Slurries for Cut-Off Walls

Based on Bentonite and Cement

SÜD-CHEMIE
Creating Performance Technology

General Information and Basics

The Keys to Your Success

- **Take into account the required specifications of permeability, strength and deformability**
- **Control the slurry during mixing and while excavating**

Süd-Chemie Bentonites and Additives recommended for Cut Off Walls

Excavation under mud, and filling with plastic mortar or concrete

Drilling fluid Products for drilling fluids:		**Grouts & Mortars** Bentonites for making plastic mortars and concretes:	
BENTONIL® CF:	45 to 80 kg *	BENTONIL® CF:	20 to 70 kg **
BENTONIL® C2/GTC4:	35 to 65 kg *	CALCIGEL:	100 to 200 kg **
Additive:			
SC MUD:	0.5 to 3 kg *		
(in low permeability grounds)			
*) based on 1 m³ of mud		**) based on 1 m³ of concrete	

Excavation using self hardening mixture

BENTONIL® CV 15:	20 to 35 kg/m³ of slurry	(Highly cement stable sodium bentonite)
BENTONIL® CF:	40 to 60 kg/m³ of slurry	(Quality sodium bentonite)
BENTOCRYL:	0.5 to 2 kg/m³ of slurry	(Fluidifier, water retaining agent)
SC 6FF:	0.5 to 4 kg/m³ of slurry	(Set retarder)

Basics on Cut-Off Walls

In geo-technical works, cut off walls correspond to linear structures to reduce, prevent or divert underground water circulations.

Examples:

- Landfill confinements
- Protection of construction below groundwater table.
- Protection of compartments of large excavations
- Waterproofing of dikes or dams

Different names are commonly used according to their size, the excavating techniques, the type of material or any additional waterproofing device such as PEHD sheet or sheet piles. The table below presents the main techniques used for the realization of cut off walls:

Conventional name	Digging method	Drilling fluid	Main component of the cut off wall	Additional device
Plastic cut off	• Back hoe (up to 15m depth) • Clam shell	Self hardening mixture (Water +Bentonite + Cement)		Possibility to insert • Geomembrane • Sheet pile
Vib wall	• Vibrated steel beam	The stability of the boring is insured by the beam itself and by the slurry during the pulling out.	Bentonite-Cement-slurry and additional fillers if required.	
Plastic concrete cut off	• Back hoe • Clam shell • Rotary drilling	• Bentonite based mud • Polymer based mud	• Plastic concrete • Plastic mortar	

Main Characteristics of the Cut Off Material

Permeability

The main function of a cut off wall is to reach a designed impermeability.

- The "global" permeability is measured in situ by piezometric levels or pumping tests.
- The "intrinsic" permeability is measured by a system incorporated into the wall (Results of such a measure do not integrate possible local defaults in the wall).
- The permeability may also be measured on samples taken either in the trench or at the plant.

The results of these tests allow to calculate a coefficient of permeability, traditionally represented with the letter "k" and expressed in m/s.

The conditions of contracts generally foresee target values for the coefficient of permeability associated with the controlling method.

Most common requirements – Permeability "k" on samples, taken in situ before hardening.

- Hydraulic works: **$1x10^{-7}$ to $1x10^{-9}$ m/s**
- Confinement of polluted zones: **$1x10^{-8}$ to $1x10^{-10}$ m/s**

"k" on a sample depends on several parameters such as:

- Dosage of dry material
- Curing time
- Drilled material additions
- In situ loss of water

Mechanical Properties

A cut off wall is designed to cope with expected ground movements, without disrupting and fissuring. To do so, the formulation should present an elastic modulus closed to the insitu ground. This requirement is linked to the Unconfined Compressive Strength (UCS), which generally has to be lower than 1 N/mm^2.

For certain applications, such as polluted zones, long term stability is required:

The formulation has to take in consideration an eventual external chemical reaction as well as physical erosion.

An appropriate selection of constituents (water, bentonite, hydraulic binder, aggregates, admixtures) allows to ensure the final in situ performances.

Cut-Off Wall Designs

The mix design for cut off walls belongs to the designer.

However, bentonites are common to all these types of products. The Süd-Chemie Group offers their site proven products and know how to customers.

