

TECHNOLOGY


Diaphragm walls

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Drilling and Foundation Equipment

Diaphragm walls are one of the most important technologies of special foundation engineering. A diaphragm wall is constructed using a trench excavated in ground and supported by a mud fluids (typically bentonite or polimer mud) until the mud is replaced by concrete, after the steel cage installation.

Walls generally range from 600 to 1500 mm thickness, in wide between 2000 and 3500 mm and can be excavated to depths of 60m or more.





Can be installed in all soil conditions
and through rock

Used in high water table conditions
without excessive dewatering

Low costs and speed of construction for
temporary and permanent soil support

C-70

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Technology

Diaphragm walls are rectangular-section excavations with a complete ground asportation that is made in situ. The result is an underground concrete wall.

They are essentially retention walls, which are constructed for instance at wharfs. A rectangular-section tool is generally used to remove the soil, thus creating a rectangular excavation. Furthermore the rectangles making up the wall must be interlocked to ensure structural endurance and water tightness.

The diaphragm wall panel construction entails three steps: the construction of guide wall, the panel excavation (*demolition – removal - stabilization*), and the construction phase (*reinforcing cage – casting – curing*).

To build a continuous diaphragm wall the primary panels are firstly constructed and spaced at a distance slightly larger than the panel width. The secondary panels are built in the empty spaces between the primary ones.



Construction stages



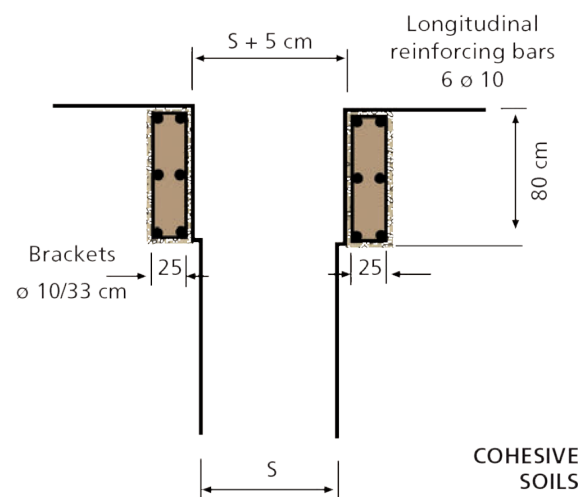
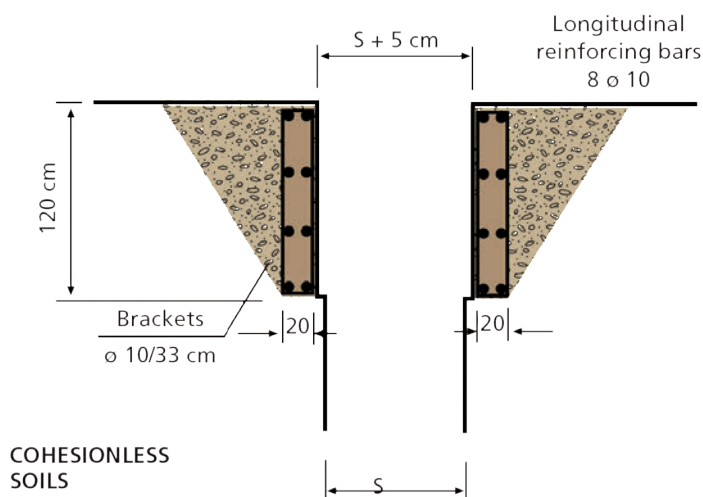
Diaphragm wall construction requires that a proper sequence of works is followed. A rectangular-section tool is generally used to remove the soil, thus creating a rectangular excavation.

The main digging tool for panels is the grab, which shall have the same size of the component it shall dig. Holes are stabilized with bentonite slurry. Concreting is performed using the tremie technique as for cast-in-place piles.

Guide wall installation

Prior to diaphragm wall excavation is necessary to construct two temporary parallel concrete beams to guide the excavation tool and to stabilize the upper.

