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The "Odex"-drilling concept in Micro-piling application

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Introduction:

The word Odex is a short for overburden drilling excentric. This drilling is using casing to line the hole when passing through the soil overburden before entering the sound rock. The most frequently used diameter of the hole 5 inch or 127 mm with a casing having an inner diameter of 4 _ inch or 115 mm. This technique is well proven and has been on the market for three decades in surface applications. The steel-lining is left in the hole after finished drilling and forms a part of the of the pile.
This paper will deal with the practical application of the method and the rather newly underground use of it. As the Odex drilling is a niche-technique and might be unknown to many a brief presentation of the method as such will be given followed by regular surface applications and finally the lately discovered underground use of it. By the word niche is here meant that the method is frequently used on some markets but on others very sparsely.

Drilling with Odex (The Odex method):
The Odex equipment enables you to drill and case deep holes simultaneously in most time of geological formations even those with large boulders as well as in old construction material as bricks and concrete. The casing outer diameter vary from 89 mm to 273 mm. The method is based on a pilot bit,eccentric reamer and guide device, which together drill a hole slightly larger than the external diameter of the casing tube. This enables the casing tube to follow the drill bit down the hole. Part of the impact energy meant for the drill bit is diverted to the casing tube via the guide device to the casing shoe at the lower end of the casing. The impact energy can be supplied either by top hammers or DTH hammers. In both cases the casing is driven down into the hole without rotation. The top hammer cover smaller hole dia 96 to 152 mm and the DTH 123 to 306 mm.
As the casing enters bedrock drilling is temporarily stopped careful reverse rotation is applied, which causes the reamer to turn in thus reducing the overall diameter of the drill bit assembly. Now the drill string can be retracted which is normally the case for micro piles or continue the drilling in rock without casing. This is often the case in grouting campaigns.
Flushing media is normally air but water is used in underground application and sometimes foam is preferred. The drill cuttings are carried by the return flow between the rod and the steel casing and are discharged via a hose nipple.
The steel tube joints are either threaded or welded. In some applications the steel tube may be retrieved and here is the threaded joint to prefer. The sequence of operation as described above is shown in figure 1 series below.

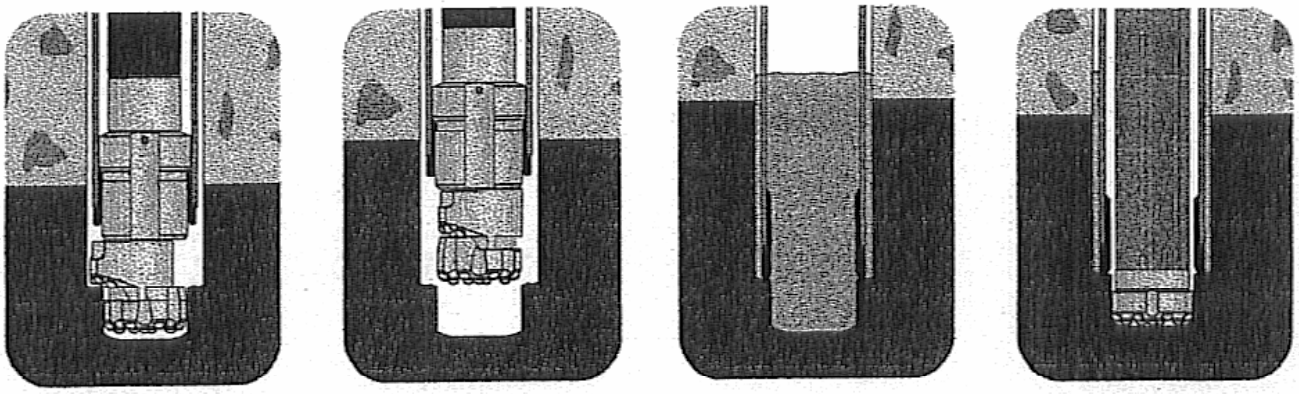


Fig. 1a-1d Drilling sequence ODEX.

1. When drilling starts, the ODEX reamer swings out and reams the pilot-hole wide enough for the casing tube to slide down behind the drill bit assembly.

2.When the required depth is reached, rotation is reversed carefully, whereupon the reamer swings in, allowing the drill bit assembly to be pulled up through the casing.

3. Casing tubes that are to be left in the drill hole should be sealed at the bottom of the hole by means of cement grout or some other sealing agent.

