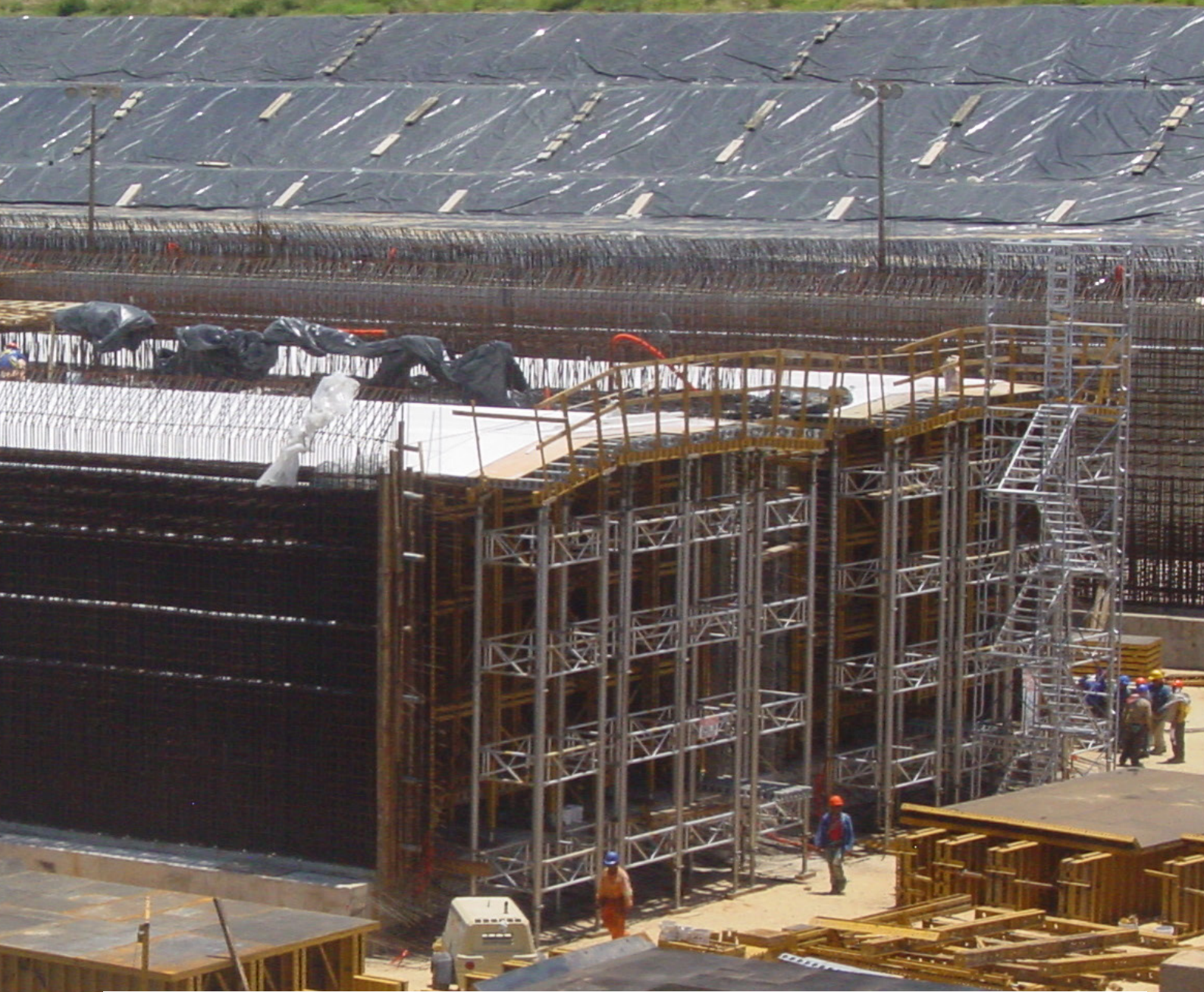


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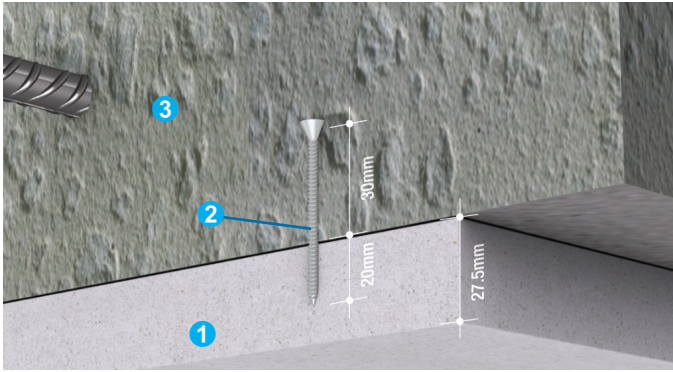


Tunnel Fire Protection

Lost formwork method with PROMATECT®-H system

www.promat-tunnel.com





Technical data

- 1 PROMATECT®-H, thickness as required
- 2 Dry wall screw, length, number and steel quality as required (note manufacturer's information)
- 3 Concrete

Certified according to RWS, HCM, HC, ZTV-ING & EBA

Installation

THE BOARDS ARE LAID ON THE LOADBearing FORMWORK

The PROMATECT®-H boards will be laid with the smooth face down (**Figure 1**) as this will provide the fair faced finish after completion of the tunnel.

