KELLER

Diaphragm walls/barrettes

Stabilisation for heavy foundations and deep excavations

Geotechnical solutions for the construction industry

For large construction projects and deep excavations

Diaphragm Walls (D-walls) are concrete or reinforced concrete walls constructed in slurry supported open trenches using mechanical/ hydraulic clamshell grabs or hydromill cutters to form a continuous cut-off, retaining and/or structural wall. They can be used to carry vertical and horizontal loads as well as to minimise or cut off water flow.

D-walls and cut-off walls can be constructed to a depth of approx. 150m and a wall thickness of 40cm to 200cm.

D-walls are typically used as retaining walls for deep excavations while cut-off walls are used as a water barrier, in dams for example.

They are excavated using rope grabs, hydraulic grabs or cutter/hydro-mills attached to a base machine. Grab units are recommended for use in cohesive and non-cohesive soils (not in rock) down to a depth of approx. 40m. If rock is encountered a chisel should be used to break the rock before the grab can excavate the material. Cutter/hydro-mills are suitable in non-cohesive soils and rock in depths of approx-imately 40–150m. Using a cutter in some cohesive soils may require the bentonite slurry to be recycled/re-generated.

Bentonite or polymer slurry support the side walls of open trenches during excavation and installation of rebar cages until they are refilled with concrete.

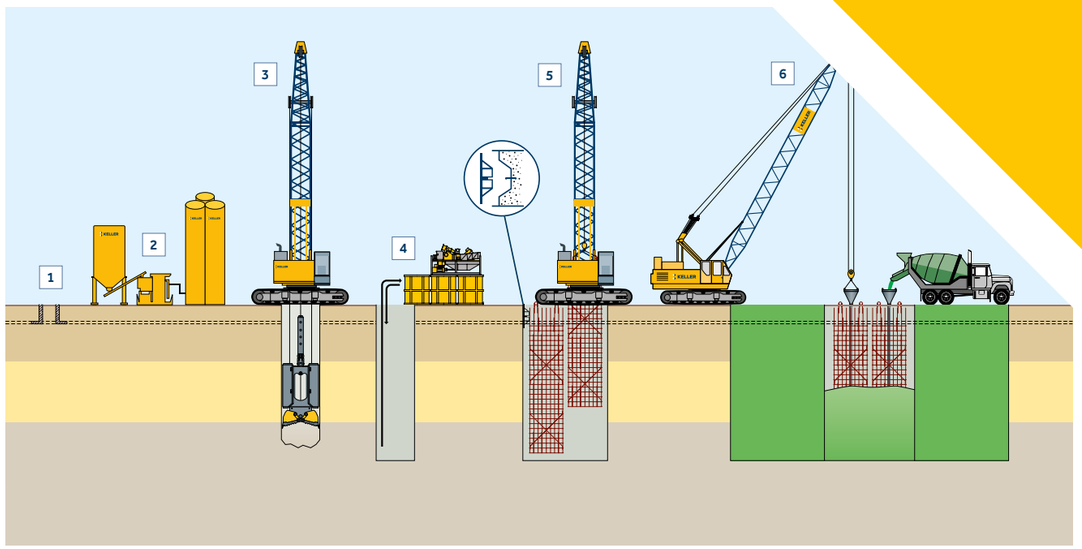
D-walls can be constructed as self-supporting walls (requiring a sufficient amount of reinforcement), or supported by a single or multiple layers of bracing or anchors.

Advantages of diaphragm walls and cut-off walls

- Can be constructed in any geology
- Moderate noise only, no vibration during construction (as long as no chisel is used)
- A very economical solution, since the same element can be used as a retaining wall, a cut-off wall, and as a deep foundation element
- Construction is possible close to adjacent buildings
- Low environmental impact
- Able to bear very high vertical and horizontal loads and bending moments
- Can be used as a top-down method in order to optimise work sequence for inner-city construction
- High-performance rate and fast execution

Applications

- Create barriers to groundwater flow
- Retaining wall for deep excavation



1 Construction of guide walls

Guide walls are built of reinforced concrete to:

- Ensure the correct location of d-walls (in x and y-direction)
- Provide guidance for vertical excavation (z-direction)
- Provide a reservoir for supporting slurry and ensure the stability of the open trench
- Stabilise the working platform, allowing operation of heavy d-wall equipment
- Carry loads from reinforcement cages during installation
- Support the tremi string during installation of concrete
- Carry loads from the extraction system when recoverable joints are used

2 Preparation of slurry

Open trenches of diaphragm walls and cut-off walls need to be stabilised during excavation, installation of rebar cages and casting concrete. This is done by using slurry until the concrete is poured into the trench. If trenches are excavated using a trench cutter the slurry is also used to transport the loosened material out of the trench.