Bentonite-Cement slurry

Such slurry is used:

- For cut off walls excavated with clamshells or back-hoe, two functions:
  - Drilling fluid during excavation
  - Waterproof wall once hardened.
- For vib walls

In both cases, the slurry has to be a fluid with no separation between solid and liquid phases.

The addition of BENTONIL® to the slurry is the guarantee of such a behavior.

The following will help to determine a formulation.

- Choose an appropriate quality of hydraulic binder. (Generally CEM III A, B, C).
- According to the targeted permeability, deduct from the right graphs the necessary UCS.
- Choose an appropriate grade of bentonite to stabilize the mix and reach the required viscosity.

Süd-Chemie proposes a wide range of bentonites, in particular two grades, BENTONIL® CV15 and BENTONIL® CF. Other grades are available for special slurries.

If filler has to be added, it is necessary to adapt the bentonite content.

Calculate the composition by considering the following data:

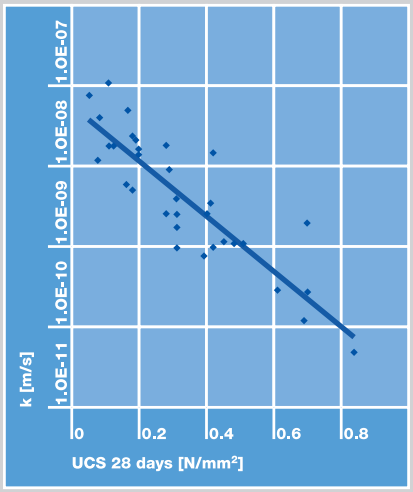
e.g. for cement:
2,9 kg/l for CEM III C
→100 kg of cement has a volume of: 100/2,9 = 34 liters

e.g. for bentonite:
2,3 kg/l
→50 kg of bentonite has a volume of: 50/2,3 = 22 liters

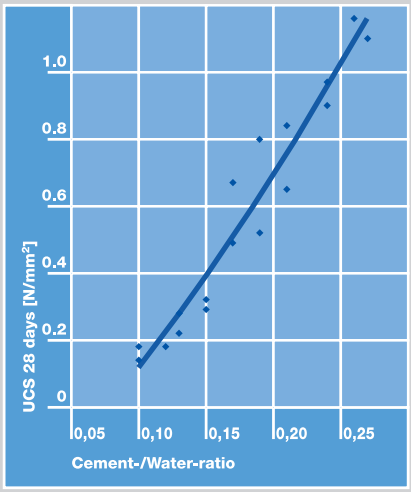
Test the composition and adjust the performance by adapting the dosage of bentonite. Avoid modifying the Cement/Water ratio which actually affects the final UCS and the permeability.

Additives are sometimes necessary to face special conditions such as, by example, the insert of PEHD geo-membrane in the slurry, which needs an extended workability, or the excavation through a sandy soil promoting the dewatering of the slurry. Retarder and water loss reducer may largely help the realization of the cut off wall.

k = f (UCS)



UCS = f (C/W-ratio)



Quality	Use	Indicative range of dosage, for stable slurries containing 100 to 200 kg/m³ of cement.
BENTONIL® CV 15	Cement stable sodium bentonite	20 to 35 kg/m³
BENTONIL® CF	Quality sodium bentonite	40 to 60 kg/m³
CALCIGEL	Calcium bentonite for high solid content slurries	100 to 200 kg/m³

Süd-Chemie proposes two additives to overcome these difficulties:

Main function	Süd-Chemie Additive recommended	Indicative range of dosage, (for mixes containing 100 to 200 kg of cement/m³)
Retarder	SC 6FF	0.5 to 3 kg/m³ of slurry
Water loss reducer	BENTOCRYL (to be introduced in the bentonite mud **before the addition of cement)**	0.5 to 2 kg/m³ of slurry
Thinner	BENTOCRYL (to be introduced in the final slurry)	0.5 to 2 kg/m³ of slurry

Plastic mortar and concrete

Concrete and plastic mortar distinguish themselves from bentonite cement slurry by the existence of a granular skeleton, generally constituted with sand and gravels. Their implementation requires the preliminary excavation of a trench under a drilling fluid.

