# Sealings for well construction

## Clay sealings
## Cement grouts

GWE pumpenboese SBF-HAGUSTA

# Sealings for well construction

## General

The construction of wells for the purposes of extracting, monitoring or surveying groundwater reservoirs usually involves drilling through cohesive sediments which, in their undisturbed state, represent hydraulic barriers. These sediments separate groundwater reservoirs of differing quality and mineralisation and prevent contaminated waters from influencing deeper aquifers. Therefore, in general, if boreholes are completed as water or monitoring wells, all perforated clay beds must be reconstructed by the installation of suitable sealing products.

As a leading manufacturer and supplier of well construction materials, the GWE Group provides a professional range of highly effective sealing products based on swelling clays and ready-made clay-cement mixtures.

**Sealing clays** vary in shape, swelling capacity, structural stability, inherent density and geophysical detectability. The installation in the borehole is completed by pouring the clay pellets into the well, where they settle down at the hole bottom. Plumb-line checks indicate that the seal has been placed at the correct depth. Limits are set by the depth of the borehole and the annular geometry.

**Pumpable grouts** based on a special clay-sealant cement recipe can also be used. Stable slurries are produced by mixing the grout material with water.

## Requirements

The core requirements for sealants in well construction are:

- Effective seal in finished well, without any leakages between different layers and borehole wall
- Safe for potable water
- Secure and accurate placement
- Detecable by means of geophysical logging

## Clay sealings

High swelling clay products have proven to be particularly successful in the sealing of wells. These products are composed, to a large extent, of the clay mineral *bentonite*.

The principal advantage of bentonite clay sealings over less swelling materials composed of kaolinitic/illitic clays lies in their ability to expand in volume and to create swelling pressure. This compression pushe the seal firmly to the surfaces (casing/borehole wall) which prevents any leakage through its superior sealing properties.

## Place of installation – Well annulus

As a result of the annular geometry, the gravitional force is reduced. The implementation of filler material (e.g. gravel, sands) results in less compaction of the underlying clay seals due to relative low constant vertical loads, which are caused by friction of the fill material along the borehole wall. This is all the more the case in small diameter wells, with the result that previously placed clay seals are not subject to any appreciable compaction.

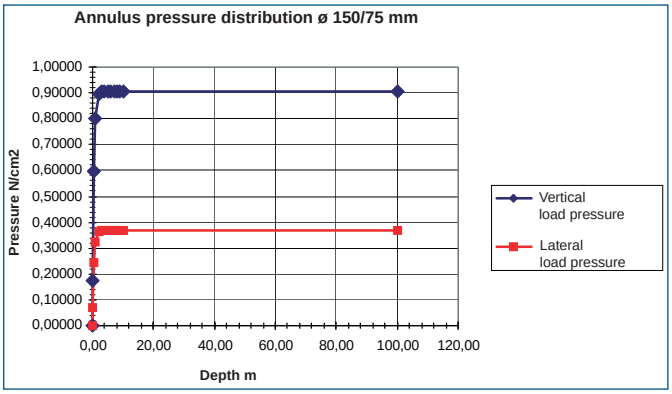



Diagram 1: Load distribution in a gravel-filled well annulus.
Ø hole 150 mm / Ø casing NORIP DN 65

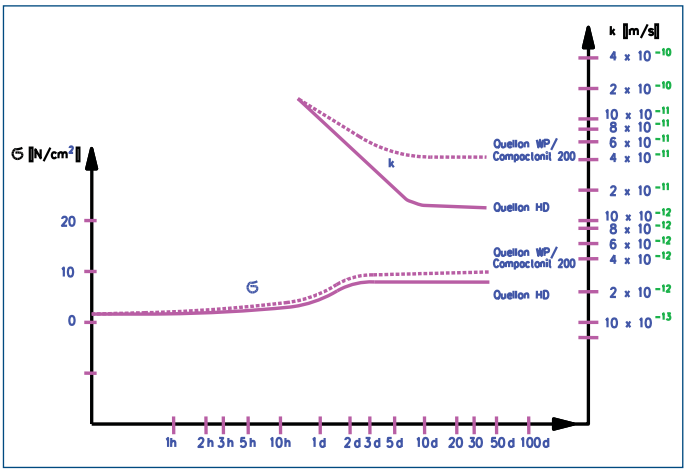
This must be taken into account when determining the test parameters for investigating the effectiveness of clay materials in borehole sealing. To ensure that measurements of the sealing behaviours are taken under realistic conditions, vertical loads of max. 1 N/cm² should be applied in the test cells (Diagram 1). Greater vertical loads would induce an inadmissable compaction of the sample; only if the swelling pressure from the clay sample is higher than 1 N/cm² (Test 1 with constant volume) would this be acceptable.