Guide walls are cast-in-place or pre-cast lightly reinforced concrete elements. Guide walls maintain the horizontal alignment and wall continuity of a diaphragm wall while are adopted to avoid superficial soil collapse, to mark the panels position and to support the steel cages during the concrete aging. This temporary support is important as the slurry levels vary during construction and the wall tends to be unstable. Equally important, guide walls help guide the diaphragm wall grabs vertically and aid in the positioning of the final structure. The dimensions and shape of the guide walls may change depending on the nature of the surface soil. As it happens in bored piles, the bentonite slurry inside the excavation hole shall always be kept some meters above the height of the water table. In some special cases where the water table is very close to the surface and the soil has poor mechanical properties, the guide walls may be built on a higher height compared to the ground plane to preserve the above mentioned height difference.



Construction stages

Panel excavation

The single panel is excavated downward using grab until reaching the required level. The trench is prevented from collapsing during excavation, reinforcing and casting by the use of supporting bentonite slurry.

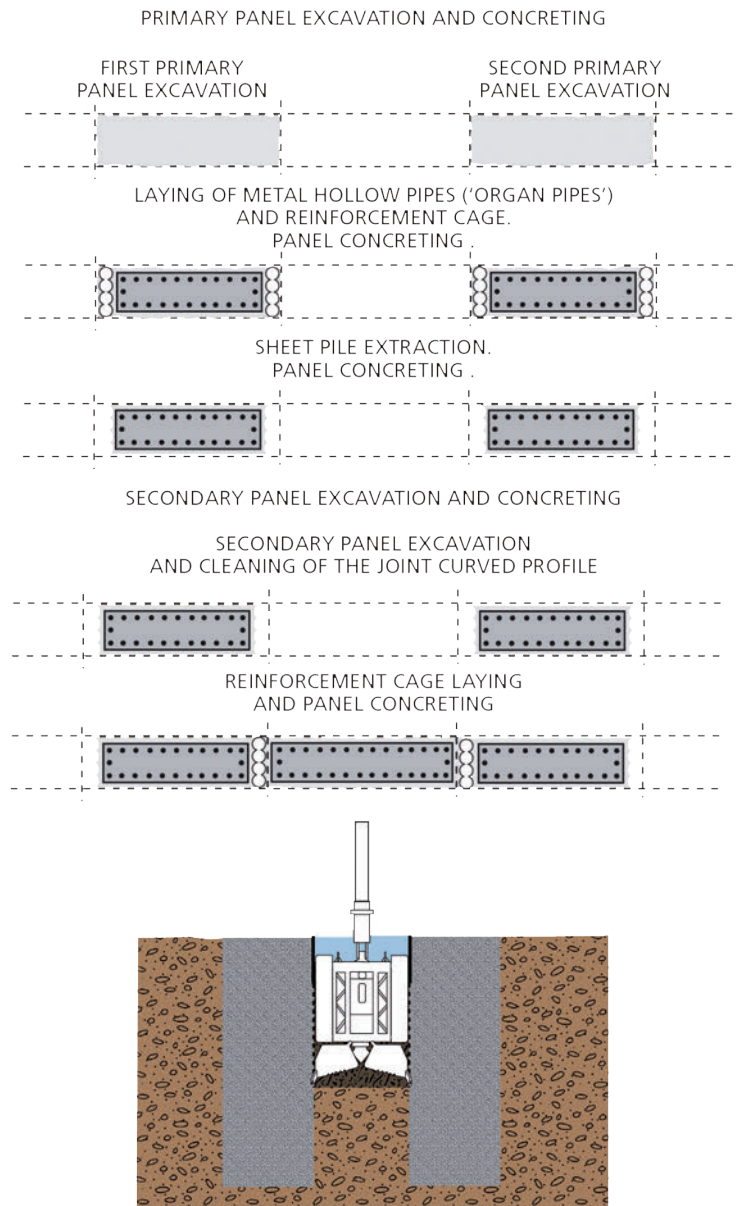
The slurry forms a thick deposit (the cake) on the walls of the trench which balances the inward hydraulic forces and prevents water flow into the trench. A slurry made of polymers can also be used. Grabs are diaphragm wall digging tool consisting of two jaws which can open and close to collect cuttings and take them out of the excavated trench. Jaw outer profiles are fitted with teeth to cut the soil.

The excavation work cycle starts with the open grab rested on the ground: thanks to the tool weight and speed, the teeth penetrate the soil. By activating the closing system, the grab excavates the soil and keeps part of it inside the jaws. Teeth arrangement on the jaws is usually an odd number of teeth on one jaw, and an even number of teeth on the other, to ensure perfect closing. The jaws asymmetrical configuration tends to deviate from straightness and for this reason the grab is not always used in the same direction, but alternately in both directions: every time the grab is lowered into the excavation, it is rotated by 180°.

