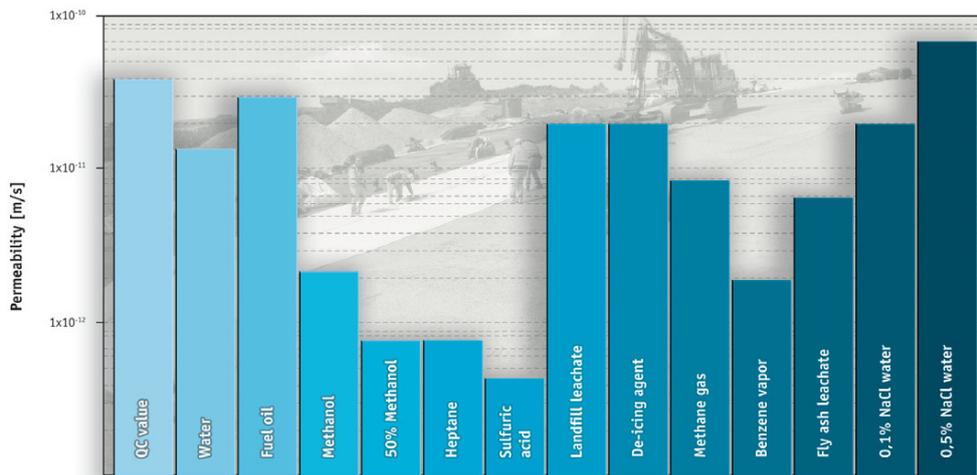
containment geosynthetics. GCLs are significantly cheaper and easier to install than compacted clay liners; and GCLs, with their encapsulated, uniform bentonite cores, and the extra polymer-

soils and liquids. Bentofix® GCLs provide outstanding environmental protection and are flexible to accommodate differential settlement. Also, they are not subject to the elevated cracking risk of conventional clay. Further, Bentofix® is far more economical and environmentally advantageous compared to traditional mineral seals. Clay layers are inexact in thickness, time-consuming to install and require many truckloads of material; Bentofix® is uniformly thick, quick to install, and requires only a fraction of the delivery traffic. Time

and money are saved, and the environmental impact of site work is minimised.

These are just some samples of many applications in which the various types of Bentofix® GCLs are being used.

**Fig. 4**  
Permeability of pre-hydrated Bentofix® GCLs with approx. 4,000 - 5,000 g/m<sup>2</sup> bentonite) tested against various liquids and gases at approx. 30 kN/m<sup>2</sup> confining stress.



### Waterproofing:

The waterproofing of large infrastructure footprints and structures is a natural fit for GCLs. The speed and safety of Bentofix® roll installation, and options such as the addition of an extra layer of powder

### Tunnels:

In tunneling, geosynthetics are used to seal areas subjected to high hydraulic pressures as well as areas of seepage. Bentofix® X2 BFG 5300 serves this application well. Its extra layer of bentonite, placed

coating Bentofix® X2 types are far less prone to the same desiccation risks than compacted clay layers are. Bentofix® X2 types, installed with the polymer-coated side up, provide exceptional secondary containment and the coating provides



Bentofix® Thermal Lock geosynthetic clay liners (GCLs) are needle-punched, reinforced composites that combine two durable geotextile outer layers and a uniform core of high-swelling powder sodium bentonite clay. This construction forms a shear-resistant hydraulic barrier with self-sealing characteristics. When hydrated with fresh water, the bentonite swells and forms a low permeability gel layer, the hydraulic performance of which is equal to or better than traditional, thick compacted clay liners.

Additionally, the proprietary heat-treating process – Thermal Lock – permanently locks the needle-punched fibres, increases the pull-out resistance of the fibres and ensures long-term shear resistance. Bentofix® GCLs are impregnated with a 500 mm wide, uniform layer of bentonite in both longitudinal directions. This enables an immediately sealed overlap without the need for further bentonite addition on site. Bentofix® BFG is also impregnated with an additional, uniform layer of sodium bentonite powder across its nonwoven surface. This advance is ideally suited for pond and waterproofing applications, since the outer layer of the nonwoven geotextile creates an intimate contact zone in overlap areas, such as with concrete surfaces.

Bentofix® GCLs are part of an important trend toward the combined use of geosynthetics and clay materials in barrier applications as a stand-alone liner system and in the synergistic use of GCLs and geomembranes to maximise liner system efficiency. Bentofix® Thermal Lock GCLs are utilized in but not limited to the following applications: landfill caps and liners; environmental protection under roads, railways, and airports; dam and dyke sealing; vertical barriers; ponds; waterproofing; and secondary containment.

NAUE's most recent GCL development, Bentofix® X, exemplifies how modifications to GCL product design can be made to anticipate the special challenges of a particular site. Bentofix® X is a polyolefin polymer-coated GCL. The woven fabric is coated with a low-permeability polymeric polyolefin coating to achieve an immediate barrier prior to hydration. Bentofix® X is an advance for GCLs in some specific applications, such as waterproofing, oil and gas tank farms, landfill capping and cover systems or where high hydraulic gradients are present.





NAUE GmbH & Co. KG  
 Gewerbestrasse 2  
 32339 Espelkamp-Fiestel  
 Germany

Phone +49 5743 41-0  
 Fax +49 5743 41-240  
 E-Mail info@naue.com  
 Internet www.naue.com

Memberships of the NAUE Group

Member <b>DGGT</b> Deutsche Gesellschaft für Geotechnik e. V.	Member <b>ITG</b>	Member <b>Ivg.</b>	Member <b>17</b>	Member <b>DWA</b>	Member <b>GWS</b> ARBEITSSICHERHEIT GRUNDLAGENSICHERHEIT E.K.	Member 	Member <b>AK 19</b>	Member <b>GMA</b> Geotechnische Gesellschaft für die Anwendung der Geotechnik	Member <b>ING</b>
Member <b>E.A.G.M.</b>	Member <b>EGMA</b> EUROPEAN GEOTECHNICAL SOCIETY	Member <b>STUVA</b>	Member SMBG   ISSMGE 	Member <b>IGS</b>	Member 	Member <b>IRGI</b> International Association of Geotechnical and Soil Engineers	Member <b>ASTM</b>	Member <b>OIAV</b>	Member <b>AWEA</b> BUSINESS MEMBER

Approvals for the NAUE Group

<b>BBA</b> BRITISH BOARD OF AGREEMENT CONCRETE, STEEL, WOOD, GLASS Bentofix® BFG 5000	<b>BBA</b> APPROVAL CERTIFICATION SECUGRID® Q6 and R6
<b>CE</b>	<b>TUV NORD</b> ISO 9001



and Bentofix® are registered trademarks of NAUE GmbH & Co. KG.

The information contained herein is the best to our knowledge, true and accurate. There is no implied or expressed warranty.  
 © 2011 by NAUE GmbH & Co. KG, Espelkamp-Fiestel, Germany · All rights reserved. · Status 11.02.2011