

Landslide repair in Km 11 CA-6 Highway using MSE walls

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Abstract. During the winter of 2010, a landslide occurred at the km 11 of CA-6 Highway between the cities of Tegucigalpa and Danlí in Honduras. Because of excessive precipitation, landslides are common in countries with tropical weather like Honduras, producing the increase in pore water pressure inside the earth. The proposal of this document is to show the mechanism that caused the landslide and expose the solution adopted to repair and ensure a long time stability of the landslide. For reach this goal, a Mechanically Stabilized Earth wall (MSE wall) was constructed. The MSE walls have proven to be an efficient solution around the world to landslides stabilization. Moreover, in many cases, there are compressible soils that have poor quality behaviour doing the MSE walls a more suitable solution because of their flexible structure and good performance to differential and total settlements. This is the case of a tiered MSE wall constructed to repair the slope failure in the km 11 of the CA-6 highway. This wall is the highest MSE wall constructed in Honduras and consists of three-tier structures with a total height of 23 meters. According the Federal's Highway Administration (FHWA), the tiered walls have showed to be an efficient solution because it tends to increase the factor of safety of the slope. For the design and evaluation of the global stability of the MSE wall, DEMO 82 and FHWA NHI-10-043 design methodologies have been used.

Keywords: *Landslide, MSE wall, tiered wall, global stability, factor of safety.*

Introduction

During the 1960's Henry Vidal discovered and patented the modern concept of reinforced soil. But, since 2000 year ago Chinese people used bamboo to stabilize many sections of the Great Wall of China. Moreover, since the 1960's the use of mechanically stabilized earth (MSE) walls have increased in a rapidly way around the world.

MSE walls, consist of an earth fill constructed and compacted with thin earth layers reinforced with discrete metallic or geosynthetics elements to give tension resistant that soil lacks for itself. Moreover, to avoid erosion damage, the MSE walls are constructed with a specific facing type (e.g. masonry blocks, concrete disreet panels, welded wire mesh, geogrid wrap around, etc.)

Today, MSE walls are one of the most suitable solutions to landslide stabilization projects and where poor soil conditions are presented is an efficient type of wall to use, because of its flexible structure that allows this type of walls to better withstand the total and differential settlements.

The principal goal of this paper is to present a real case of design and construction of a MSE wall that was constructed to repair a landslide and recover a highway lane on the CA-6 Highway in Honduras.

Problem and background

During the winter of 2010 a landslide occurred in the km 11 of CA-6 Highway that connects the principal cities of Tegucigalpa and Danlí, Honduras. Different types of landslides are common in the CA-6 Highway because of it complex geological and hydro geological conditions. These conditions are very influenced for excessive precipitations that take place between the raining period between the months of May and November.

Geological and Hydrogeological conditions

The unstable soil mass presented a laminate structure. These types of soils are very susceptible to the increments of water table conditions, converting their apparent hardness into unstable soil and increasing the pore water pressure into the ground. Also, their laminate structure and mineral composition gives the chance to develop slip surfaces through thin surfaces with very poor residual strength. At this project, the soil field test revealed the existence of a well defined failure circular plane that passes through the contact zone of the embankment fill and the bedrock. The soils found consist of silty sand soils resting on a layer of clay soils with residual soil behaviour which at the same time was resting on the bedrock. (See fig 1.) Laboratory tests were

performed at the zone of the thin surface where the slide occurred. According with the engineer supervisor the frictional and cohesion parameters at the slip surface are: $\phi' = 0^\circ - 5^\circ$ and $c' = 73.0$ to 98.0 kN/m^2 for the material at the sliding band of soil.

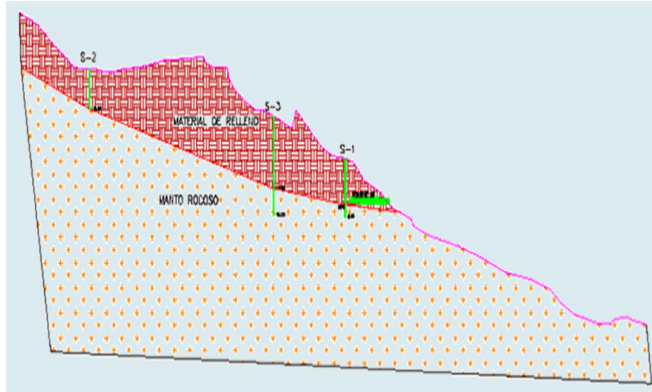


Figure 1. Geological conditions at Km 11+400 in CA-6 Highway.