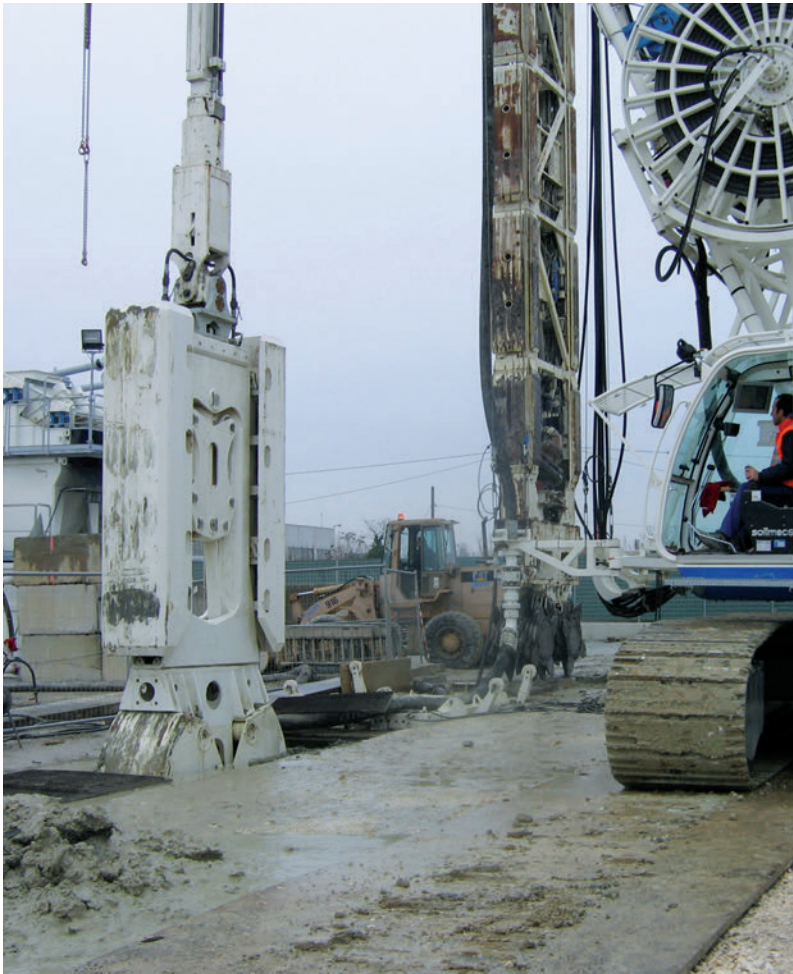
The grab is lifted with the jaws closed and the soil is discharged in a designated area. The work cycle is repeated a number of times until excavation has been completed. The primary panels are excavated first and Secondary panels are constructed between primary diaphragm wall panels. Once the panel is excavated, prior to concreting, the supporting slurry fluid must be cleaned and refreshed so its density, sand content, viscosity and PH are within specified levels.