It is very important to align the first row of boards alongside a straight edge reference marker, which is screwed to the formwork (**Figure 2**). The rest of the boards are laid next to each other, with butt joints, utilising the previous row as the next starting point or datum. No special treatment on the joints is required (**Figure 3**).

The dimensions of each tunnel section in the ceiling area are approximately 16m x 25m on a typical Dutch cut and cover or immersed tunnel. If the dimensional and squareness tolerances on the PROMATECT® boards are too large, gaps occur while laying the boards as the tolerances tend to accumulate and add up. In order to avoid this effect, PROMATECT® boards are cut to tight tolerances in the factory, such that gaps in between the boards will be minimised.

Where the tunnel is designed with sloped sections, the so-called haunches, the edges of the boards are simply cut at an angle and installed butt jointed (**Figure 4**).

In order to minimise tolerances by cutting on the job site, there are two options. One is to lay the boards on the formwork, draw the cutting line (for example, at the end of a section) and cut all boards in one go alongside a datum on the formwork. The second option is to pre-cut the boards in a dedicated on site workshop.

The boards can either be installed using staggered joints or straight joints. Experience from contractors indicates that staggered joints result in less gaps between the boards. This method allows compensation for certain tolerances, whereas the straight joint method does not allow for much compensation.

The locations of the screws are marked on the boards, using a template and a spray can of paint (**Figure 5**).



Figure 1: boards laid with the smooth face down using lost formwork



Figure 2: fixed strip of plywood serves as a datum for the first row of boards



Figure 3: board joints are simply abutted, no special treatment required



Figure 4: boards cut to an angle at the haunches



Figure 5: pre-marked screw locations on the boards

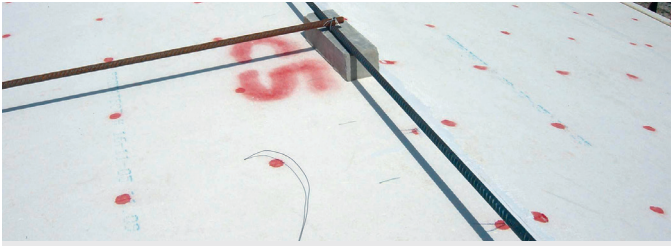


Figure 6: first layer on reinforcement installed, prior to screw insertion

THE FIRST LAYER OF REINFORCEMENT IS INSTALLED

Prior to the installation of the stainless steel screws, the first layer of reinforcement is installed on the stools (spacer blocks creating concrete cover thickness). In this way the screws are always protected from foot traffic (**Figure 6**).

STAINLESS STEEL SCREWS ARE PARTLY INSERTED IN THE PROMATECT®-H BOARDS

The 50mm long screws are inserted to a depth of 20mm, through the openings in the reinforcement; the remaining 30mm projects out of the board creating the anchorage to the concrete after it has been poured (**Main figure**).



Figure 7: screw insertion

Figure 8: screw installed and protected by reinforcement

Several methods are available on the market to ease the installation of the stainless steel screws (**Figures 7 & 8**):

- Battery-powered screwdrivers can be equipped with depth guiding devices to ensure the correct depth of 20mm.
- Screws can be supplied on a plastic strip, which is fed into the screwing machine, increasing installation speed.
- Battery-driven drilling machines can be equipped with a tube through which the screw can be dropped down onto the surface of the board. The installer remains standing upright while installing the screws.

A combination of the above features can be made and should first be discussed with a local power tool supplier.

The screws for the lost formwork system are 5mm x 50mm chipboard screws, with a countersunk (CSK) head type and a Pozidrive-2 connection.

The design of a screw has major influence on mechanical performance and fire performance, in combination with PROMATECT® boards. Among others, properties like shaft-diameter versus thread-diameter, sharpness of the tip and distance of the winding (thread) will influence the stickability of the screws and the performance of the final system.

The number of screws should be in the region of 12 screws per m². In order to ensure the same fire performance in practice,

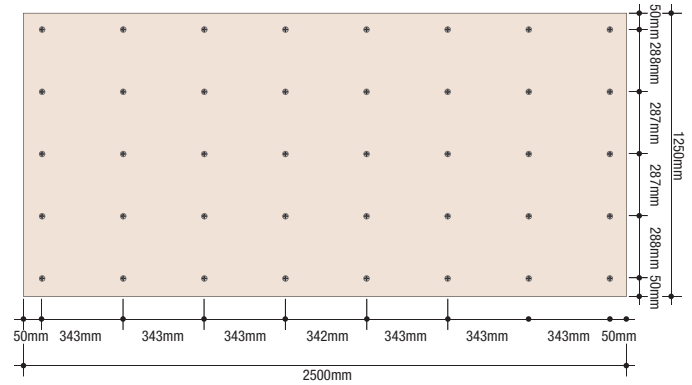


Figure 9: example of screw pattern of lost formwork

the exact same set-up as during the fire test should always be followed, including fixing materials.