4. Drilling continues to the desired depth in the bedrock using a conventional drill-string.

Odex and micropiling

In a geological environment characterised by a relatively thin overburden big blocks followed by a hard bedrock point bearing piles are favoured. This overburden may also hold big blocks and a sloping rock-surface. Here the Odex system offers great advantages by being able to percussion drill through the blocks and penetrate into the hard and load bearing basement rock. In case the point-load bearing capacity of the rock is inadequate the hole in the rock can be extended by regular percussion drilling without casing to allow for load transfer via the walls of the hole.
In case there is no competent rock or friction soil stratum of sufficient strength within reach to handle the planned point load, the steel core piles can be be adapted to function as friction piles. Within this alternative, cement grout is forced out through slots in the casing to to create bond between the pile and the surrounding formation.
As the hole is completed the drill-string is retracted and a steel-rod is mounted inside the casing. The annular space between the rod and the casing is then filled with mortar or grout a load distributing steel-cap is welded to the top to complete the installation. A so called steel core pile is now the result.

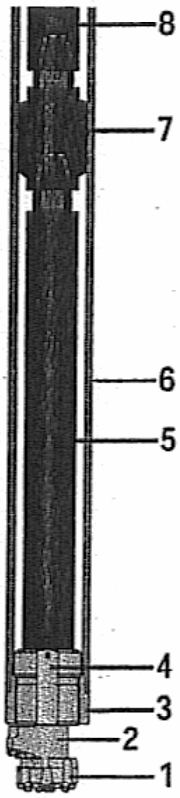


Fig. 2
ODEX drilling equipment
1) Pilot bit, 2) Excentric reaming bit,
3) Casing shoe, 4) Guide device,
5) DTH hammer, 6) Casing tube,
7) Wing coupling, 8) Drill tube

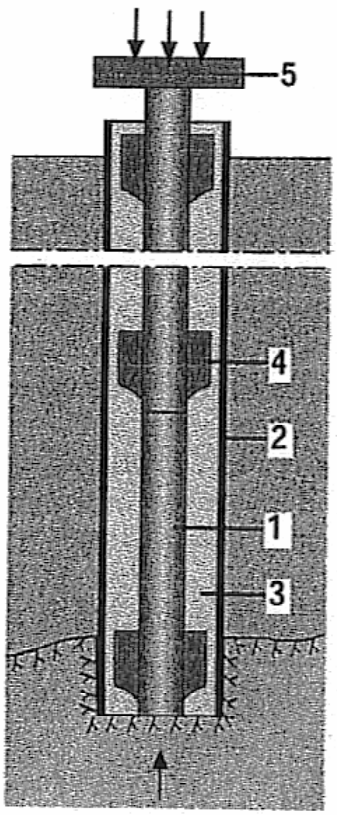
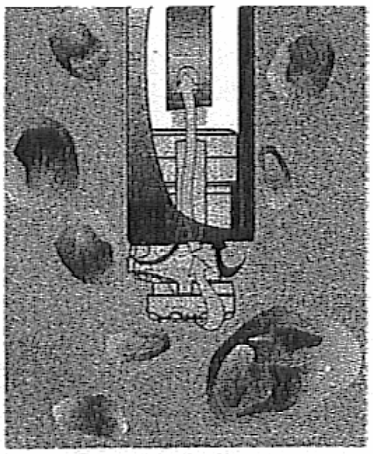


Fig. 3
Point-bearing steel core pile resting on hard rock.
1) steel core, 2) casing tube,
3) mortar or grout, 4) guide web,
5) load distribution plate

The above described micropile has all the established advantages of drilled micropiles. When drilling either down to load bearing rock or to a suitable soil strata it is important to ensure that the thrust, the drilling parameters are properly controlled to match the prevailing conditions. Drilling in soft and fine grained soils below the water table requires that the evacuation of water and soil is continuously monitored and if necessary restricted to avoid undermining. Tophammer drilling with water flushing is a mean to avoid excessive soil erosion. (See figure below)



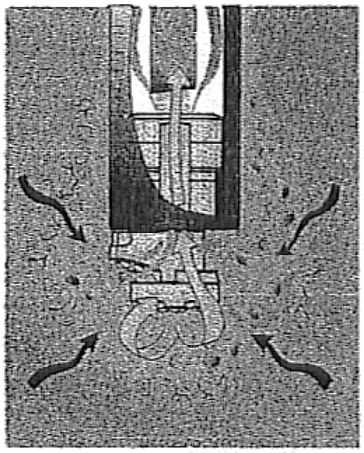


Fig. 4 Flushing conditions in ODEX drilling.

a) Normal flushing situation.,

b) Soil erosion due to large flow of water washing out fine particles from the borehole wall

