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).
All geosynthetics have their individual advantages. For geosynthetic clay liners, the swelling capacity and "self-sealing" characteristic of the sodium bentonite core truly separate them from other barrier materials. Swelling occurs during contact with moisture and fresh water. However, if the GCL is punctured during construction, this swelling reaction is known as self-sealing and is a characteristic not found in any other single or composite geosynthetic material and unlikely to be found in traditional clay barriers. The key rests in how GCLs encapsulate sodium bentonite, a unique, natural material that is the result of volcanic ash settlements from more than 50 million years ago.

Bentonite qualities:
The exceptional qualities of sodium bentonite have only been fully realized in the past centuries. Sodium bentonite is characterized by the lowest known permeability of naturally occurring geological materials and a high absorption capacity. Its swelling ability is significantly greater than conventional clay that a relatively thin layer of it, properly secured between geosynthetics, can be used in place of thick layers of compacted clay. This extraordinary swell characteristic stems from its montmorillonite content. Montmorillonite swells approximately 900 percent when in contact with fresh water. Products with more granular bentonite begin their service life in the field with voids. While bentonite's swelling capacity is exceptional, granular voids do not close as quickly as powdered bentonite. Powdered bentonite swells immediately in contact with fresh water and acts as a barrier.

Importance of powder:
Bentofix® uses high-swelling, sodium bentonite clay, which has a lower permeability than calcium bentonite. Bentofix® also uses the powdered form of this bentonite, which is unique in GCL manufacturing today and allows a very constant distribution within the GCL. Products with more granular bentonite begin their service life in the field with voids. While bentonite's swelling capacity is exceptional, granular voids do not close as quickly as powdered bentonite. Powdered bentonite swells immediately in contact with fresh water and acts as a barrier.

Testing:
NAUE utilises stringent testing regimes and frequencies for both raw materials and finished products. The bentonite suppliers conduct rigorous testing, such as sieve analysis to assure the powder quality, which is essential to ensuring immediate swell performance or the montmorillonite content. NAUE's quality control bentonite testing includes ASTM International's swell index (D5890) and fluid loss test method (D5891). Also, NAUE conducts water absorption testing (in accordance with DIN 18132) and methylene blue (MB) absorption testing. MB testing is not common among GCL manufacturers, but it is standard for NAUE. These single tests are not fully indicative of permeability, but together with NAUE's knowledge and database of permeability results over the decades allow an important understanding of the overall bentonite performance combined with the NAUE needle-punching technology.

Bringing it together:
Once the sodium bentonite's high quality is verified and approved, it can be used in the Bentofix® GCL manufacturing process. A uniform core layer of it is sandwiched between two outer geotextile components, such as through needle-punching, which ensures the bentonite erosion stability and gives the GCL the necessary strength properties as well as durability. Consistency of the bentonite quality, uniformity in its thickness in the GCL, and the geotextile protection enable a single Bentofix® layer to outperform thick compacted clay landfill liners, under roads for environmental protection, in dams and dykes, as secondary containment and in other applications.
High-Quality Components

Bentofix® is a needle-punched, self-sealing barrier composite material. In addition to a core sodium-bentonite layer, Bentofix® GCLs excel in versatile barrier applications due to the outstanding strength and quality of their components. The balanced combination of polymeric fibres and naturally occurring clay creates a long-term sealing system which relies on each single component.

Nonwovens:
NAUE’s extensive history of success in nonwovens manufacturing is key to the manufacture and performance of Bentofix®. The uniform layer of sodium bentonite is secured by millions of needle-punched, nonwoven staple fibres, a process that eliminates the concerns of the low friction coefficient of bentonite by transferring the strength to the nonwoven geotextile. Also, NAUE does not rely upon another company’s nonwoven product. Instead, NAUE selects and purchases its own fibres for reinforcing the surface of Bentofix® GCLs. It is the same expertise utilised in the manufacture of the internationally successful Secutex® line of nonwoven geotextiles. Manufactured from 100% synthetic fibres, the nonwoven geotextile outer layer of Bentofix® ensures long-term stability.

