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Use of structural geogrids for earth dam heightening

Surelevation de barrage en terre avec structurel geogrilles

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ABSTRACT: The 40 m high Tlacayan tailings containment dam, located in the Central Zone in Peru, was designed to raise its height since another appropriate location to deposit tailings could not be found. In view of the location of a major roadway close to the toe of the dam, it was necessary to increase the dam height using structural geogrids in order to safely design the steep slopes. This Paper summarizes the geotechnical parameters, geogrid layout and the factors of safety achieved for the final dam height of 63 m.

RÉSUMÉ : Le barrage de stériles miniers Tlacayán, 40 m. Haut, localisé dans la Zone Centrale au Pérou, a été conçu pour élever sa hauteur depuis qu'un autre emplacement approprié déposer les stériles miniers ne pourrait pas être trouvé. Vu l'emplacement d'une chaussée majeure près de l'orteil du barrage, c'était nécessaire d'augmenter la hauteur de barrage qui utilise le geogrilles structurel pour concevoir les inclinaisons escarpées sans risque. Ce Papier résume les paramètres du géotechnique, disposition du geogrilles et les facteurs de sécurité accomplis pour la hauteur de barrage définitive de 63 m.

1. INTRODUCTION

The Tlacayan embankment dam is located in the Central Zone of Peru, and stores polymetallic tailings produced by the Compania Minera Atacocha S.A.A. The original dam was designed for a maximum crest height of 50 m. However the increased mill output required additional storage volume which would increase the height of the dam to 63 m.

The increased crest elevation at the steeply terrained site was limited by the presence of a major roadway at the toe of the dam. This roadway could not be moved due to geographical constraints. The space limitation between the present toe of the dam and the roadway severely restricted the design of safe conventional downstream slope. Recourse was therefore made to some complementary structures to safely design the slopes to comply with the dam safety regulations in Peru.

This Paper documents the design criteria and the technique adopted for the safe design of the dam.

2. CHARACTERISTICS OF TACLACAYAN DAM

The dam is constructed as a zoned embankment dam. It comprises of a central impervious core constructed with clayey gravel (GC); an upstream shoulder of coarse non-acid generating tailings (SP) obtained from an older dry tailings stack; and downstream shoulders with coarse tailings and mine waste rockfill, SP and GM, respectively. Filters comprised of sandy gravel (GP) and wrapped in a geofabric are placed both upstream and downstream of the clay core. All materials are mechanically compacted with a vibratory roller.

The space between the toe of the dam and the adjacent was extremely limited, in places as small as 6m. It was therefore necessary to construct a counterfort reinforced concrete retaining wall at the downstream toe with a total length of 195 m, and a maximum height of 15 m. The retaining wall was designed against K_0 earth pressure from the dam in addition to seismic forces.

3. DESIGN OF THE EXTENDED HEIGHT

The Table 1 summarizes the geotechnical parameters of the embankment materials.

In the absence of any liquefiable materials, the pseudostatic analyses were carried out with a seismic acceleration coefficient $a = 0.15g$.

The initial design of the dam raise with the limited downstream space available resulted in static and pseudo-static factors of safety of 1.23 and 1.0 respectively. These factors were considered low in view of the height of the dam and the resulting environmental and property damage from a potential failure.

In order to improve stability, the use of structural geogrids placed horizontally between El 3370 and 3383 m was employed.

The selected geogrid has a long-term (after age and creep effects) tensile strength of 3 t/m. Between El. 3370 and 3381, the geogrids are installed every 0.6 m in compacted fill, while between El. 3381 and 3383, the vertical spacing is reduced to 0.3 m. Each horizontal geogrid layer extends from the upstream slope of the impervious core to the downstream slope. The geogrids extend through the downstream filter.

The static and pseudostatic factors of safety for the designed section are 1.5 and 1.15 respectively, indicating the efficiency of the measures employed to increase the stability of the structure.

An additional important benefit of geogrids, consists in the superior section of embankment will develop small displacements during a great seismic event, as consequence of the major stiffness.

The figure 2 shows the critical failure surface obtained from pseudostatic analyses, with a seismic acceleration coefficient $a=0.15g$.

Table 1. Geotechnical parameters of the embankment materials

Materials	γ_t/m^3	$c' \text{ t/m}^2$	$\phi' \text{ deg.}$
Impervious core (clayey gravel)	2.0	2	35
Shoulders (coarse tailings)	2.1	0	34
Shoulder (mine waste)	2.2	0	35
Filters (sandy gravel)	2.1	0	35

5. REFERENCES

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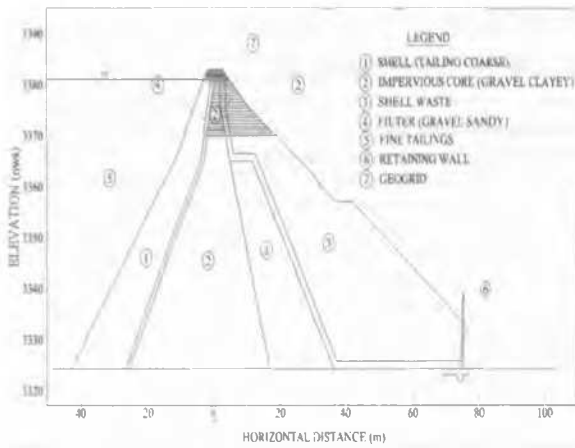


Figure 1. Designed section with the structural geogrids

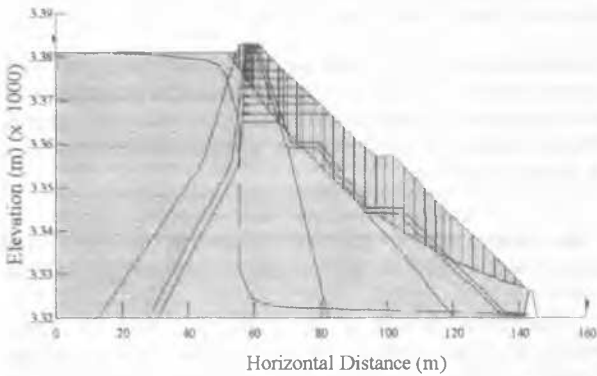


Figure 2. Shows the critical failure surface

Fig. 1 shows the designed section at the maximum height of the dam, with both the structural geogrids and the retaining wall at the downstream toe.

4. CONCLUSIONS

The limited space at the downstream toe required the following measures to safety increase the height of the dam from 40 to 63 m, and to provide acceptable factors of safety.

- Construction of a reinforced concrete retaining wall, 15 m high, at the downstream toe.
- Installation of horizontal layers of reinforcing geogrids, with a vertical spacing of 0.3 to 0.6 m between elevations 3370 and 3383 m. Figure 3 shows details of the geogrid layout.

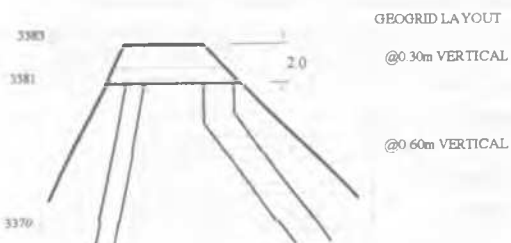


Figure 3. Details of the geogrid layout