Diaphragm wall construction diagram



Construction stages

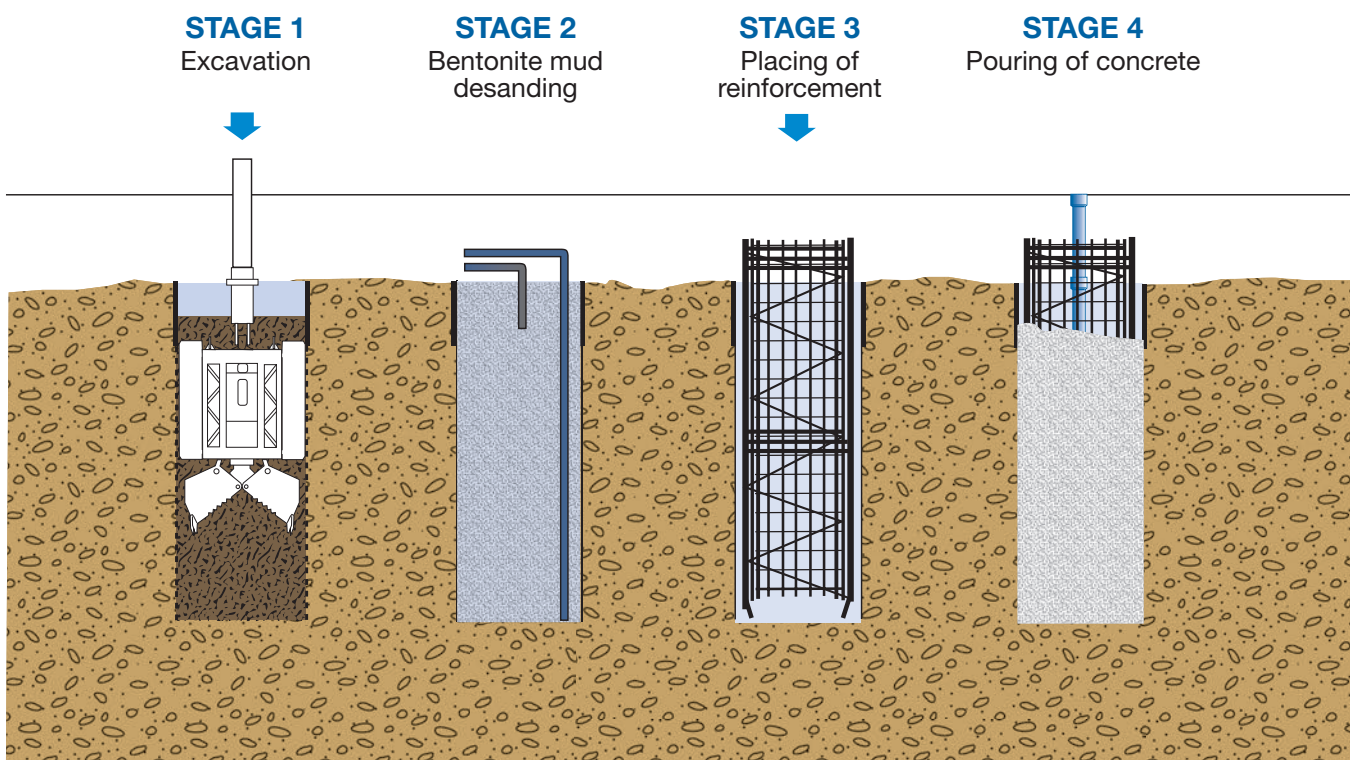


Panel construction

One of the most delicate issues in the diaphragm wall construction is represented by the waterproof joints between panels.

One of the main functions of the diaphragm wall, in addition to supporting the soil up to the final excavation inside it, is preventing settlement of buildings and superstructures beside the excavation and also guaranteeing the wall's waterproofness. The Joints are available in various type and their choice depends on the excavating equipment as much as contractor preference. Once the bottom of the panel is reached and cleaned, the reinforcement cage can be lowered into position. The reinforcement cages have a significant size and weight, as a general rule, the cage is built by laying the components (of adequate length) on the ground then connecting them together. If there is the need for building the cage in separate sections, said sections shall be properly connected using a method approved by the engineer.

The concrete is placed through a vertical steel pipe with an open, funnel-shaped upper end named tremie. With the tremies, concreting of a diaphragm wall starts from the bottom and the tremies are lifted progressively as the concrete level rises. Simultaneously with placing concrete, slurry is pumped from the panel to be refreshed and re-used in the next panel excavation.



