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Success cases of an innovative embankment treatment in Mexico and Latam

Les cas de réussite d'un traitement innovant des remblais au Mexico et en Amérique Latine

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ABSTRACT: Estatec System is a slope stabilization method on road works. It's a versatile system that could create a solution adapted for every geotechnical problem. It's a strong and permanent solution for several cases that can be combined with other technics. We will expose relevant study cases, working principles, applications, and advantages.

Estatec System has a long career and high experience. Nowadays there are Estatec works in excellent conditions built more than 2 decades ago, that are a permanent solution for difficult situations. In Latam there are more of two hundred of success cases solved, Estatec has a renewed patented and improved solution in Mexico, Costa Rica, Colombia, Peru and Bolivia.

The working principles are the mix of a ground improvement with grouting and a nailing system that provide shear strength to the treated soil. This solution provides a highly stable geometry. It's a ductile solution, with an excellent dynamic behavior.

Estatec is recommended for slope stabilizations in roads with complex geotechnical problems, as mountain areas, adverse climatology, difficult geology. It's a top-down method that can maintain the functionality of the road, while it's on construction.

RÉSUMÉ : Le système Estatec est une méthode pour stabiliser les remblais et pentes dans des ouvrages en particuliers routiers. C'est un système d'application polyvalent qui peut s'adapter a plusieurs défaillances géotechniques. Une solution permanente et solide qui peut se combiner avec autres techniques pour résoudre des problèmes complexes. Cet article presente plusieurs cas d'études, les principes de fonctionnement, ainsi que les avantages et principes d'application. Le système Estatec a une histoire de succès où l'expérience s'est accrue durant plus de 2 décennies incorporant des améliorations. En Amérique Latine on a plus de 200 cas de succès qui témoignent la solidité de cette solution. Une nouvelle méthode améliore ha été breveté au Mexique, Costa Rica, Colombia, Peru et la Bolivie. Cette solution est une amélioration mécanique du sol basé sur l'injection et le clouage du sol. La solution développe a la fois une géométrie stable et une masse de sol non rigide qui permet le transfert des efforts excédant, ayant un comportement dynamique supérieur. Le système Estatec est une solution ayant des performances supérieures pour des problèmes géotechniques complexes qui incluent des zones de montagne avec des conditions climatiques et géologiques défiant. Un avantage additionnel est la construction descendante (top-down), permettant en tout temps la fonctionnalité de la voie.

KEYWORDS: slope stabilization, ground improvement, mountain areas, Latam, top-down method.

1 INTRODUCTION

Estatec System is a versatile solution for slope stabilization, that could create a strong and permanent solution for every geotechnical problem. Estatec is a ground improvement technique that create a robust solution, and the system has the additional advantage that can be easily combined with other solutions and geotechnical works (drainage solutions, micro tunneling, micropiles, high-capacity ground anchors, ...).

The working principles are the mix of a ground improvement with grouting and a nailing system that provide shear strength to the treated soil. The treated soil is connected to a bentonite cement wall, in combination with a drainage system. Therefore, this solution provides a highly stable geometry. It's a ductile solution with an excellent dynamic behavior, that could support great movements, when exceptional adverse factors could occur.

Estatec System has a long career and high experience. Currently there are Estatec works in excellent conditions that were been built more than 2 decades ago. In Latam there are more of two hundred of success cases solved with Estatec. The system has a renewed patented and improved solution in Mexico, Costa Rica, Colombia, Peru, and Bolivia. It's an optimal solution for landslides in mountain areas with complex geotechnical problems, adverse climatology, difficult geology, highly steep slopes, in order that Estatec is a robust solution that solve the factors that provoked the landslide (drainage, soil shear strength, stabilizing geometry, consolidation, ...).



Figure 1. Slope Stabilization with Estatec System with two levels in mountain areas in Chiapas (México).



Figure 2. Pachuca – Tuxpan Road, Km 105+200. It's observed cracks on the top of the rotational movement

It's a top-down method that can maintain the functionality of the road while it's on construction. So, we can avoid the isolation of communities and maintain transportation routes, with social and economic benefits

We will present relevant study cases, working principles, applications, and advantages of the system.

2 SUCCESS CASES

Next study cases are located in Mexico but are representative of similar problems on mountain areas of Latam (tectonic and seismic areas, steep slopes, rainy weather, complex geology).

2.1 Pachuca – Tuxpan Road, Km 105+200.

In 2012, Pachuca – Tuxpan Road was affected for a landslide that cut one lane of the road. The road is on the mountainside, with a gabions wall that failed.

Main reason of the slide was the modification of the slope geometry with an embankment in the top of the slope, and in the rainy season, pore pressures increased, that provoked a rotational slide.