Case story: Underpinning of an apartment block in Sweden

Background

A City block built round 1880, is situated on the island of Kungsholmen in the centre of Stockholm. The foundation was made partly on rock and gravel, partly on a timber raft consisting of wood and timber piles.
In some parts of the buildings, especially at the change-over between different methods of foundation, cracks of considerable sizes in facades and walls had arisen. Tests had shown that the settlement was continuing . In connection with a complete restoration of the buildings it was decided that the foundation had to be reinforced before starting the restoration. Piling was chosen for the reinforcement. A problem was content of ground, wood and filling material from earlier building works. Furthermore, a method of piling was required that gave no vibrations or movements in the surrounding buildings.
Reinforced foundation
Considering the obstacles in the ground Odex drill foundation with steel core piles was chosen. After studying different alternatives it was decided to use piles with a steel core of 90 mm and a Odex casing of 142 mm diameter.
The drilling was done with 4 inch down the hole hammer equipped with Odex 115 drilling tools.

Difficult drilling.

The drilling became very difficult due to obstructions by wood, boulders and filling material. Despite the difficulties the complete and approved piling schedule could be presented to the main contractor within the required time. After the piles had been cut to size and furnished with cap plate of steel they were cast into horizontal beams of reinforced concrete. All the work had been carried out inside the basement, a great advantage as the work progressed during a very cold winter period.
Steel core piles durability
The permitted load of the current steel piles is 700 kN. The load is limited by the support against buckling that the surrounding marine clay can mobilise.
In this case when calculating the bearing capacity of the piles, it is presumed that the Odex casing is completely destroyed by rust, which is estimated to 70 years with a corrosion rate of 0,1 mm per years. The steel core has a jacket of concrete and is therefore not affected by corrosion.

