Estatec®, A Innovative Earth Retention System

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Abstract

Traditional bottom up slope stability methods, such as concrete, masonry or gabion walls, produce ground movements that create successive soil failures during the excavation and big interferences, resulting in indirect costs such as road closures. On the other hand, top down construction methods such as slurry wall or sheet pile need a stable ground platform to support heavy equipment and are costly.

Estatec is a top down soil treatment consisting of a self-setting plastic mortar wall and an arrangement of anchors pressure grouted to create a cohesive soil mass that stabilize the slope or deep excavation. The construction starts by digging a trench stabilized with self-setting bentonite - cement slurry. The upper face of the wall is then exposed and anchored to create the cohesive soil mass. The process is repeated following the project geometric needs. It can be done vertically or with terraces

Because of the top-down construction soil failures are avoided; the interference on the slope vicinity (crest and foot) is minimal; and the deformations are controlled.

The Estatec method is of general application for any soil type and any slope geometry or dimension. It has been successfully applied to repair roads after heavy rains or hurricane disasters to reopen quickly the transit.

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Before

Fig 1

After

Fig 2

Estatec system description and construction method

The Estatec system is a robust stabilization solution mainly used in Mexico to repair failed embankments on roads and a substitution to traditional methods such as masonry walls, concrete walls or sheet piling. The Estatec system consists of a soil treatment method composed of (see figure 1 and 2):

1. Plastic mortar wall
2. Tension or Friction anchors
3. Grouting
4. Shotcrete
5. Drains

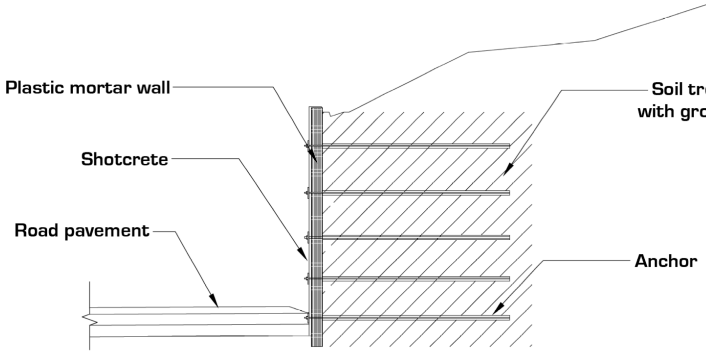

Fig. 3 Estatec Vertical Solution

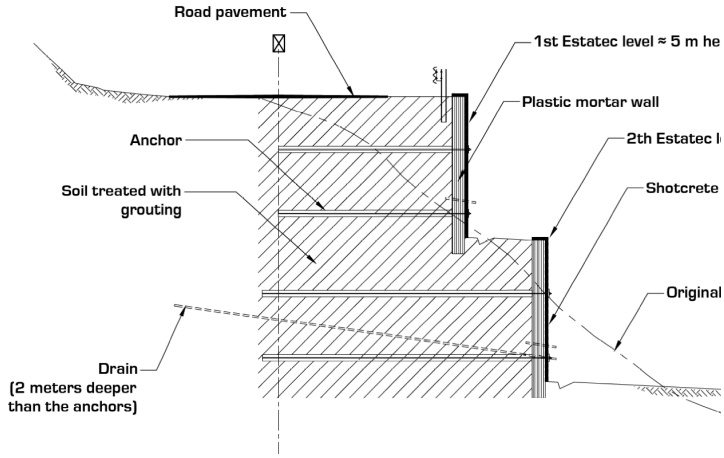

Fig. 4 Estatec Terrace Solution

The Estatec system is a top down construction method whose steps are as follow:

1. *Embankment Restitution*; in the case the Estatec system is applied as a repair solution on a failed road, the first step is to restore the embankment. This process implies the placement of soil material up to the project height (the selection of this material depends on site availability); the placement can be done with a track-type tractor. The compaction is not a critical activity because the soil will be improved during the grouting process.