## Material characteristics

Considering the special placement conditions, two different test set-ups have proven successful in providing comprehensive information on the characteristics of clay sealings when used in well construction:

## Test 1 with constant volume

Describes the case where the water-filled space is completely filled with poured-in clay pellets. Once the pore spaces in the clay filling have been closed through the swelling process, the resulting **swelling pressure** $\sigma$ and the **coefficient of permeability** $k_f$ are measured according to Darcy's law.

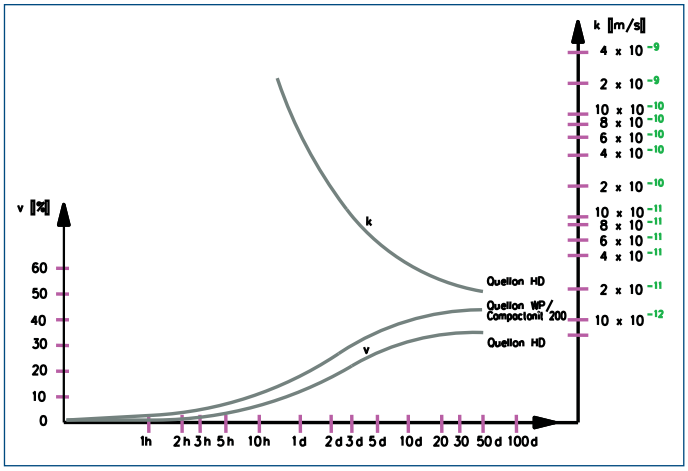



## Test 2 with constant low pressure

This describes the case where, for geometrical reasons, unfilled spaces are present, as it may occur in large reamed boreholes. If a low vertical pressure is applied (1 N/cm²), a measurable **volume expansion V** (depending on swelling capacity) will be observed in the well. At the same time the **coefficient of permeability** $k_f$ can also be determined. (see top right graph)

**Typical values for high swelling clay sealing:**

| | |
|---|---|
| **Swelling pressure σ test 1:** | **up to 10,0 N/cm²** |
| **Volume expansion test 2:** | **20 - 40 %** |
| **Coefficient of permeability $k_f$ test 1 + 2:** | **< $10^{-10}$ m/s** |




## Effectiveness in salt water

The ability of bentonite sealings to expand in volume and create swelling pressure diminishes in mineralised water. Studies investigating sodium chloride waters and SBF Quellon WP at the Institute for Foundation and Soil Mechanics at the Technical University of Braunschweig have observed the following behaviour:

**Test series 1**

- **Activation in tap water**
- **Perfusion with salt water**

If the high swelling clay pellets are first activated in fresh water, the clay seal in relation to sodium chloride water was proven effective to a concentration of 30 g/l.
**Limit 30 g NaCl/l**

**Test series 2**

- **Activation and perfusion with salt wasser**

If Quellon WP is introduced directly into salt water, the material characteristics of the clay seal are stable to a concentration of 5 g NaCl/l. At 10 g/l the coefficient of permeability increases by a power of ten to $10^{-10}$ m/s. Higher salt loads cause a significant decrease in the swelling capacity and the coefficient of permeability rises by several powers of ten.
**Limit 10 g NaCl/l**