Scrim reinforcement:
The carrier layer of every Bentofix® GCL has a slit film scrim reinforcement geotextile as a carrier layer. This component is mainly needed for on-site handling and allows the pulling and dragging on the GCL for proper placement without too much elongation of the GCL. Combined with the proprietary heat-treating process (Thermal Lock), it is used to anchor and more permanently lock the needle-punched fibres for superior long-term internal shear performance.

Additional bentonite:
For projects that may require additional bentonite to ensure a proper seal, NAUE offers Bentofix® BFG. This series is just as robust, but in addition to the normal layer of high-swelling bentonite it features a cover nonwoven geotextile that has been uniformly impregnated with a second layer of sodium bentonite powder. This is important for installation security. Some applications require additional bentonite at the panel overlaps. Bentofix® BFG provides the solution. All other Bentofix® types have this same technology on a 500 mm wide strip on both longitudinal edges to ensure sealed overlaps in this area.

The “X” Factor:
While the strongly bonded geotextiles hold a GCL’s bentonite layer in place and improve the composite material’s durability and performance, gas can flow through in the first phase of an application if the bentonite is not yet hydrated; or desiccation can influence the performance of the GCL’s bentonite layer. This can be issue for some specific situations, such as waterproofing in areas where radon gas occurs or applications with low confining stresses. NAUE’s most recent GCL advance, Bentofix® X, exemplifies how modifications to GCL product design can be made to anticipate the special challenges of particular sites. The uniform layer of powder sodium bentonite in Bentofix® X is encapsulated between a slit-film woven and a staple-fibre nonwoven geotextile. The woven fabric is coated with a low-permeability polymer polyolefin coating to achieve an immediate barrier prior to hydration.

Quality Control:
Regardless which of these components needs to be tested, it is all done in-house under national or international regimes in an ISO 9001-certified facility. Where applicable, CE marking is available.
Superior Manufacturing
Independent construction quality assurance (CQA) monitoring on construction sites is increasingly required, but the role of CQA and secondary manufacturing quality assurance (MQA) tests are rendered largely moot if the materials are manufactured and tested properly before site delivery. NAUE ensures a high level of manufacturing quality control (MQC).

Mechanical strength:
To ensure superior durability and long-term performance of Bentofix® GCLs, rigorous standards are adhered to in the manufacturing process. Among them are numerous mechanical checks and tests. The needle-punch method of manufacturing bonds the central, uniform layer of bentonite and the outer geotextile layer with the strength of more than two million needle-punched nonwoven fibres per square metre.

The end result:
The dedication to manufacturing quality and decades of research and experience enable Bentofix® GCLs to significantly outperform conventional, expensive, thick clay layers on all measures: cost, safety, long-term durability, permeability, ecologically, etc. The uniform core of powdered sodium bentonite is secured through the needle-punching process and the bond is reinforced by the Thermal Lock Process. Rigorous and frequent testing confirm the quality of the individual components and the composite Bentofix® rolls, as well as verify their qualification for numerous hydraulic designs and barrier system needs, such as for landfill capping, environmental protection in transportation, dam linings, secondary containment, levee construction and much more.

Bentofix® IQ
Manufacturing

The IQ of Applications: Resists high water heads, ideal environmental protection, ideal barrier for landfills, versatile sealing applications

»Made right, made to last, made to seal«

This balanced combination creates a long-term sealing system with high shear strength. The Thermal Lock Process is a proprietary heat-treating process used to modify and more permanently lock into place the needle-punched fibres. Tensile and peel testing confirms the strength and security of the bond. NAUE’s technical experts even developed a correlation between the peel test and the internal shear strength of Bentofix®.

Hydraulic suitability:
The extensive testing NAUE performs on their high-quality, powdered sodium bentonite and on finished material rolls verifies the suitability of Bentofix® as an exceptional barrier for a great range of containment applications, also due to the superior, immediate swelling characteristics of powdered sodium bentonite. NAUE’s bentonite suppliers verify the bentonite powder quality with various tests which are also confirmed upon arrival at the GCL plant. Furthering the verification process, NAUE’s quality control testing includes testing of the laboratory and manufacturing processes combine to provide the essential documentation and manufacturing quality control for confidence in GCL design, specification, installation and performance. While standard MQC regimes ask for a minimum test frequency, NAUE commonly tests at higher frequencies than requested or done by other manufacturers.