2. *Plastic Mortar Wall*; the plastic mortar wall is constructed with a backhoe loader. This machine performs a trench that is filled with liquid cement slurry. This slurry stabilizes the excavation walls and when set, would become the mortar wall. The advantage of performing the top down construction with the slurry in a trench is to ensure at all times stability of the embankment. After the depth of the trench is reached, sand is poured on the slurry to transform it into a mortar. The plastic mortar wall has an excellent contact with the surrounding soil, filling any voids encountered. This characteristic is critical to ensure a good transfer of stresses between the soil and the plate anchors.

3. *Face Excavation*; once the plastic mortar wall is set, the face is excavated in steps to permit the anchor and grouting processes. This mortar wall acts temporarily as a retaining structure, ensuring a safe work environment and preventing new failures on the embankment. The great advantage to perform the works from this face is the increment on performance during the soil treatment.

4. *Anchor Installation*; on the face of the mortar wall, holes are drilled to install the anchors. The anchors are installed in rows, ensuring their activation prior to the next row´s face excavation.

5. *Grouting*; the grouting is performed through the anchor drills; the anchors have preinstalled the grouting hose. Depending on the soil encountered the rheology and performance of the grout is tuned. The grout has two main objectives. To ensure a proper of the anchor and soil, and to improve the mechanical behavior of the soil.

6. *Shotcrete*; to ensure long lasting performance of the mortar wall and reinforce its face, a lining of shotcrete is placed between the mortar wall and the anchors plates. Depending on the performances required the shotcrete resistance and thickness is specified. The shotcrete can be reinforced with fiber or wire mesh.

7. *Drains*; on the lower portion of the Estatec system a row of deep drains is installed. This activity is performed after the grouting to ensure the

permeability of the drains. In general the drains are 2 meters deeper that the anchors.

The steps 2 through 6 are performed until the project geometry is reached. The main variation is between the talk systems illustrated by figs. 3 and 4. The terrace solution is used on roads because a precarious stability doesn't allow using big equipment; the plastic mortar wall is commonly 5 meters depth. The vertical method is used for deep excavations; mainly because the development's area costs are a big commercial component.

Working principle

The aim of the Estatec system is to improve the soil (or rock) on situ in order to perform as a monolithic structure. This treated soil will supports the forces exerted by the surrounding soil or water. The working principle is similar to the reinforced earth used on bridges; with the big difference that it is a top down construction method. The elements that ensure a monolithic behavior are:

- *Anchors*; the anchors reinforces the soil structure and gives the capability to transfer tension forces. It ensures that no failure surface develops on the treated soil. In a way the anchors redistribute the excess stress into larger soil volume.

- *Grouting*; the grouting bonds the anchors with the soil, ensures an efficient strain/stress transfer, and improves the soil mechanical performance. The mechanical improvement results in an increase of the compression resistance and a decrease of the deformation. Depending on the soil (fine, granular or rock) the grouting method and mix is designed.

- *Plastic Mortar Wall*; the mortar wall ensures the confining of the soil, with the action of the anchors. In the long term, it ensures that no soil is washed out. One great advantage of the method is the perfect surface contact with the soil, due to the stabilized trench construction process.

- *Drains*; the drains ensure a safe water path without washing out the soil particles.

On road applications, the typical height is 5 meters per terrace, and the anchors depth range from 6 to 15 meters. The soil that performs monolithically is equivalent to a wall 5 meters in height and from 6 to 15 meters thick. This geometry is very stable; it has a great moment of inertia and a large surface to transfer the loads. Additionally the excavation of the vertical terrace diminishes the loads on the embankment. Compared with a typical embankment, the volume of soil is lower due to the vertical geometry; in the case of an embankment reparation, the excess volume before the treatment acts as a pre-consolidation. Compared to a gravity wall or diaphragm wall, we do not have stress concentration and foundation instabilities; this is due to the fact that the treated soil has almost the same volumetric weight as the original soil, (compare with the concrete, masonry or gabion volumetric weight) and the distribution of stresses is transfered on a larger surface (6 to 15 meters compare with a gravity wall around 1 meter) to support the same forces.

We have observed a great performance on deformed embankments for the roads. This is related to the explained diminution of the loads on the embankment due the vertical geometry, and also to the fact that the soil treated is beneath the road. The treated soil has a lower void ratio and lower deformation thanks to the grouting process.