## Swelling capacity in fresh and salt water

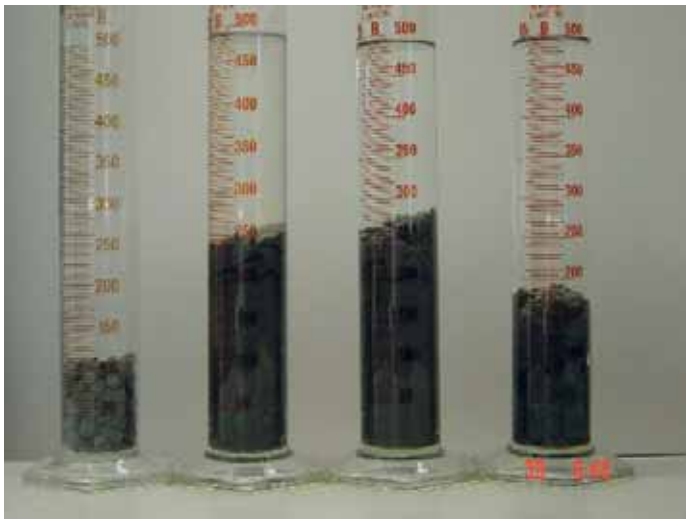
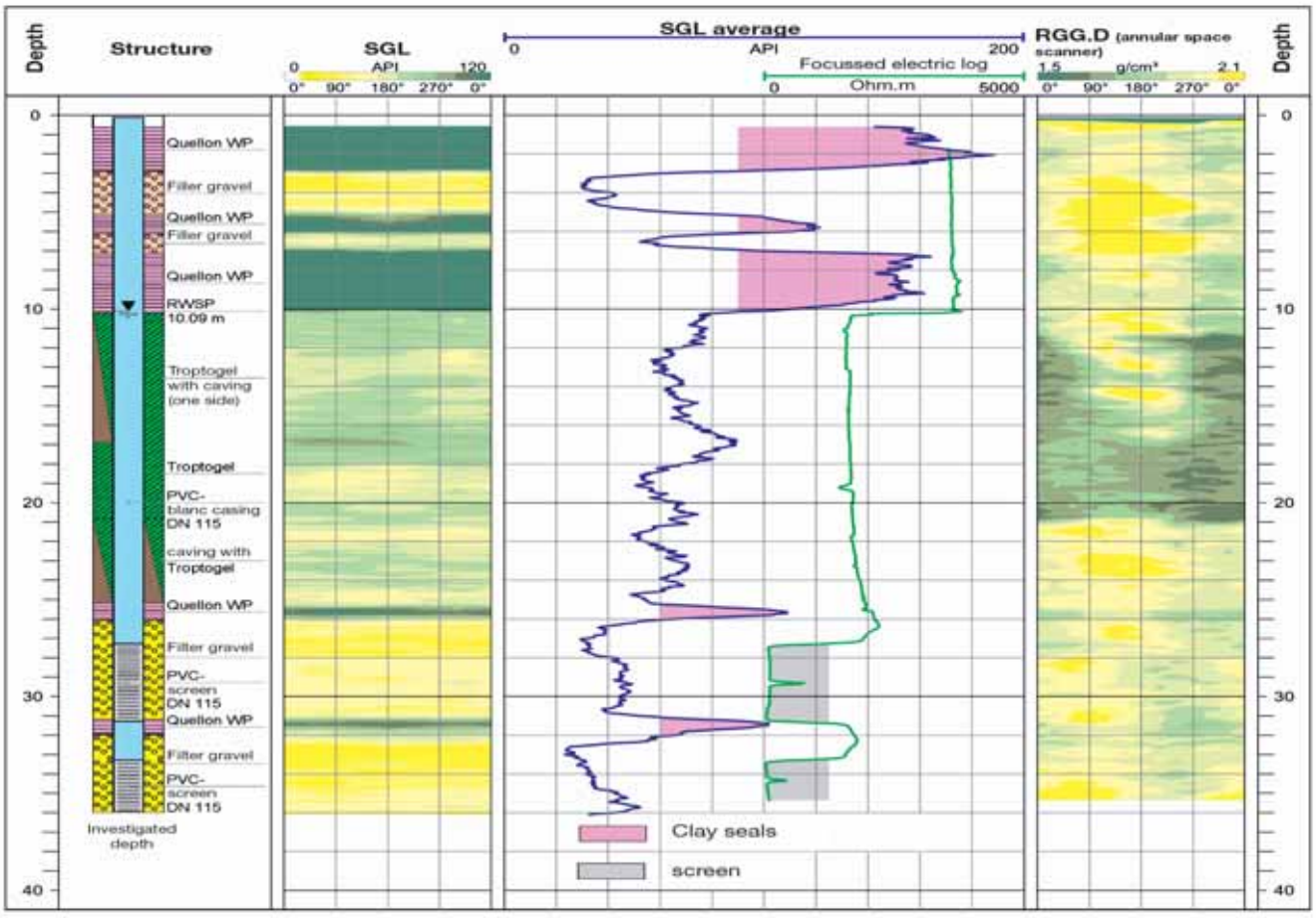