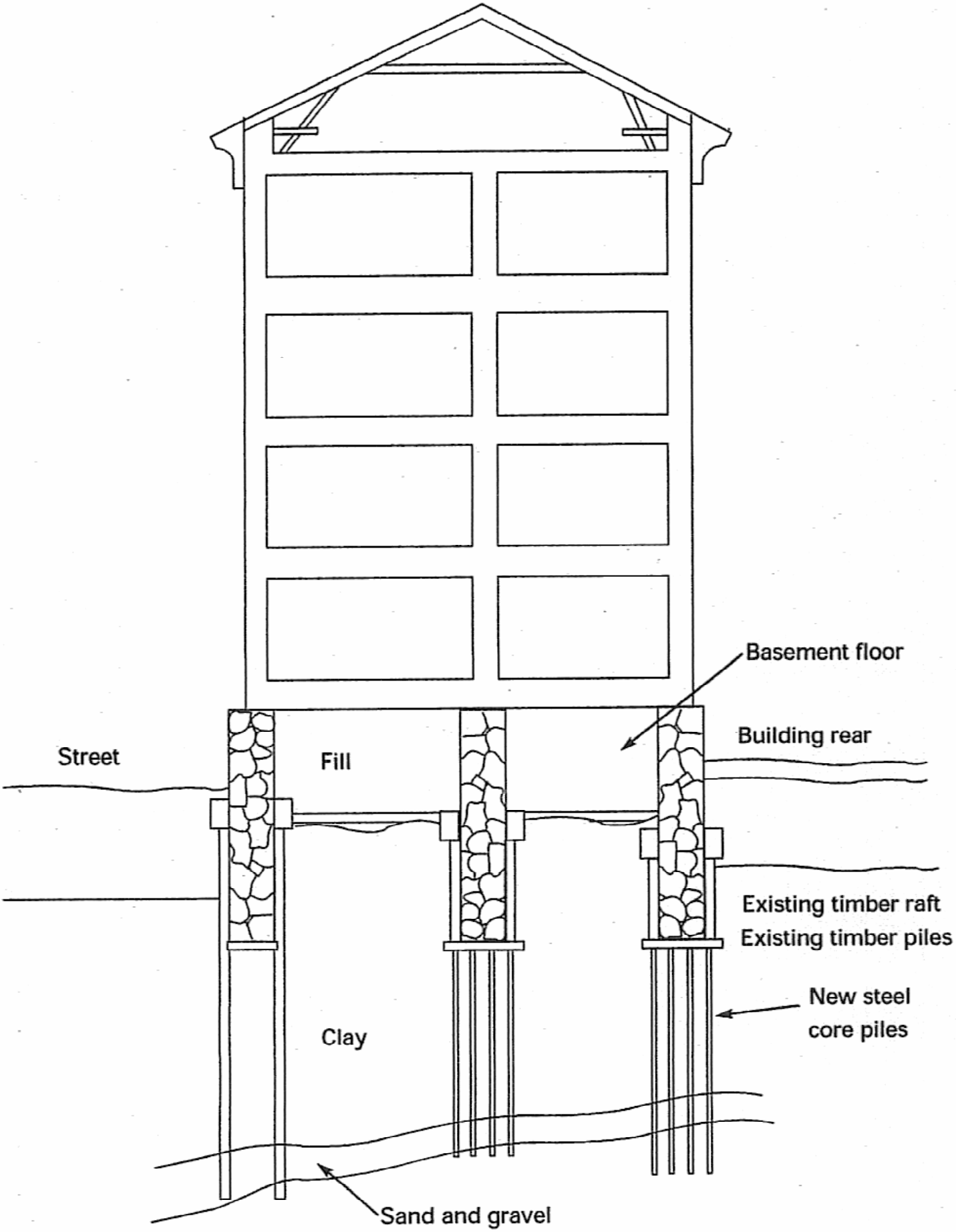


Fig 5 Typical section of the underpinned building.

Odex drilled wall piles: Problem solver in blocky ground
Pile walls , constructed with drilled casing tubes as soldier piles and shotcrete are not stopped by obstacles like boulders, concrete blocks or building rubble. The drilled pile walls are similar to Berlin pile walls but the H-beams are replaced by drilled casing tubes and the lagging with shotcrete. To increase the bending stiffness and strength of the casings, steel rebars are inserted and the casings filled with mortar. or concrete.
Excavation is done stepwise like with Berlin walls. If possible the soil should be excavated to an arch shape so that the applied shotcrete so that mainly compressive stresses will be induced in the shotcrete. As with other types of pile walls lateral support is needed to prevent displacement or collapse of the wall. The advantage of the pile wall is that it can be placed very close to walls of neighbouring buildings. This advantage is even more pronounced in cases where the buildings are vulnerable to vibrations.
The distance between the piles is depending on the soil-conditions but is usually 0, to 1 meter. Suitable dimensions of the Odex pipes are 140 to 193 mm outer diameter with a wall thickness of 4 to 8 mm.
Drilled pile casings can be fitted with axial load bearing steel cores to serve a simultaneous function as piles. The drilled pile wall can then be integrated into the permanent concrete wall.

Case story: Pile walling system in Hong Kong

Background

Odex drilled pile walls have been used in Hong Kong since 1980. Hong Kong is a city where the top layers often consists of completely decomposed igneous rock with so called core stones. Odex is used where boulders make ordinary sheet piling difficult or almost impossible. By drilling ,all obstacles are penetrated, not only boulders but also other waste material such as wood and fill containing parts of concrete.
Method of construction
The piles are installed using the Odex drilling system. Usually is a down the hole hammer employed. The Odex casing is either 142 0r 196 mm in outer diameter. The distance between the piles has to match the ground conditions and typically is the distance 0,3 to 0,7 meter.
In order to avoid soil from falling out between the piles, grouting may be used. It is carried out either through slots in the Odex casing or through additional drill holes behind the wall. The tube a manchette grouting is used employing either cement or chemical grouts all depending on the soil conditions.
The excavation in front of the wall is carried out in stages and tie backs or struts are installed consecutively in regular manner. Walings are put in place to transfer the earth pressure reaction from the piles to the supports (See figure below).
It should be noted that the same drilling equipment is used for piles, grout holes and tie backs.