Technology

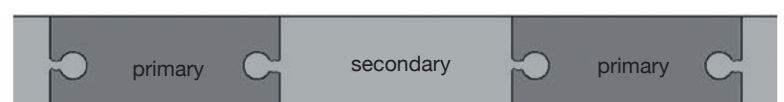
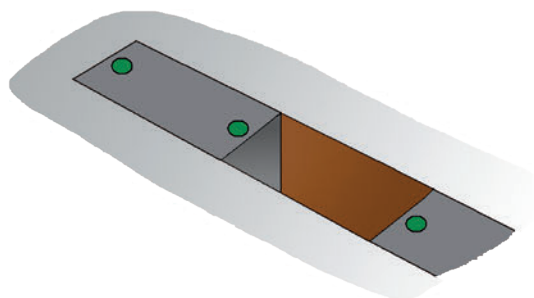
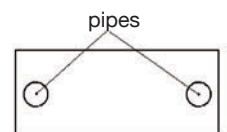
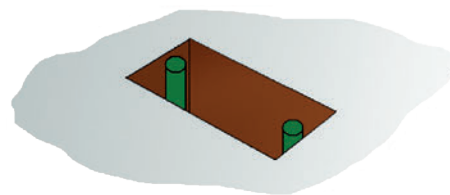
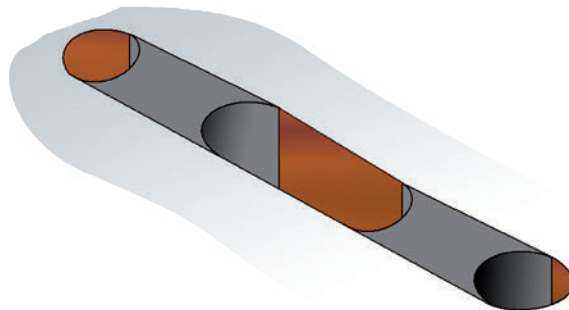
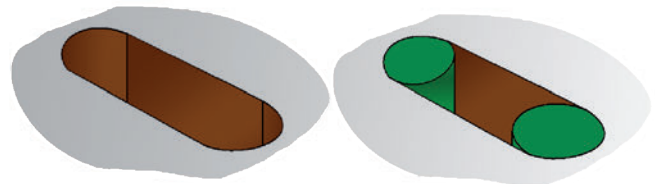
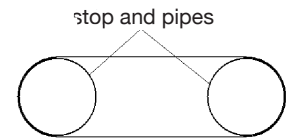
There are three main types of joint design used for diaphragm walls:

Stop end pipes

The steel pipes are installed at both panel fronts before concreting. The pipes rest on the excavation bottom and match the circular shape of the panel fronts. The concrete injected takes the shape of the stop end pipes, the latter are filled with bentonite slurry and the panel has concave fronts. Once primary panels have been constructed and the stop end pipes removed, secondary panels are executed. Once secondary panels have been fully excavated, concreting can start. Concrete fills the semicircular joints and provides a very good interlock.

Disposable pipes

Pipes are in PVC; they are fixed to the cage and lowered to rest on the bottom. During concreting, the whole section is filled by concrete, except for the pipes which remain full of bentonite slurry. The result is a panel with two holes. After excavating the secondary panels, by using a dedicated tool the concrete seam separating the pipe from the secondary panel and the pipes are demolished. As a result, a round indentation is created in the primary panel. When concrete is cast in the secondary panel, it fills the recess and creates a joint with the primary panel.