Fig. 1 Quellon HD dry / in deionised water / tap water / - salt water 10 g NaCl/l

Clay materials that demonstrate swelling capacities < 30% when placed freely under water, and hence are smaller than the pore volume of the clay filling, should only be used for well sealing under certain conditions. In such cases there is a possibility that air pockets may remain in the filling, particularly at the boundaries (borehole wall/casing surface) which will then result in increased permeability. Large hydraulic gradients will consequently cause erosion that will, in the end, lead to the total failure the barrier, resulting in the fillers being rearranged above the seal.

It is only possible to achieve effective borehole seals using low swelling clay in holes of at least Ø > 400 mm due to the large vertical loads which result from the pouring process. For reasons previously mentioned, we recommend that only bentonite-type materials are used for smaller borehole/annulus diameters.

## Geophysical detection of annulus backfilling




Source Well Logging: BLM Storkow GmbH

Other characteristics of clay seals include:

- Sinking behaviour / placement reliability
- Shape
- Structural stability
- Geophysical detectability

Vacuum-pressed clay pellets have proven advantages over granulated products in relation to placement reliability and structural stability. Smooth, compact surfaces delay the swelling process when the pellets sink down the borehole, thus reducing the risk of bridges or pile-ups forming along the trajectory.

Thanks to special mineral additives, products with special qualities, such as higher inherent density/sinking speed with magnetic properties and higher intrinsic radiation, are available which ensure reliable detection in well logging (see Diagram BLM Storkow GmbH).

Our R&D Department will be pleased to advise you on a suitable choice of product.

## Cement grouts

In addition to clay products for sealing wells and groundwater monitoring wells ready-made mixtures, like SBF-Troptogel B have also been successfully used in the creation of pumpable suspensions. These consist principally of:

- Hydraulic binder
- Low swelling clay (kaolinite)
- High swelling clay (bentonite)
- Special mineral additives for more advanced applications

Clay cement suspensions can essentially be used for all sealing work in well projects, both for basic well decommissioning and for annular grouting in groundwater monitoring wells. By using tried and tested placement technologies, reliable well seals can be produced at great depths.

Just as is the case for clay products, special mineral mixtures (for example with high natural gamma ray activity) are also available for pumpable grouts.

This improves the material's geophysical detectability. Meaningful geophysical measurements are an important basis for qualitative assessment of remedial work, especially in the case of retrospective annular pressure grouting. Here, we are able to offer you SBF-Troptogel C as a suitable product for this purpose.

Pumpable cement grouts also have advantages in completion of boreholes for the exploitation of geothermal energy. Their free-flowing consistency allows for a complete and secure seal of built-in probe tubes, bends and spacers while at the same time reconstructing perforated hydraulic barriers. Depending on requirements, simple sealant suspensions or filling compounds with high thermal conductivity can also be employed.

## Requirements

Pumpable cement grouts for professional sealing of wells and groundwater monitoring wells should have the following properties:

- Absolute volume consistance
- $k_f$- values < $10^{-10}$ m/s
- Excellent system seal
- No heat generation during setting
- Sedimentation-stable
- High resistance against (or concrete-aggressive waters.)
- Filter stability at permeable barriers
- Geophysically detectable
- Hygenically safe for potable water

## Mixing

High-speed mixers have proven effective in making up cement grouts. These agitate the binder/clay mixture and, if the correct quantity of material is added, produce a colloidal grout (a lump-free, stable suspension). It is important to select the correct capacity of mixer for the particular grouting project at hand so that the required quantity of suspension can be produced in the available time. For colloidal mixing and injection of Howable grout slurries we recommend the use of compact hydraulic driven plants, like the IEC-404H, produced from our sister company MAT (Mischanlagentechnik GmbH).