Estatec System solved the problem working over the landslide causes. Estatec was built with 3 levels in terraces. Its geometry reduce load on the top of the slide circles. The ground improvement and nailing system consolidate the existing embankment and create a stable geometry.

One of the main advantages is that the road could maintain his functionality, and it hasn't been closed.

2.2 Zoquital – Catalina Oil Pipeline. Puebla St. (Mexico)

Estatec has been used to solve some landslides at oil pipeline system between Xicotepec de Juárez and Huauchinango, near to Coaxicala (Puebla), (km 2+600, and 2+720 of the pipeline). Landslides may damage the pipeline and provoke relevant environmental affections on natural areas

Study area has an adverse weather on rainy season. The area is formed by mudstone with a high alteration at surface levels. The pipeline run over clearings and embankments in a mountain area with steep slopes.

At km 2+720 of the duct, we built two levels Estatec wall, with 90 m length in the upper level, and 60 m length in the lower level. Estatec System solved a rotational landslide with additional problems of regressive erosion.



Figure 3. Pachuca – Tuxpan Road, Km 105+200. 3 levels Estatec



Figure 4. Case 2. Km 2+720 Zoquital – Catalina pipeline. Rotational landslide and regressive erosion.



Figure 5. Km 2+720 Zoquital – Catalina pipeline. Stabilization with Estatec System.

Estatec acts on the causes that provoke the landslide. The terrace geometry removes soil load of the unstable zone to the lower area of the slope.



Figure 6. Km 2+600 Zoquital – Catalina pipeline. Landslide and regressive erosion.

Nails and improvement grouting consolidate the embankment soil mass and provide shear strength. Besides Estatec system avoids the weathering of mudstone levels and protects the slope from erosion.

At km 2+600, had been built a simple level Estatec System of 50 m length. We observed regressive erosion and water accumulation problems because there was a larger river basin.

Estatec was combined with surface drainage and an erosion and scour protect system

2.3 Km 46+130 Huixtla – Motozintla Road. Chiapas (Mexico)

Next case was a stabilization located in Chiapas (Mexico), at km 46+130 Huixtla – Motozintla road. There was an important landslide in 2012. The study area is placed in a mountain area with steep slopes, high rainfall, in a zone with clearing and embankment. Road failure was caused by the collapse of the drain tube and the accumulation of water.

In reference to geological conditions of the area, there are intrusive rocks (granite) with some metamorphic degree. The area is highly tectonized and the rock mass has an intensive fracturing and weathering of soils and rocks. High rainfall and a fractured rock mass provoke the presence of a significant thickness of alteration horizons.

Landslide impact on one lane of the road. Two levels Estatec System had been built in order to restore the lost platform and solve the slide. The upper level is 50 m length and 25 m in lower level.

3 WORKING PRINCIPLES AND SYSTEM COMPONENTS

3.1 Working principles of the method.

The aim of the Estatec system is to improve the soil (or rock) in situ in order to perform as a monolithic structure. The working principle is similar to the reinforced earth used on bridges; with the big difference that it is a top-down construction method, so it could allow to maintain the use of the road.

Estatec System acts on the causes of the slopes instability, with the next working principles:

- Creation of improvement soil mass, with a stable geometry. Estatec System uses existing soil, and it acts like a gravity retention wall.
- Stabilizing geometry. Terraces configuration removes destabilizing load from the top of the slide. This soil mass is put at the foot of the slide, where it acts as stabilizing load.
- Improvement of existing soils and embankment infills with a grouting system.



Figure 7. Km 2+600 Zoquital – Catalina pipeline. One level Estatec and erosion protection system.



Figure 8. Landslide Km 46+130 Huixtla – Motozintla road.



Figure 9. Landslide Km 46+130 Huixtla – Motozintla road.

- Estatec avoid slide circles, in order to increase shear strength of embankment soil mass.

- Estatec is a ductile solution. It could support movements and settlements without structural failure, so could be repaired and reinforced if weather or geological conditions exceed design conditions.

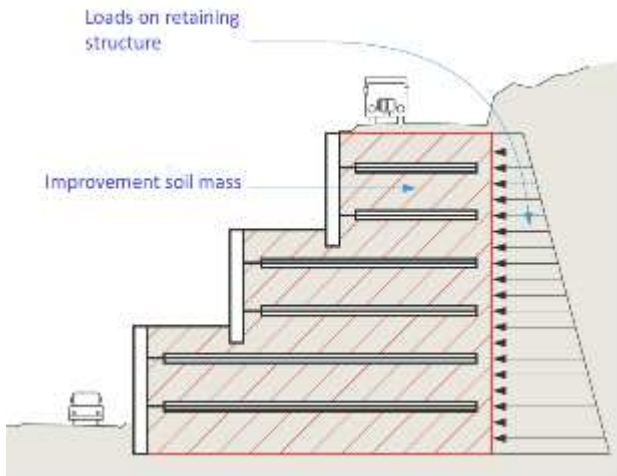


Figure 10. Working principles. Creation of improvement soil mass.