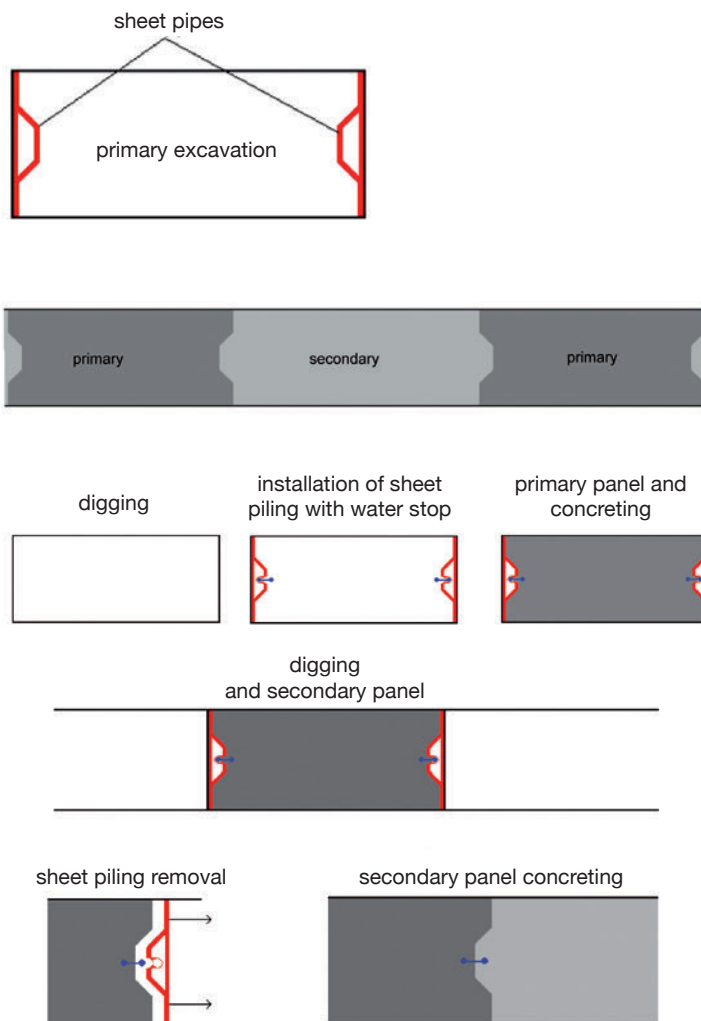
Technology

Sheet piling

With this method, a steel sheet pile is driven into the primary panel, before concrete is cast. After concreting has been completed, the concrete on the fronts of the panel takes on the shape of the sheet pile and a recess is created. When concrete has hardened enough to keep its shape, sheet piles are extracted. Afterward the secondary panel is excavated using a suitable tool to copy the recess of the primary panel and remove soil from this area. When concreting, concrete fills the recess and provides a good interlock between the panels. This technique allows for the insertion of plastic elements called water stops between the panels, in order to guarantee increased water tightness.

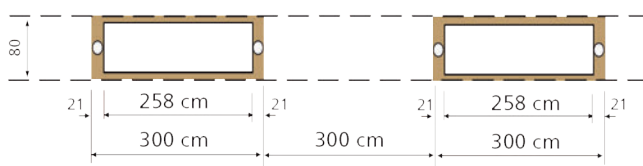
The Milan joint

Trevi Group has developed a special system during the works for the Milan Underground line 3 project in 1985, a system which has been called "Milan joint" because of its origin. The joint is built using a PVC pipe, connected to the primary panel cage. The bottom end of the pipe is closed by a holed cap so as to allow the bentonite slurry to flow in the tube thus preventing the walls of the tube from collapsing due to the pressure the concrete, rising up during the excavation, will exercise on the tube walls. After excavation of the secondary panels has been completed, a cleaner is mounted on the grab; the grab is then lowered and the cleaner breaks the wall of the PVC pipe. This way the concrete penetrates into the pipe's cross-section thus creating a waterproof joint.