Additionally, the Estatec system has a row of deep drains to diminish the hydrostatic pressures on the stabilized zone. These drains are deeper that the treated soil and are placed on the lower part to improve their performance. These drains are tubes lined with a geotextile and placed in horizontally drilled holes.

- Granular soils (sand and gravels)
  - The grouting will be a permeation grouting to fill the voids between the soil particles and form a matrix that holds it together.
  - Confine the granular soil between the anchor bulb and plastic mortar wall. A greater confinement of the sands increases the soil

resistance as the limit state on the Mohr Coulomb theory.
  - The permeation grouting diminishes the voids and the deformation.
- Fine grained soils (Silt and Clay)
  - The grouting method employed is fracturing grouting. The grouting improves the soil performance by consolidating the soil and the intercalation of grouting "discs" on the soil structure.
  - The fracturing grouting is performed with the help of "manchette" tubing to ensure a proper grouting deposition on different phases.

- Rock
  - The grouting is a permeation grouting to fill the fractures and discontinuities found on the rock. It can also fill voids encountered.
  - The filled fractures improve resistance and diminishe the deformation in the rock mass
- Boulders and Rock Embankments
  - It will be similar to the granular soils, using permeation grouting.
  - The grouting matrix will stop the wash out of soils

The permeability and type of soil will determine the grouting design. The grouting liquid properties are:

- Viscosity
- Density
- Stability of the mix
- Bleeding of the grout
- Particle size

These properties ensure the penetrability of the grout and a correct bonding with the soil. For example, if the permeability of the soil is low, we will design a less viscous grout to penetrate easily into the voids. During the grouting, the main variables are the pressure and volume injected. Careful monitoring of these parameters permits a correct evaluation and validation of the process. A well done grouting treatment is a closed loop process, from the data and results obtained the process is adjusted; that include pressures, flow and volume of grout and the properties of the grout. The solid properties of the grout (resistance, elasticity, permeability) are also important in the design of the grout and the overall performance of the soil treatment.

Applications

In Mexico, the Estatec system has been applied widely on road embankment stabilization. In 2012, Tecnosuelo has stabilized more than 100 road sites. Initially it was used as a repair solution, mainly on hill roads with heavy rain. During hurricane seasons, the landslides and embankment affectation were major concerns for the road authorities. Not only regarding the direct reparation costs but also related to the road temporally closure in an emergency situation. The time to open the road is an important concern. Because the Estatec system is done after the re-filling of the embankment, it has been proved as a major success. From this experience the road Mexican authority started to specify the Estatec system as a solution for road slope deformation or instabilities prior to failures. As example it has been applied to solve:

- Soil creep; on some geological slopes where a clay (or silt) overlay a rock (mainly limestone or claystone), the clay can slide slowly. This process can be accelerated with the increased load on the surface; for example the construction of the embankment for a road. The Estatec system has been applied to stop the clay movement, and eliminate the pavement deformation, integrating the clay and rock stratums.

- Cut and Fill road sections; on this type of sections the interface between the cut and the embankment can form a stepped deformation or a failure. Underground hydrostatic pressures increase these instabilities. The Estatec system ensures integration of the embankment to the rock mass; eliminating the deformation on the pavement.

- Increase of shoulder width; in the case the road will need an expansion, the interface between the existing embankment and the new one can cause instabilities or the existing right of way doesn´t permit a sloped embankment. The vertical Estatec system can be a solution.

Other applications for the Estatec system, besides the road sector, are for deep excavations on urban areas, shafts or entrances for tunnels or for bridge abutments.

Conclusions

The main advantages of the Estatec system are:

- Top Down Construction
- Robust solution
- Applicable to any type of soil
- Elimination of deformation on the pavement
- Wide range of applications
- Can be built with low road interference
- Can be used as a repair or preventing methods for embankment stabilization

References

1. Blanco, A. (1994). "Bitácora de Cálculo Proyecto el Mexicano, Autopista México-Acapulco", México

2. Bowles, J. (1996). "Foundation Analysis and Design", EE.UU. ,5ta ed

3. Jekyll, P. (1996) " Soil Nailing of Excavations, An Introduction to Design", McGill University, Montreal

Acknowledgement

To Mr. Antonio Blanco, Tecnosuelo General Director, for the resources that made possible this presentation.