Testing frequencies and facilities:
NAUE’s ISO 9001-certified laboratory and manufacturing processes combine to provide the essential documentation and manufacturing quality control for confidence in GCL design, specification, installation and performance. While standard MQC regimes ask for a minimum test frequency, NAUE commonly tests at higher frequencies than required or done by other manufacturers. Furthermore, NAUE’s 24-hour facility conducts MQC tests on finished rolls to ensure the quality of both the components and the security of their bond. Since NAUE produces its own nonwoven geotextile layers from specially selected staple fibres, it can also provide the detailed certification of these components. CE Marking and other special specification assisting labels are available.

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Years of Field Experience, Research and Development
NAUE’s long history of materials development, testing and manufacturing have made the various types of Bentofix® geosynthetic clay liners robust, versatile products that meet the highest safety standards and provide exceptional cost efficiencies. When in need of an effective, long-term barrier system, choosing Bentofix® will ensure quality, preserve our natural environment, and reduce construction costs and time.

Also of note, the previously low friction coefficient of the bentonite clay used in GCLs ceased to be of concern because of needle-punched geotextile encapsulation. This new method of manufacturing transferred the shear stress from the clay to the highly engineered geotextile. Other innovations from NAUE include being the first to impregnate the topside and the longitudinal overlap areas of the GCL with powdered bentonite, adding a sand ballast layer on top of the GCL for underwater installation, thermally locking the needle-punched fibres for long-term shear strength and much more. Also, NAUE has, from the beginning, manufactured GCLs with scrim-reinforcement for secure handling on site.

Testing and Standards:
NAUE’s experts have been and are active in international committees and societies, helping to write new standards to improve the geosynthetics field and publishing technical articles to transfer knowledge of geosynthetics manufacture, installation and performance. NAUE’s ISO-accredited laboratory performs rigorous tests on all the components used in Bentofix® and has even helped to develop tests for standardization, such as the peel test. NAUE has also helped to establish a minimum thickness for the textile component to ensure proper bentonite encapsulation.

Research and development:
From the beginning of NAUE’s GCL involvement, one main task has been to remain continuously involved in research. This quest has included the excavation of multiple sites to investigate GCL properties, building lysimeters to collect permeation data and verify the sealing efficiency of Bentofix®, researching the diffusion rate and long-term shear resistance of GCLs, investigating hydraulic conductivity under various confining stresses, gradients and against different liquids, correlating peel strength against internal shear strength, and many other developments.

Innovation:
Since the 1960s, NAUE has used needle-punching as one method of creating materials. The expertise gained during those early years led to the discovery of how to use needle-punching in the manufacture of GCLs. This invention occurred in 1988, and the process revolutionized the field. Rather than just bonding an independent geotextile and a layer of clay, the needle-punching method used here was developed to be specific to GCL manufacture and performing transferred the shear stress from the clay to the highly engineered geotextile. Other innovations from NAUE include being the first to impregnate the topside and the longitudinal overlap areas of the GCL with powdered bentonite, adding a sand ballast layer on top of the GCL for underwater installation, thermally locking the needle-punched fibres for long-term shear strength and much more. Also, NAUE has, from the beginning, manufactured GCLs with scrim-reinforcement for secure handling on site.

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Awards:
In 2008, the International Geosynthetics Society (IGS) honoured NAUE GmbH & Co. KG with the society’s highest award, the IGS Award, for overall excellence. The award recognized NAUE’s numerous manufacturing innovations and contributions to the field of geosynthetic engineering, the most significant of which have involved geosynthetic clay liners. In addition to the manufacturing advances, NAUE’s research and installations around the world have also benefited the entire geosynthetic engineering community. Key developments include self-sealing overlaps in GCL panels, underwater installations with GCLs and sandmats, and landfill capping.
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.