- Internal drain system reduces pore pressures and increases effective stress.
- Creation of a barrier from chemical weathering of rock mass, in rocks with sensibility to be exposed to adverse weather (mudstone, marls, ...).
- Estatec could be combined with others geotechnical solutions in order to improve application field of Estatec System:
 - Micropiles curtain when there are deep slide circles, in order to increase shear capacity of the soil.
 - Micro tunneling or surface drainage solutions when the road cross natural water flows.
 - High-capacity ground anchors, in order to increase stabilizing forces, adding a friction force on the slip circle.



Figure 11. Combination of Estatec System with microtunnelling techniques

3.2 System components and main functions.

Estatec System is a robust method of landslides stabilization. It's composed of the following elements:

- a) Cement – bentonite plastic wall.
- b) Active and passive nails system, with steel bars.
- c) Grouting of soil improvement.
- d) Shotcrete on the wall parament.
- e) Drain System.

Main elements of the system give him properties to achieve a robust landslide stabilization:



Figure 12. Excavation of cement-bentonite wall with conventional machinery.



Figure 13. Drilling of nails.

— Nailing system. Estatec nails are made with steel bars. The bars give shear and tension strength to the threatened soil. Bars have a double protection for corrosion, steel are precast with concrete cover before installation, in order to provide a good durability to the system.

— Grouting. The system uses a repetitive selective injection that produce a soil vertebration. It improves geotechnical properties of soil. It reduces its deformability. Soil improvement acts by different principles for every soil type:

- Granular soils (sand and gravels). The grouting fills the voids between soil particles and form a matrix that holds it together. In granular soils, grouting increases the confinement pressure and improves soil strength, according to Mohr Coulomb theory.
- Fine grained soils (silt and clay). The grouting method employed is fracturing injection. The grouting improves the soil performance by consolidating the soil and the intercalation of grouting “discs” on the soil structure.
- Rock slopes. Grouting fills the joints, discontinuities and voids found on the rock, and it improves rock strength and reduces deformability in the rock mass. Besides, the improvement soil protects the rock mass from weathering when rocks such as mudstones or marls are subjected to progressive alteration by exposure to environment.



Figure 14. Grouting of soil improvement in active and passive nails.



Figure 15. Preparation of cement-bentonite wall for shotcrete



Figure 16. Shotcrete on cement-bentonite wall parament.

— Cement-Bentonite Wall. The plastic wall creates a barrier that boost soil confinement and allows to increase the injection pressures, in order to obtain a better soil improvement. The plastic wall forms a vertical geometry in terraces, with a stabilizing effect. The vertical geometry removes soil load of the top of the slope, in order to reduce risk of develop landslides circles.

— Drain. A sub horizontal drainage system is placed on the lower zone of Estatec wall, in order to avoid water effects. The drainage system reduces pore pressures and increases effective pressures on the improvement soil.

4 CONCLUSIONS

Estatec System is a renewed patented solution for landslides stabilization with an optimal development in mountain areas of Latam, as Mexico, Bolivia, Colombia, Peru or Costa Rica. These countries have common factors that favors the occurrence of unstabilities. Seismic areas cause highly fracturing and weathering of rock mass. Highly rainfall and hurricanes provoke landslides due to water problems (increasing of pore pressures o, drainage failures, erosion). Tropical weather favors presence of poor soils (clays, silts). Mountain areas have isolate communities, that are very sensitive to interruption of communication routes, due to economic and social problems that could provoke.

Estatec system has a lot of advantages about their construction and functionality, in order to make a permanent solution for the most of unstability problems.

— Estatec is built with lightly machinery, that make possible a fast mobilization to working areas. A quick and determined intervention avoids progressive failures and a worsening of landslide stability and provides a definitive solution.

— It's a robust stabilization system that acts on a wide variety of causes that provokes the slide.

— Top – Down construction procedure in terraces allows to maintain the functionality of the road throughout the works.

— Estatec creates a retaining structure that is formed by the existing soil, improving its geotechnical properties, and reducing its deformability. This solution minimizes earthworks with economic and environmental advantages.

— It avoids progressive failure, due to intercept potential slide surfaces that provoked the unstability.

— It's a versatile system that could be combined with complementary works (micropiles, high-capacity ground anchors, surface drainage works, microtunnelling) in order to adapt the solution to each geotechnical problem.

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From Tecnosuelo, we dedicate this article to the memory of Eng. Juan Carlos Mendiola who died due to the COVID pandemic. He was a great leader and a great professional, who is part of the soul of the Tecnosuelo team.

We also dedicate to the memory of Mr. Jose Tlalpan, member of Tecnosuelo, for many years of effort and dedication, at the service of the company.

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