Back Analysis calculations

Back analysis calculations have been done in order to get the real soil parameters (ϕ' and c') of the sliding zone at which limit equilibrium was reached (i.e. Factor of safety around 1). To make this analyze was necessary to use of a commercial program of limit equilibrium. . For this particular case, Bishop Method was used. Evaluating different scenarios a ϕ' and c' values were obtained considering water table position near to the ground surface. The parameters estimated were: $\phi' = 2^\circ$ and $c' = 20.0 \text{ kN/m}^2$ for the fill material, $\phi' = 0^\circ$ and $c' = 73.0 \text{ kN/m}^2$ for the material in the sliding band of soil. See in fig. 2 the results of the back analysis made and see how in the failure zone the factor of safety is around 1, indicating the limit equilibrium has been reached.

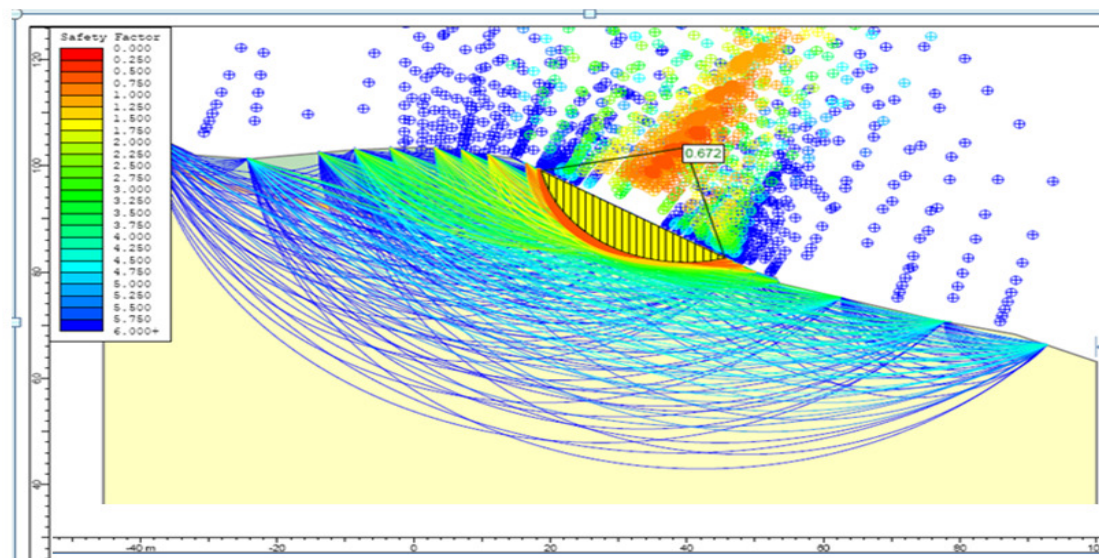


Figure 2. Back analysis calculations ($FS \approx 1$) (Slip plane in orange)

Solution

MSE Wall

To solve the problem different solutions were analyzed, but finally a MSE wall was designed and constructed. This solution involves the remove of some portion of the slide mass and replacement of this material for a new and better material in order to construct an earth reinforced fill with polymeric geogrids and guarantee the future stability. Additionally, the removed material from the slide mass was placed and re compacted to add more weight at the landslide's foot.

In the last decade, a significant amount of MSE walls (more than $15,000 \text{ m}^2$) have been constructed in many highway new and repair projects around Honduras. For this project, a three tiered wall was constructed. The first wall (at the bottom) has 10.00 m high, the middle one 6.00 m and the third has 5.00 m.

Design Methodology

For external and internal stability calculations DEMO 82 (FHWA, 1997) has been used. However, FHWA-NHI-00-043 (2001) recommendations for tiered MSE walls also have been used.

Reinforced Soil

The reinforced soil used consists of a granular fill that has a greater friction angle than $\phi' = 34^\circ$ and has a weight of $\gamma' = 19\text{kN/m}^3$.

Type of Reinforcement

Integrally formed structural uniaxial geogrid made with High Density Polyethylene (HDPE). Geogrids with different levels of resistance have been placed.