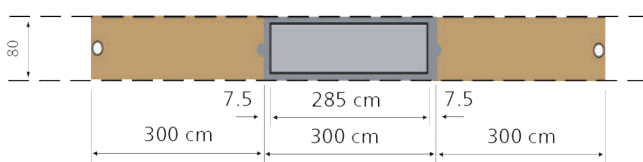


Construction of a diaphragm wall with Milan joint

Stage 1: Primary panel construction
PVC pipe ϕ 180 mm



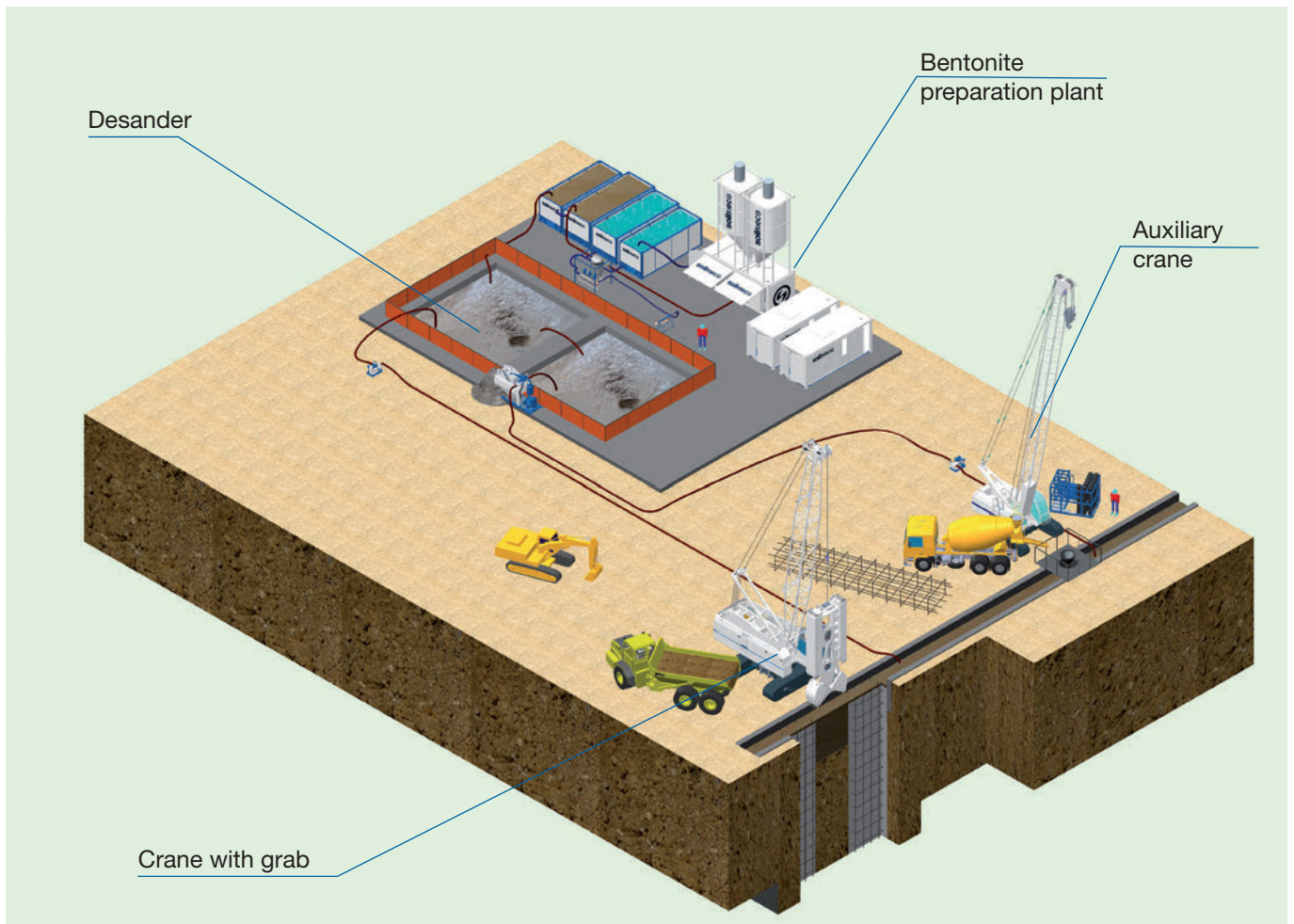
Stage 2: Secondary panel construction



Job site logistics

A typical jobsite constructing Diaphragm walls through slurries will use the following equipment:

- A crane equipped with grab
- A plant to produce the slurry
- A plant to desand the slurry
- A service crane to position steel reinforcement cage in the borehole and to handle the tremie pipes to cast the concrete



Technology advantages



The main advantage of Diaphragm wall technology are listed below:

- Can be constructed in a very wide range of soil types and rocks.
- Diaphragm walls can be constructed **to depths of 60 meters (and above) and to widths of 600 to 1500 mm.**
- Diaphragm walls tend to be used for retaining very deep excavations as they can be designed to take very high structural loads.
- The water tight walls formed can be used as permanent structural walls.
- Reduced number of joints in the wall which ultimately improves the walls water tightness.
- Work may be carried out right against existing structures and the line of wall may be adjusted to any shape in plan.
- Diaphragm wall construction is relatively quiet, and minimum noise and vibration levels make it suitable for construction in urban areas.
- Can be used as top-down method in order to optimize the sequence of operations to be performed in densely-populated inner city areas.



