

DIAPHRAGM WALLS, CUT-OFF WALLS AND SLURRY WALLS



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Diaphragm Walls

Diaphragm walls are concrete or reinforced concrete walls constructed in slurry-supported, open trenches below existing ground. Concrete is placed using the Tremie installation method or by installing pre-cast concrete panels (known as a pre-cast diaphragm wall). Diaphragm walls can be constructed to depths of 100 meters and to widths of 0.45 to 1.50 meters.

Diaphragm wall construction methods are relatively quiet and cause little or no vibration. Therefore, they are especially suitable for civil engineering projects in densely-populated inner city areas.

Due to their ability to keep deformation low and provide low water permeability, diaphragm walls are also used to retain excavation pits in the direct vicinity of existing structures.

If there is a deep excavation pit at the edge of an existing structure and groundwater is present, diaphragm walls are often used as the most technically and economically favorable option. They can be used for temporary support or as load-bearing elements of the final building. Diaphragm walls can be combined with any anchor and bracing system.

Diaphragm wall panels are also used in deep, load-bearing soil layers as foundation elements to carry concentrated structural load in the same way as large drilled piles do. These foundation elements are known as "Barrettes". 1 Diaphragm wall excavation

Excavation pit retained by tied back diaphragm wall and partially braced by cast-in-place building floor slab.

Excavation pit retained by diaphragm wall and bracing



If diaphragm are socketed into impermeable soil layers of sufficient thickness or if they are combined with seal slabs (grout injection or tremie concrete slabs) almost waterproof excavation pits are created. After reducing the initial groundwater level within the excavation, only small amounts of residual water will penetrate.

Diaphragm Wall construction using grab excavation and removable Stop-End Pipes

- Preliminary excavation to 1.0 1.5 meters below ground elevation to install guide walls
- Prior to diaphragm wall excavation, cast-in-place or pre-cast **concrete guide walls** are placed. These braced guide walls stabilize the soil in the upper diaphragm level and provide a stable guide-way for the grab. In addition, they also support the diaphragm wall reinforcement and provide sufficient bearing for the hydraulic jacking system to remove the Stop-End Pipes. The space between both guide walls serves as a storage space for the stabilizing fluid.
- Lamella excavation Using hydraulic grabs with clam shell sizes of 2.8, 3.4 or 4.2 meters, single diaphragm panels can be excavated down to tip elevation. To avoid collapsing ground, trixotropic stabilizing fluids (Bentonite slurry = clay/water slurry) are pumped into the excavated panel. Depending on ground condition and geotechnical design, several single panels can be combined to one large lamella. Hard soil, rock or obstructions can be removed using chisels in addition.

1	Diaphragm wall excavation using hydraulic cutter disk and grab excavation

2 Guide wall

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3 Diaphragm wall chisel



- Stop End Pipe Installation. To separate the single concreting phases, stop-end pipes are installed at both panel fronts. These have the same diameter as the panel's wall thickness and are removed after initial concrete setting. The remaining semicircular joint provides a very good interlock between the individual concrete panels.
- Slurry Refreshing.
- Placing of Rebar Cage
- **Concrete Placing by Tremie Method.** Simultaneously with placing concrete, slurry is pumped from the panel to be refreshed and re-used in the next panel excavation. Since the slurry is replaced by concrete, this method is called "Double-Phase Method".
- Removal of Stop -End Pipes after concrete setting using hydraulic pipe extractors.

Diaphragm Wall Joint Design

- There are three (3) types of joint design used for diaphragm walls constructed by the grab excavation method
- Steel stop-end pipes, which are removed before the concrete has set completely (as mentioned before). Concrete seeped around the stop-end pipes can be safely removed by the use of chisels.
- Pre-cast reinforced concrete panels, which remain in the panels as permanent stop-ends (high weight, twice the number of joints). Seeping concrete can not be removed safely.
- Steel joint element. This flat steel panel element contains one or two elastic joint tapes, which remain in the setting concrete after the joint element has been removed. Removal of the element can only take place after the adjacent panel was completely excavated.

1	Diaphragm wall reinforcing cage with block-out

Stop-end pipe with hydraulic pipe extractors

3 Flat steel joint element

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If diaphragm walls are constructed using the hydro-cutter technique, stop- end pipes do not need to be installed. After the primary panel set sufficiently, the secondary panel excavation will slightly cut into the fresh concrete to ensure a tight overlap during the concrete placement.