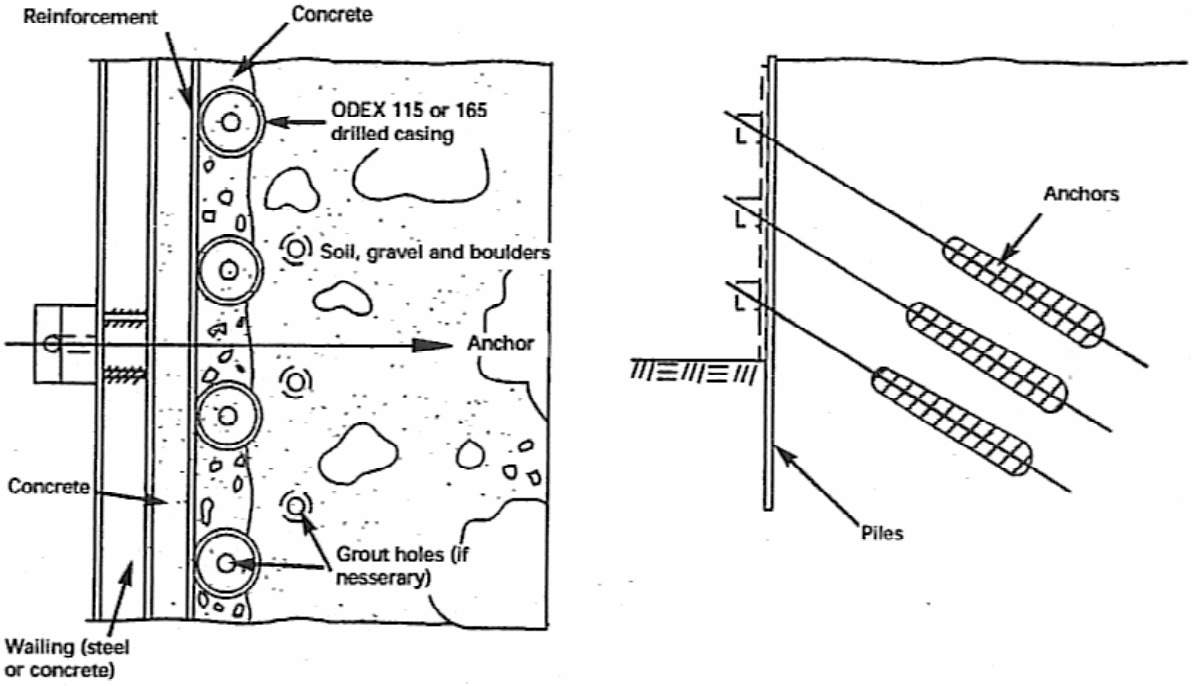


Fig. 6 Typical Odex pile wall system in Hong Kong

Underground application of the Odex system.

Above has only the above ground applied Odex drilling been coped with. A system as pointed out that has long been in use. It is only in the last years that the underground application has been given a breakthrough and this in connection with the creation of system where the Odex can be applied on drill rigs for tunnelling. Here is solely tophammer drilling used and the casing diameters are 89, 115 and 142 mm maximum diameter. The largest is very new and has not so far been used. The flushing media is water but water mist is also possible. In principle the drilling procedure is exactly the same and the only difference is that the holes are horizontal and not vertical. The system has been given a name by its own namely Boodex which is a merger of Boomer and Odex where Boomer is a frequently used name for the underground drilling rig. Then potential for vertical Boodex drilling will briefly be discussed in the end of this paper.

Boodex drilling for spiling of the tunnel roof.

Spiling of the tunnel roof is frequently used in tunnelling where the strength properties of the rock or soil are such that the roof and tunnelface is collapsing immediately after excavation. The stand up time is practically nil in those cases. By applying a row of grouted reinforcement bars or pipes just outside the perimeter of the roof and wall the collapse or partial is hindered. The spacing between the pipes may vary considerably depending on the ground conditions but is usually in the range of 0,3 to 0,6 m. This pipe roofing as it also often is named has a lot in common with the pile wall and it can be considered a horizontal one. The structure of it is shown in the figure below.

The use of the Boodex method offers like in the pile wall case the possibility to grout the ground. The pipes are often equipped with valves and grouting can be done in stages by use of a double packer probe. This means that a vault of improved ground is created above the periphery of the tunnel. Depending on the ground conditions cement or chemical grouting is preferred. The grouting set up which has much in common with the tube a manchette method is displayed in figure below.