Both bentonite and polymer slurry can be used as a stabilising fluid. Bentonite slurry is suitable for both grab excavated and cutter excavated trenches, while polymer slurry can only be used to grab excavated trenches. For both slurries, the slurry level inside the trench must be maintained above the water level (groundwater) outside the trench at all times, to ensure hydrostatic over-pressure.

3 Excavation of diaphragm-wall panel

Diaphragm walls and cut-off walls consist of several panels. Panels are separated into either primary and secondary panels (grab and cutter excavated) or into starter, follower and end panels (grab excavated only). The design length of panels can vary from 2.80m (single panel) up to 7.2m (panel consisting of three ‘bites’) but can be increased to up to 10m in specific conditions.

When using a grab, the excavation is performed in steps. Every 50cm (approximately) the grab has to go in and out of the trench, getting increasingly deeper as the trench is excavated. A cutter allows continuous operation as the loosened soil is transported out of the trench by the stabilising fluid towards a de-sanding unit. The regenerated slurry is pumped back into the trench. The cutter unit doesn’t have to interrupt the excavation unless teeth need to be changed because of wear and tear or if the geology is changing.

4 Recycling/regeneration of bentonite slurry

If bentonite slurry is used to stabilise the open trench it will be enriched with soil particles through the excavation process. For quality reasons, the slurry needs to be exchanged or cleaned/regenerated before installation of reinforcement cages and pouring concrete.

Polymer slurry can combine fine and suspended particles into larger ones. These are then removed from the trench during the excavation process.

5 Installation of stop end elements and reinforcement cages

The joints between grab excavated panels are considered to be 'cold joints' and so require extra measures to ensure their water tightness. There are a variety of stop end element systems that can be used:

- Stop end pipes at both ends of the panels increase the seepage path. They are installed before installation of rebar cages and are loosened after curing starts.
- Stop end sheet piles with rubber sealing strips at both ends of the panel. They are installed before installation of rebar cages and removed during excavation of the adjacent panel.
- Pre-cast concrete stop end elements equipped with rubber sealing strips at both ends of the panel. They are installed before rebar cages and will become part of the final d-wall.

The reinforcement of a single panel consists of a reinforcement cage for short panels (2.80m length) or several cages (longer panels). The space between reinforcement bars must be at least three times the diameter of the largest aggregate to ensure the necessary flow of concrete during reinforcement.

For deep panels, the reinforcement cage may consist of several cage elements connected by welding, couplers, clamps or wire in line with the applicable standard and with the client’s approval.

A sufficient number of spacers are fixed to the reinforcement cages to ensure the required concrete cover.

Depending on test requirements pipes for a sonic cross-hole test, an inclinometer or extensometer, or similar might be attached to the rebar cages and installed into the panel.

If necessary, connectors can be attached to the rebar cages allowing the connection of other construction elements at a later stage.

The reinforcement cages are positioned using cranes and hung onto the guide wall before casting concrete.

6 Concreting of panels

The panels are concreted immediately after the reinforcement cages are installed using tremi pipes installed into the trench. Depending on the length of the panel, one or more tremi pipes are installed, each one in any reinforcement cage. Before pouring concrete, a device to separate the concrete from the slurry is put into the tremi pipe on top of the slurry. Concreting can start as soon as a sufficient number of concrete mixer trucks are on site to ensure casting concrete up to a level of at least three meters. Concreting is done without interruption. The displaced slurry is pumped into a special storage facility where it is regenerated for further use. During concreting the tremi pipe must be inserted at least three metres into the fresh concrete and not removed until the concrete reaches the final cut-off level of the d-wall.

After the concrete cures, it can be chipped away to the final cut-off level.

Excavation

Preparing the joint elements

Reinforcement cage

Concreting

Project example

Enlargement of the trade fair center Strasbourg, France

One of France's most important trade fair and exhibition centers is located near the European Parliament in Strasbourg. Keller was commissioned to secure the excavation pit for its expansion.

Diaphragm walls with a grouted slab and piles were chosen as the River Ill surrounds the area resulting in a very high ground water level.

The Warsaw Hub
Warsaw, Poland

Six underground levels were required under three 80m towers, in Warsaw's central business district. These were constructed using a top-down method with 32m-deep, 100cm d-walls and another 20m of jet grouting wall (to underpin the d-wall). Raft and slabs were supported by 190 barrettes (up to 38m). All optimisation and design work including the pile-raft foundation and d-wall PLAXIS analysis, were done by Keller Poland.

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