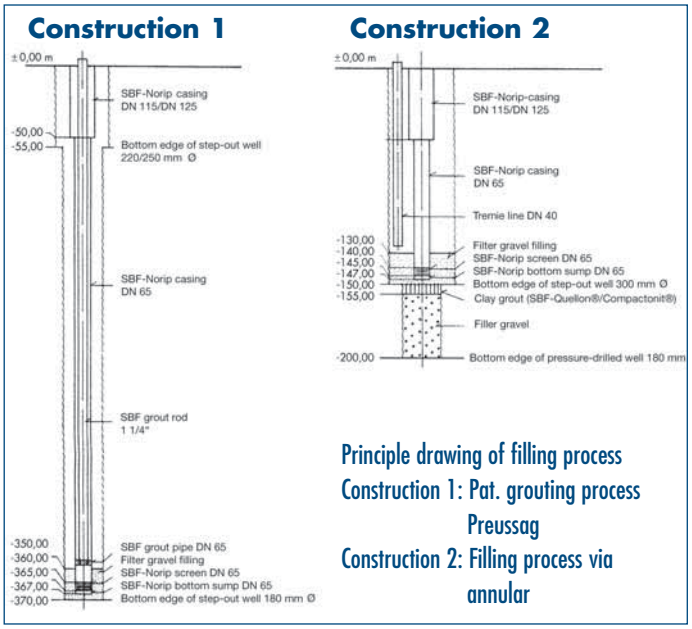
Guidelines relating to suspension characteristics (e.g. Marsh times, density, processing times) must be observed and documented.

## Grouting process

For professional annular seals in deep wells or monitoring wells, it is advisable to use the grouting process developed by Preussag which is registered under patent no. DE 3 84 13 16 C2 (construction version 1).

The SBF-NORIP casing system has been specially designed for use with this method and allows the cement to be grouted into the annulus from the interior of the well. Built into the blank casing section above the screened zone is a cementation valve, through which the suspension is pumped to surface via a pistonpacker. There are numerous advantages to this method in comparison to conventional placement techniques:

- Only small hole diameters required
- Efficient use of material
- Short filling times
- Uniform, homogenous annular backfill
- Seals depths up to 500 m




Principle drawing of filling process
Construction 1: Pat. grouting process Preussag
Construction 2: Filling process via annular

A detailed process description is available on request.

In construction version 2, the grout suspension can also be applied directly into the annular space using the conventional tremie method. The depth for which this method may be used is limited. On oneside, the frictional resistances increase dramatically when the tremie line is installed, and on the other side, the large borehole diameters that are required pose a considerable costfactor.

The cement job is completed when the slurry which leaves the borehole shows identical properties like suspension which is pumped into the well.

## Overview of clay sealing products – Recommended applications

| | Quellon HD | Mikolit 300<br>300 M | Quellon WP | Compactonit<br>10/200 | Compactonit<br>10/80 | Compactonit<br>TT 20 | Mikolit 00 |
|---|---|---|---|---|---|---|---|
| **Product characteristics** | Pellets with high swelling capacity, and increased density with magnetic behaviours | Pellets with moderate swelling capacity/300M has magnetic behaviours | Pellets with high swelling and gamma ray activity | Pellets with high swelling capacity | Pellets with moderate swelling capacity | Pellets with low swelling capacity | Pellets with low swelling capacity |
| **Sealing behaviours** | ++ | ++ | ++ | ++ | ++ | **0** | **0** |
| **Sinking behaviours during installation** | ++ | + | + | + | + | + | + |
| **Geophysical detectability** | ++ | + | ++ | **0** | **0** | **0** | **0** |
| **Recommended applications** | in wells > 100 m drilled with rotary mud techniques / seal is detectable with magnetic logging | in cased wells / placement of 300M is detectable with magnetic logging | in wells drilled with rotary mud techniques / seal is detectable with gamma ray logging | in wells drilled with rotary mud techniques | in cased wells | in large diameter wells > 400 mm | in large diameter wells > 400 mm |
| **Assessment key: ++ very good / + good / 0 moderate** | | | | | | | |

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# Products for well construction

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