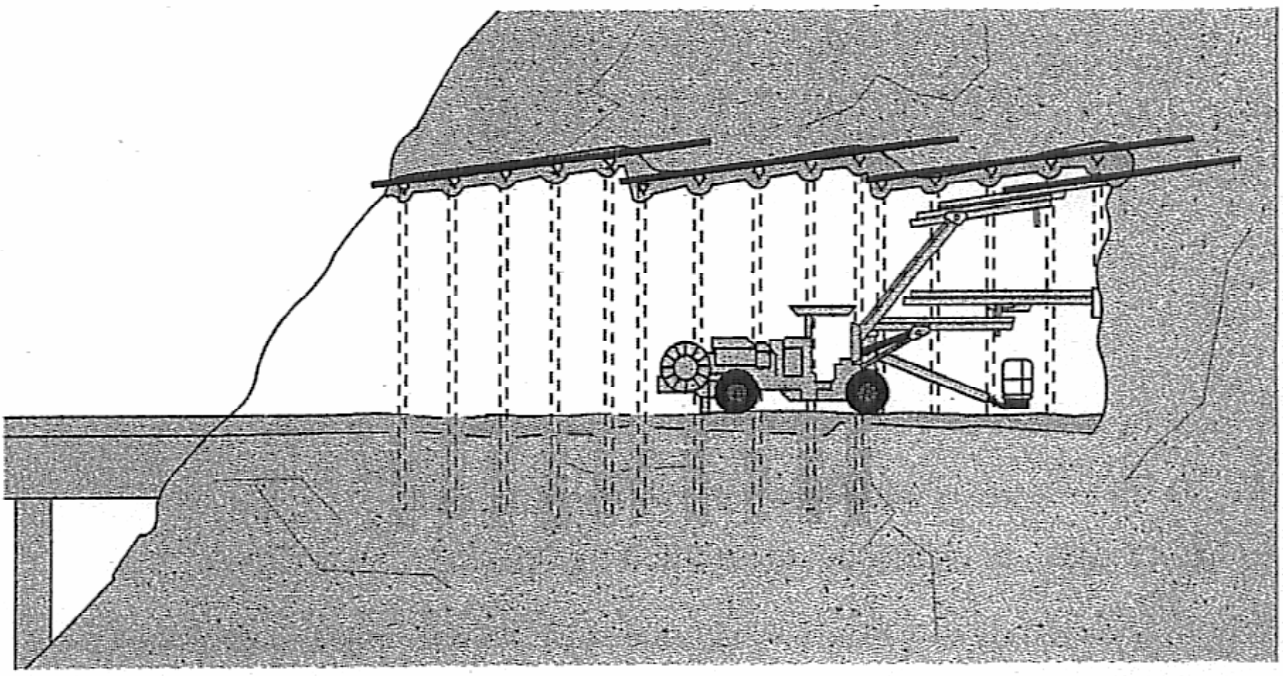


Fig. 7 Spiling by use of Boodex

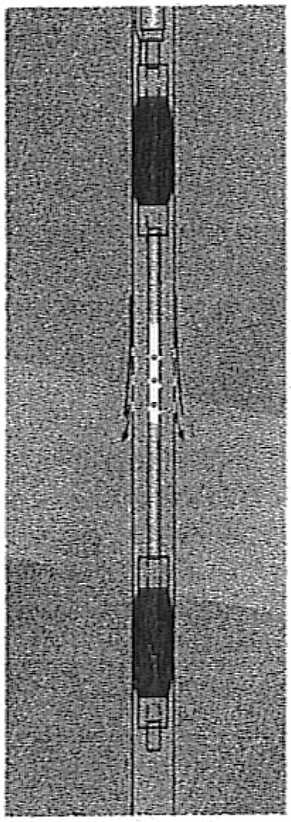


Fig. 8 Stage grouting with double packer

As said above regular tunnel drilling rigs are employed for this spiling operation. The feed and shank are modified a conversion that can be done within a few hours. Sections of rod and casing are assembled in 1,5 or 3 meter sections. A limiting factor for long assemblies is the weight of it. In portal areas with no limitations upwards 3 m may be preferred but inside the tunnel only 1,5 m has been used so far as most of the lifting has to be done manually.

The length of the spiling section varies. The longest known is the one carried out here in Japan namely the Tsuda tunnel where the where 36 meter long spiles were drilled and the shortest only 6 meters. It is likely that the portal-spiling will call for longer holes with the ambition to cover the whole reach of poor ground. While underground it is more practical to split longer reaches of poor ground in a number of repeated spiling sections.
The spiles are supported either by steel arches or by bolts and shotcrete or sometimes both. Below will briefly a few cases be quoted.

In Slovenia a former part of Yugoslavia not less than 5 double tube 2-lane road tunnels with lengths 300 to 600 meters had to be constructed. The excavation method was drill and blast using a Boomer 352 from Atlas Copco. Collapsing roof and face caused major over-break and gave very slow progress. The Boodex system was tested and turned out to be successful. The underground spiling sections were 15 meters long and the 115 mm outer diameter pipes were placed 0,4 to 0,5 m centre. The overlap was 5 meters placing the start section of the Boodex-spiles at 10 meters centre. Self drilled anchors were installed in the overlap sections.
As the tunnels were given a support with steelarches they were used as a help in the alignment of the feeds when drilling, The look out angle was 3 degrees and surprisingly the tube and casing sections were 3meters long although the were handled manually.
The site claims that the drilling of a 15 meter pipe took 30 minutes and this figure matches well the experience from other sites. It was further noted that the penetration was more or less constant over the length of the hole The pipes were grouted in one stage and the 7 mm holes placed in spiral around the tube were not given any valves.
Another similar case is from Equador . Here the spiling was done slightly different although using the Boodex system. During construction of a 2-lane road tunnel a major fault zone had to be traversed. It later turned out that it was as wide as 120 meters. The rock material in the fault was highly decomposed and was slowly creeping inwards from the face. Attempts to stabilise the face by grouting had failed.