The screw pattern of a full size board of 2500mm x 1250mm, as detailed in **Figure 9** for example, has an average of 12.8 screws per m².

The majority of the boards are laid on the formwork in their standard full size dimension. Some panels will have to be cut to size in order to cover the whole surface of the formwork and to connect to the walls and construction joints. Where cut to size panels are used, the following criteria should be followed:

- The minimum quantity of screws should be 12 per m².
- The distance from the edge of the boards should be a minimum of 50mm.
- The screws for cut pieces should be evenly distributed over the surface of the panel. In other words, the spacing distances in X and Y direction should be optimised and be as close as possible.

For example, a screw pattern on a cut to size panel of 1675mm x 1090mm in which all criteria are followed, the surface area of the panel is 1.83m² which means that the minimum number of screws should be 22.

WHEN THE CONCRETE IS POURED

Before the concrete is poured, the PROMATECT®-H boards should be hosed down to remove accumulated site debris and to moisten the boards to minimise water absorption from the concrete mixture. Excessive water should also be removed from the surface of the boards prior to the pouring of the concrete (**Figure 10**).



Figure 10: the pouring of concrete

During vibration of the concrete, the machinery being used is best kept away from the surface of the PROMATECT®-H boards.

ADVANTAGES

The following advantages of PROMATECT®-H as lost formwork system have been reported by contractors over the years:



Figure 11: extracted formwork

FORMWORK SAVINGS

- The shuttering material only has to have load-bearing properties. There is no need to apply phenol coated plywood boards as PROMATECT®-H boards will be laid on top of the formwork. The formwork elements just have to be installed properly (i.e. level and flushed).
- As concrete will not be in direct contact with the formwork, there is no need for demoulding oil (i.e. no slippery surfaces). The plywood sheets will remain clean and can be re-used.
- Formwork can be installed at a distance up to 90mm from the side walls.
- The PROMATECT®-H boards can span the 90mm distance, depending on the expected load. At this location, care should be taken with the vibrating action during pouring of the concrete. Extraction of the formwork is much easier as it will not get jammed between the walls.
- As the PROMATECT®-H forms a barrier, there is no adhesion between the concrete and the formwork, it is easy to extract the formwork and it remains clean (Figure 11).



Figure 12: opening of manholes

EASE OF INSTALLATION

- Joints between boards only have to be butt jointed. No special treatment (e.g. fillers or mastic) is necessary from a fire performance point of view. The cement water will not run through the joints. Where gaps of more than 1mm occur, mastic can be used to seal the gap in order to prevent water

from the cement leaking through the gap, causing unsightly stains.

- Vertical wall panels can also be installed using the lost formwork system.
- Curves in the tunnel can easily be dealt with by cutting the boards on the formwork at an angle to accommodate the curve.
- Openings in the PROMATECT®-H lining for manholes (Figure 12) and end-walls can easily be made by installing phenol coated formwork instead. After striking the formwork, standard size PROMATECT®-H boards will close the opening by post fixing the board into the opening.
- PROMATECT®-H boards provide a heavy duty floor surface. The abrasion resistance is such that the surface can withstand the exposure to people walking and working on top of it, even in wet conditions. Also, the weight of bundles of reinforcement steel and pallets of materials will not cause any damage to the boards. This assumes the PROMATECT®-H boards are adequately supported by the formwork.
- Rapid installation method. Installation rates for the PROMATECT®-H boards of 150m² per man per day have been reported on European tunnel projects.
- The installation of the system does not interfere with other construction activities.
- Extensive Promat expertise is available with this system in immersed and cut and cover tunnels.



Figure 13: anchor system for jet fans

TUNNEL SERVICES AND SPECIAL SHAPES

- Anchor systems for services (e.g. jet-fans, Figure 13) can be fixed onto the upper surface of the boards, prior to casting the concrete.
- Services, pipes, tubes etc. can be included within the depth of the concrete.
- After the formwork is extracted, services can be installed onto the PROMATECT®-H lining from below. Anchors can be installed through the boards into the concrete, thus providing a continuous fire protective layer.
- Special shapes in the concrete structure can easily be accommodated, e.g. beams.

OTHER BENEFITS

- As the PROMATECT®-H boards are installed in the very early stages of the construction of the tunnel, fire protection during the construction phase is provided.
- The PROMATECT®-H lost formwork system provides a flush finish ceiling.
- No obstacles such as anchor heads on the soffit of the tunnel.



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