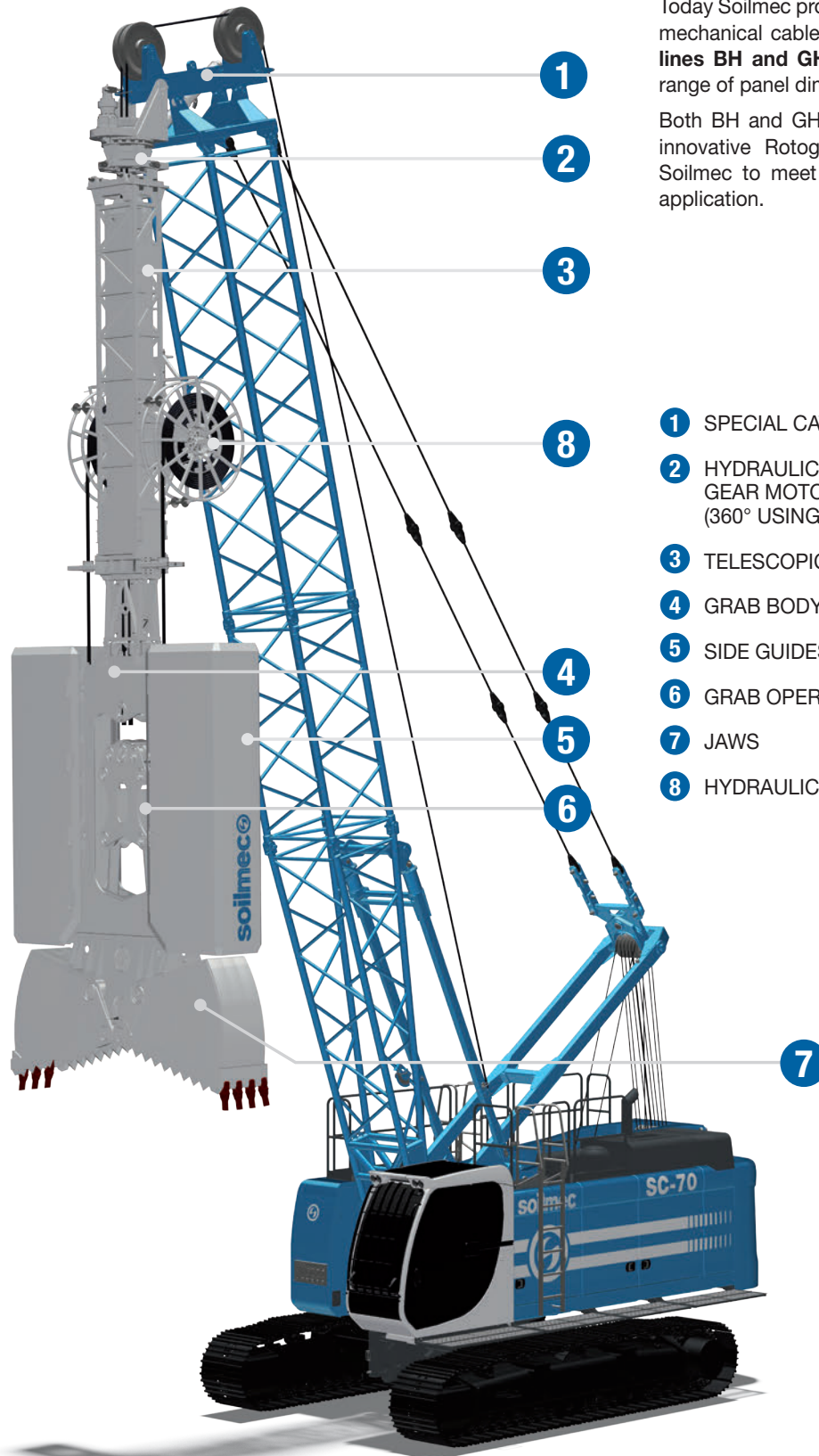


Soilmec Equipment

Since 1974, with the first BHP hydraulic grab, Soilmec is a benchmark point in the field of the diaphragm wall technology executed by grabs.

Today Soilmec produces and distributes the **GC line**, mechanical cable operated grab and the **hydraulic lines BH and GH** that allow excavation of a wide range of panel dimensions.

Both BH and GH grabs can be equipped with the innovative Rotograb Kelly System developed by Soilmec to meet the demand of the front of wall application.



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- 1 SPECIAL CATHEAD
- 2 HYDRAULIC REVOLVING GEAR MOTORS +/- 180° (360° USING ROTOGAB)
- 3 TELESCOPIC EXTERNAL GUIDE
- 4 GRAB BODY
- 5 SIDE GUIDES
- 6 GRAB OPERATION CYLINDER
- 7 JAWS
- 8 HYDRAULIC COILERS

Soilmec Equipment

Grabs Range

Mechanical cable operated and hydraulic grabs for diaphragm wall technology.



Model	BH-8	GH-12/ GH-12R	GH-15/ GH-15R	GC-11	GC-16
Max depth	75 m	75 m	75 m	depending on crane	depending on crane
Weight (approx.)	8 t	12.5 t	15.2 t	11 t	16 t
Panel thickness	350/800 mm	500/1200 mm	600/1500 mm	500/1200 mm	800/1500 mm
Panel width	2000/3000 mm	2500/4200 mm	2800/4200 mm	2500/3000 mm	2800/3500 mm
Type	hydraulic	hydraulic	hydraulic	mechanical	mechanical
Jaws clousure	cylinder	cylinder	cylinder	rope	rope





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