It was decided to test the Boodex system and insert heavy rods inside the Boodex pipe as the drill-string had been pulled out after having drilled a 6 meter long hole. This heavy rod had wall thickness of some 7 mm and an outer diameter of 89 mm. That means that it could just be over-passed by the Boodex pipe. So when this pipe had been installed the Boodex casing was retrieved. Grouting of the ground was than done via the installed pipes which were given an adequate amount of holes to fit a one stage cement-grouting.
At every 4 meter of tunnel the spiling section was set up giving two meters of overlap. The spacing between the holes was 0,54 m and boodex sections were 1,5 m long. The excavation as such was with top heading and a closely following bench. To be able to maintain a stable face it was given a central core. The ground was loosened by use of a backhoe equipped with a hydraulic hammer (see figure 10 below).
The fault zone 120 meters wide was traversed in half a year attacking from one side only.

A third case worth mentioning is a portal stabilisation in connection with the extension of the Channel-tunnel link up to London. The tunnel is named North Downs tunnel.
For various reasons it was decided to go with boodex to secure the tunnel portal of the rail tunnel.

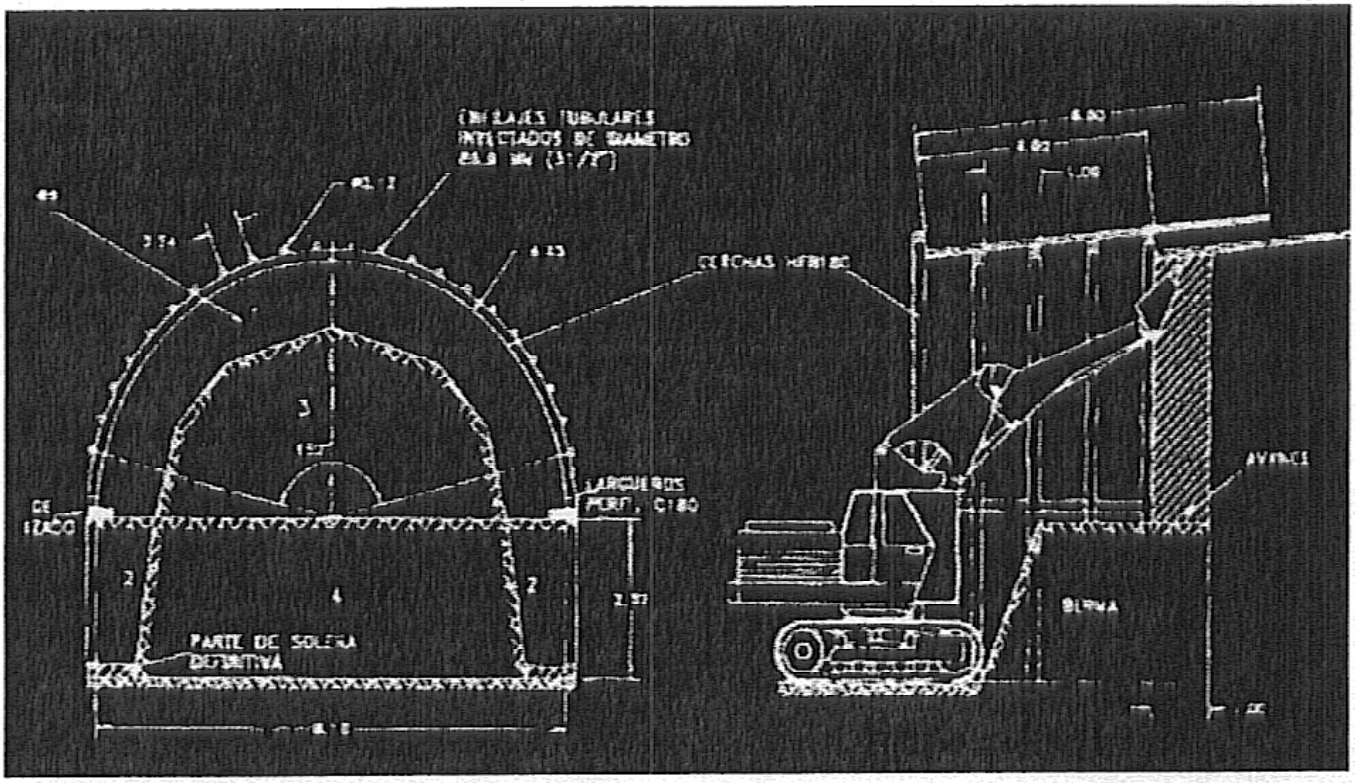


Fig. 9 Excavation sequence in the fault-zone of the tunnel Puerta del Cielo Equador

A total of 24 holes at 0,5 meter spacing were drilled to a depth of 15 meters using the casing having an outer diameter of 115 mm. As can be seen in picture below no special guiding device was used . It was judged that the deviation would not exceed 2 degrees giving max deviation of 300 mm

The boodex sections were 1,5 meter long and the penetration was 0,5 m/min the drilling of one took only minutes. It was then decided to use only one boom. The capacity including grouting was 5 holes per day w0orking on shift only.
Two working platforms were provided for the handling of the rods and pipes.