Type of Facing

Welded wire mesh with biaxial geogrid and nonwoven geotextil. See fig. 3.



Figure 3. Facing type of the MSE wall

External and Internal stability analysis

For each of the three walls, the external and internal analyses were evaluated using Tensar's software.

For external stability, the mechanisms that were evaluated are: Sliding, eccentricity, overturning and bearing capacity. On the other hand, for internal stability, these mechanisms were evaluated: rupture resistance, pullout resistance, internal sliding and connection check.

But, according to FHWA-NHI-00-043 (2001) for Tiered MSE walls evaluation of the global stability of the entire reinforced structure is an essential computation.

Global stability

The global stability was evaluated using Tensar's computer software; this program uses the Bishop's Modified method of limit equilibrium.

According to FHWA the global factors of safety of a new constructed MSE wall should be around 1.50 for static load conditions and it never has to be less than 1.30 for static load conditions and 1.10 for seismic conditions. The calculated global factors of safety of the wall for static and seismic load conditions were 1.396 and 1.187, respectively, showing that the design is safe. (See fig. 4)

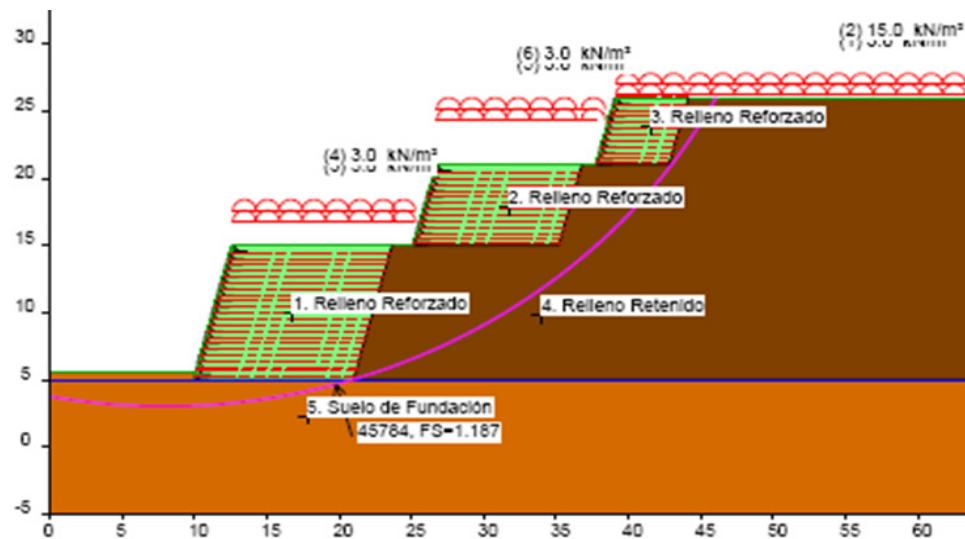


Figure 4. Global stability calculation for seismic conditions $F_s=1.187$. ($F_s>1.10$)

Construction Process

The construction sequence of the MSE wall constructed at the km 11 of the CA-6 highway was: (See fig. 5, 6 and 7)

1. Preparation of subgrade.
2. Erection of the first row of facing line.

3. Construction of drainage blanket at the base and preparation of chimney's drains of gravel and geocomposite's drains behind the wall.
4. Placement of the first layer of reinforcement elements on the backfill.
5. Placement and compactation of the backfill over the reinforcing elements to the level of the next reinforcement layer (according to design).



Figure 5. Construction of the first wall (2011)



Figure 6. Construction of the second wall (2011)



Figure 7. Construction of the third wall (2011)

6. Construction of superficial drainage and superficial protection plastic barriers to avoid runoff infiltration.
7. Enhancement of the drainage systems at the highway level.

Monitoring

At this project, monitoring points or other control devices were not placed in field. But, at this moment (2013), no movements have been observed in this project that was constructed and finished two years ago. See project recent conditions at fig. 8



Figure 8. Panoramic 2013's view of the MSE wall constructed in the km 11 of the CA-6 highway

Comments and conclusions

Because of the good behaviour of this project and other similar projects in the country, MSE walls are a suitable solution to landslide stabilizations projects.

Through the analysis made it has been proved that the design of the tiered MSE wall is stable for static and seismic loads conditions of this project.

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