Excavation

Double rope grabs as well as grabs guided by telescoping Kelly bars are commonly used for excavation in soils. Hydro-cutters can be employed for rock as well as soft soil excavations. They continuously cut into one panel by sucking the soil-bentonite slurry at the cutter head while replacing it with fresh bentonite at the panel's top.

Construction sequence

Two different construction techniques, the alternating method (or Pilgrim) and the continuous method can be distinguished for excavation. During the alternating method, only primary panels will be placed leaving out the following secondary panels. Following the first primary panels, gaps will be closed by the adjacent secondary panels. Primary and secondary panels will have different sizes due to the use of stop end pipes.

During the continuous excavation method (Endless Panel), all the panels are excavated in one continuous process. Therefore they all have the same size. 1 Concrete placement at a diaphragm wall panel

2 Two phase construction using the alternating method

3 Hydro-cutter head



Cut-off Walls

Cut-off walls are vertical slurry walls with very low water permeability to minimize the ground water flow.

In contrast to the known load-bearing, impermeable retaining walls such as:

- Concrete secant pile walls
- Reinforced two-phase diaphragm walls
- Sheet pile walls

are cut-off walls mostly without any load-bearing function.

The following cut-off wall types can be distinguished:

- Cut-off walls constructed using diaphragm wall techniques
- Secant pile walls from concrete of slurry
- Thin slurry walls
- Injection walls
- Jet-Grouting walls
- Freezing walls

They can be used as:

- Cut-off walls underneath water dams with core seals in areas of permeable soils to socket into lower impermeable layers to prevent undercurrent
- Cut-off walls for "watertight" excavation pits outside of the load-bearing retaining structure to minimize water inflow into the pit
- Cut-off walls to enclose brown fields and contaminated areas with penetration into lower impermeable soil layers

 Cut-off wall applications
Cut-off wall Rostock, Warnowquerung
Cut-off wall site set up

Cut-off walls constructed using diaphragm wall techniques

If slurry walls are intended to act as cut-off walls without any load bearing function, a mixture of water, bentonite, cement and maybe filler can be used.

This slurry remains in the excavated panel and hydrates. It also remains as a plastic seal, so that the wall can follow small displacements in the soil without cracking. Since the slurry remains in the panel, this is called the Single-Phase technique.

After completion of the guide wall, the excavation proceeds with:

- One long-boom excavator (max. depth of 10m)
- Or by the use of slurry wall grabs or hydro-cutters

Using the single-phase technique, panel depth is limited due to the relatively short time from placing and setting of the suspension.

In deeper panels, the Two-Phase technique is used to construct a slurry wall. Construction is similar to the cast in-situ diaphragm wall installation. After completion of the panel's excavation, the actual sealant slurry will replace the stabilizing bentonite fluid. This sealant has to be placed using the slurry-displacement or tremie method and needs to have a

0.75 to/m³ higher unit weight than the bentonite slurry to replace it.

To improve permeability and contaminant resistance, combination cut-off walls can be installed using the Single-Phase system. Sheet piles or plastic liner sheets can be installed within a bentonite-cement-slurry wall. 2 Installation of plastic liner sheet, combination cut-off Wall, Central Waste Dump, Huenxe

Slurry wall excavation, DW

Rostock, Warnowquerung

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Thin Slurry Walls

Thin slurry walls also can act as vertical cut-off walls to retain horizontal groundwater flow.

In contrast to cut-off walls constructed using the diaphragm wall technique (replacing the soil by slurry sealant), thin slurry walls displace the soils using a vibrated steel profile. During the extraction process, sealants are injected into the created cavities.

Drivable soils, such as sands and gravels, are required for this installation method. The created slurry wall thickness depends on the shape of the steel profile used and the soil conditions. Thickness varies between 5 cm in sands and 20 cm in gravel. In combination with high-pressure jet grouting, wall thickness of up to 30 cm can be achieved.

A continuous wall is created by overlapping single penetration elements installed one after another by the vibrated steel profile. A guide plate attached at the beam's flange is running down the already completed web of the previous panel. This ensures the correct overlap to the previous panel. 1 Construction of a vibrated thin slurry wall, Doemitz

2 Vibro-beam

3 Thin vibro slurry wall