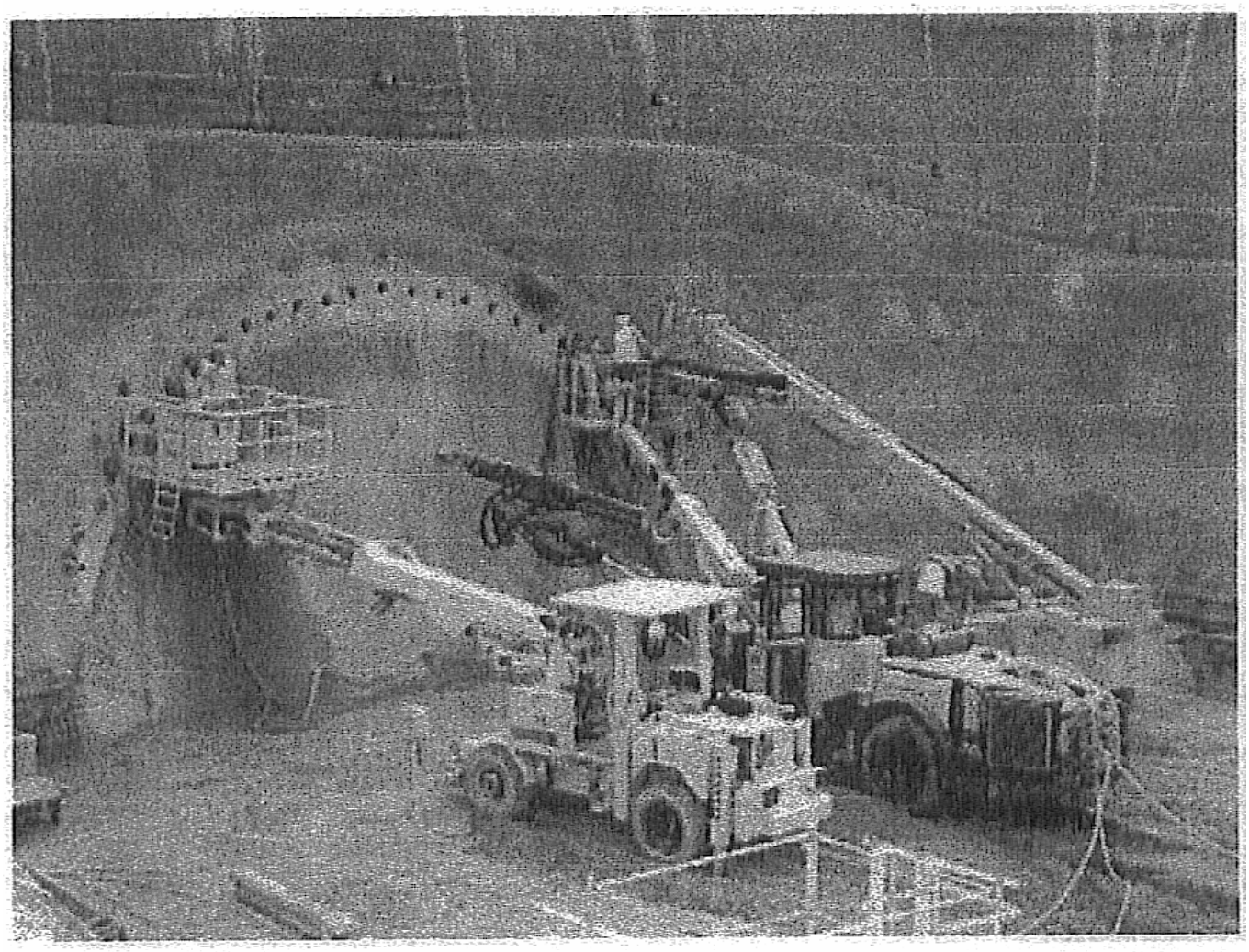


Fig. 10 Boodex drilling at North Downs tunnel UK

Underground micropiles

Piling in underground is rather sparse but do occur from time to time. In very poor ground conditions it happens that the concrete lining is given a pile support temporary or permanent, both cases do occur. Here the Odex piles could be a competitive alternative as the drilling equipment is already at the construction site.

Closing words

The Odex method is almost 30 years old but still alive. It seems that it has capacity to find new applications as the underground use. Development efforts are spent on the method and it is believed that it will stay alive for decades to come.