Mortar or plastic concrete are generally used, rather than the bentonite/cement slurry, when the cut off wall risks to be strongly or quickly submitted to mechanical constraint.

The determination of the composition has to take into account, as for slurry, the requirements for permeability, deformability and processing.

The following table shows usual compositions.

For 1000 liters of mortar or concrete:

Plastic mortar	Water: . . . . . 400 to 800 liters Sodium or calcium bentonite: . . . . . 20 to 150 kg Hydraulic binder (CEM III generally) . . . . . 75 to 300 kg Aggregates (Sand to 5 mm) . . . . . 500 to 1000 kg
Plastic concrete	Water: . . . . . 350 to 450 liters Sodium or calcium bentonite: . . . . . 20 to 100 kg Hydraulic binder (CEM III generally) . . . . . 75 to 200 kg Aggregates (Sand and Gravels up to 30 mm): . . . . . 1200 to 1500 kg

Süd-Chemie recommended Bentonites:

Quality	Use	Indicative range of dosage for plastic concrete and mortars
BENTONIL® CF	Quality Sodium bentonite	20 to 50 kg/m³
CALCIGEL	Calcium bentonite	100 to 200 kg/m³

Mixing and Control of Plastic Mortars and Concretes

Mixing

Bentonite Cement Slurries:

- Mixing of a master mud (bentonite and water) preferably using a high shear mixer
- Hydration during at least 4 hours, preferably 24 hours, in order to obtain the most economical concentration of bentonite.
- Addition of cement either in powder form or under the form of a Water/Cement slurry.
- Admixture according table on previous page.

Concrete, the three possibilities:

1. Mixing and hydration of a master mud

and then …

Mixing (dry agregates + cement) with that mud in a concrete mixer.

2. Mixing a cement/bentonite slurry

and then …

Mixing dry agregates (sand and gravels) with that slurry in a concrete mixer

3. Mixing directly all ingredients together in a concrete mixer.

Control

One may use the table below to target usefully the controls:

First of all, it is necessary to calculate the theoretical specific gravity of the mixture according to the formula given below to verify the exactness of the dosage, and to make sure of the respect for the procedures of manufacture.

$$\text{Theoret. Density } \rho_{theor}\ [t/m^3] = \frac{\sum \text{Weight of all Components } [t]}{\sum \text{Volume of all Components } [m^3]}$$

Characteristic	Apparatus	Interpretation and corrective action
Specific gravity (SG)	Mud balance	If SG measured ≠ SG theoretical: Try to identify the element(s) in excess or in deficit by measuring after addition of each component.
Stability	Graduated cylinder	If emerging water is in excess, for example > 5% within 2h: Increase the concentration of bentonite.
Viscosity	Marsh Funnel	As a general rule, increase the amount of bentonite and its hydration time to increase viscosity. Viscosity nearby 40 Marsh sec. are generally satisfactory.
Bleeding under pressure	API Filter press	This measure is rarely contractual. One can decrease the filtrate to prevent premature thickening of the slurry during excavation by introducing BENTOCRYL.

Control of Concrete

The concrete may be immediately controlled concerning its workability by the Abrams Cone Test.

Slump test results higher than 25 cm or segregation of agregates generally results from an excess of water and/or a lack of bentonite. In that case, one can verify the single weights or the weighing devices.

Consistency		Flow Table Test (DIN 1048-1)	Slump Test (ABRAMS)
stiff	**KS**	not suitable	not suitable
plastic	**KP**	300 bis 400 mm	10 – 70 mm
semifluid	**KW**	410 bis 500 mm	80 – 150 mm
fluid	**KF**	> 500 mm	> 150 mm

Reference Documents

If necessary, refer to the following standards or informative documents:

- European Standard EN 1538, Geotechnical Works: to Diaphragm Walls
- Institution of Civil Engineers (U.K.), Building Research Establishment: Specifications for the construction of slurry trench cut off walls. (Thomas Telford, 1999)
- Bulletin 51 of CIGB (1985) “Filling materials for watertight cut off walls”
- DIN Standard 4126, Germany: Diaphragm Walls (Part 100)

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