Geotextile Reinforced Retaining Wall in a Spillway Approach Channel

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ABSTRACT: For the construction of a spillway approach channel of the Sandillal Hydropower Dam Project in Costa Rica, a rock slope in vulcanic tuff had to be cut back. Due to unfavourable geological conditions, sliding of the excavated slope occurred. Because the sliding mass in the approach channel had been removed, the slope remained in unstable condition. A retaining berm at the toe of the slope was constructed to stabilize the 40 m high slope. Due to the limited width of the approach channel and hydraulic conditions, the required slope inclination of the berm of 1v:1.25h could not be achieved by means of a normal embankment out of the available random fill material. Therefore, a reinforced soil embankment was designed and constructed out of non-woven gotextile. Special shuttering was designed to allow the placing and compaction of the fill in 1 m layers between the geotextile reinforcement. The geotextile in the slope surface was protected by shotcrete against UV-radiation, atmospheric influences and water action in the spillway approach channel.

1 INTRODUCTION

The Sandillal hydropower project in Costa Rica uses the discharge from the Arenal and Corobicí hydropower plants to produce 140 GWh with 32 MW installed capacity.

In addition to the powerhouse with its intake structure, the main project structures are the rockfill embankment dam with a 51 m maximum height above foundation level and a 270 m crest length and an open chute spillway with a capacity of 900 m³/sec.

The spillway is located on the left abutment of the dam. The spillway structure comprises an approach channel, a gated overflow weir, an open chute and a stilling basin.

2 THE SPILWAY APPROACH CHANNEL

The spillway approach channel had to be cut into the left dam abutment to optimise the approach of the water towards the spillway. This resulted in a channel with an approx. 40 m high left bank and a 15 m high right bank. Hydraulic model tests indicated an optimum slope inclination of 1v:1.25h. The water depth in the 20 m wide channel will be up to 11 m. The maximum velocity of the water in the approach channel will be 4 m/sec.

The channel had to be excavated into vulcanic rock formations. The riolitic tuffs which form the lower part of the slope are weathered which resulted in a moderate strength and a friction angle of only 25° with a cohesion of 5 kN/m² under saturated conditions (obtained from the analysis of the overall slope stability). The uppermost part of the slope is built in a highly fractured basalt flow. The tuffs and the basalt rock are highly fractured by three sets of joints, one more or less parallel to the slope. During excavation a sub-horizontal thin clay zone was detected slightly above the channnel bottom. This zone was interpreted as a paleo-surface with high weathering of the lower tuff layer in turn covered by subsequent tuff sedimentation on top. Slickensides indicated movements on this potential sliding surface.

As a result of the increase in saturation of the tuffs in the left channel slope and seepage water on top of the clayey layer from

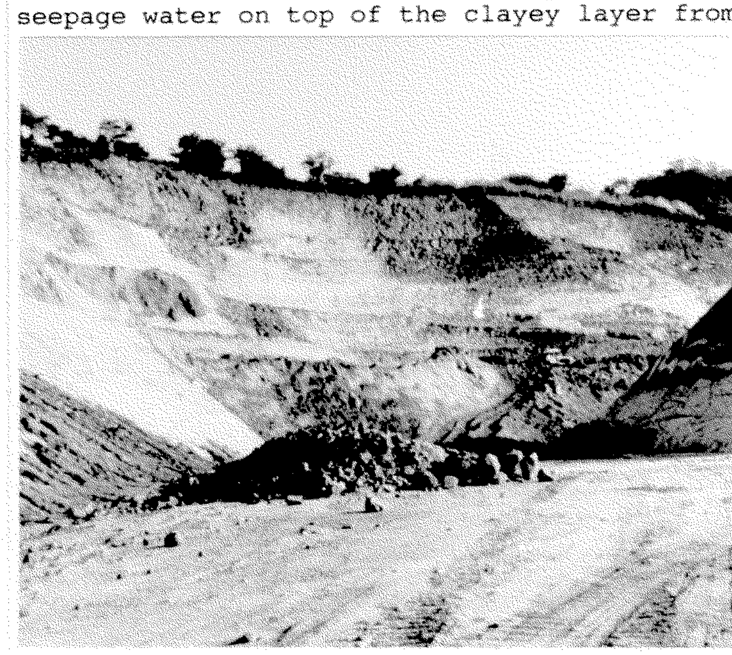

Figure 1 Sliding area of left slope of the spillway approach channel.

rainfall the relatively steep left slope became unstable. Appr. 50,000 m^3 of tuff and basalt slid down on a curved sliding plane through the tuffs and on top of the clay zone. The approach channel was filled with sliding mass material for a length of about 100 m, and this had to be removed to allow unrestricted flow of flood water towards the spillway.

3 STABILIZATION MEASURES

3.1 Alternatives

After the failure of the left slope and the removal of the slipped material in the approach channel, the left slope remained in an unstable condition. Impounding of the lower 11 m of the 40 m high slope by the reservoir would further reduce the stability of the slope due to uplift, with the consequent risk of further sliding.

Stabilization measure therefore became necessary. Several alternatives had been previously investigated such as:

- reduction of the steep slope inclination and provision of intermediate berms,
- installation of anchors both with and without reinforced shotcrete in the slope surface,
- installation of drainage tubes in the slope above the reservoir level,
- construction of a single retaining berm at the toe of the slope with a crest at the reservoir level or a double berm with a crest above the reservoir level.

Stability calculations indicated that a slope inclination of at least 1v:2h is required to obtain stable conditions. Due to the necessary, but uneconomic excavation works required, this alternative was not feasible. Anchoring of the slope would adequately increase the stability of the slope. However, the dense grid of anchors required over the entire height of the berm (3 m x 1.50 m) made this alternative also economically unfeasible.

A double retaining berm at the slope toe with a crest above reservoir level would provide sufficient stability. However, even a single berm with a crest slightly above the reservoir level would provide the required stability.

3.2 Design of the reinforced retaining berm.

Finally, a retaining berm was selected with a crest slightly above the reservoir level in combination with a stepped slope above the berm and drainage holes in order to reduce the weight of the upper part of the slope. A berm crest width of 17 m was possible between the cleaned sliding surface of the slope and the left bank of the approach channel.

The fill material to construct the berm was available from the slipped material. This is a mixture of tuff with basaltic stones and small size boulders. The friction strength was determined to be: friction angle 35°, cohesion 8 kN/cm^2. Based on hydraulic model tests inclinations of the channel slopes of 1v:1.25h were required. Using the randomly graded slipped material, a stable retaining berm with the required slope inclination could not be achieved for a normal embankment.

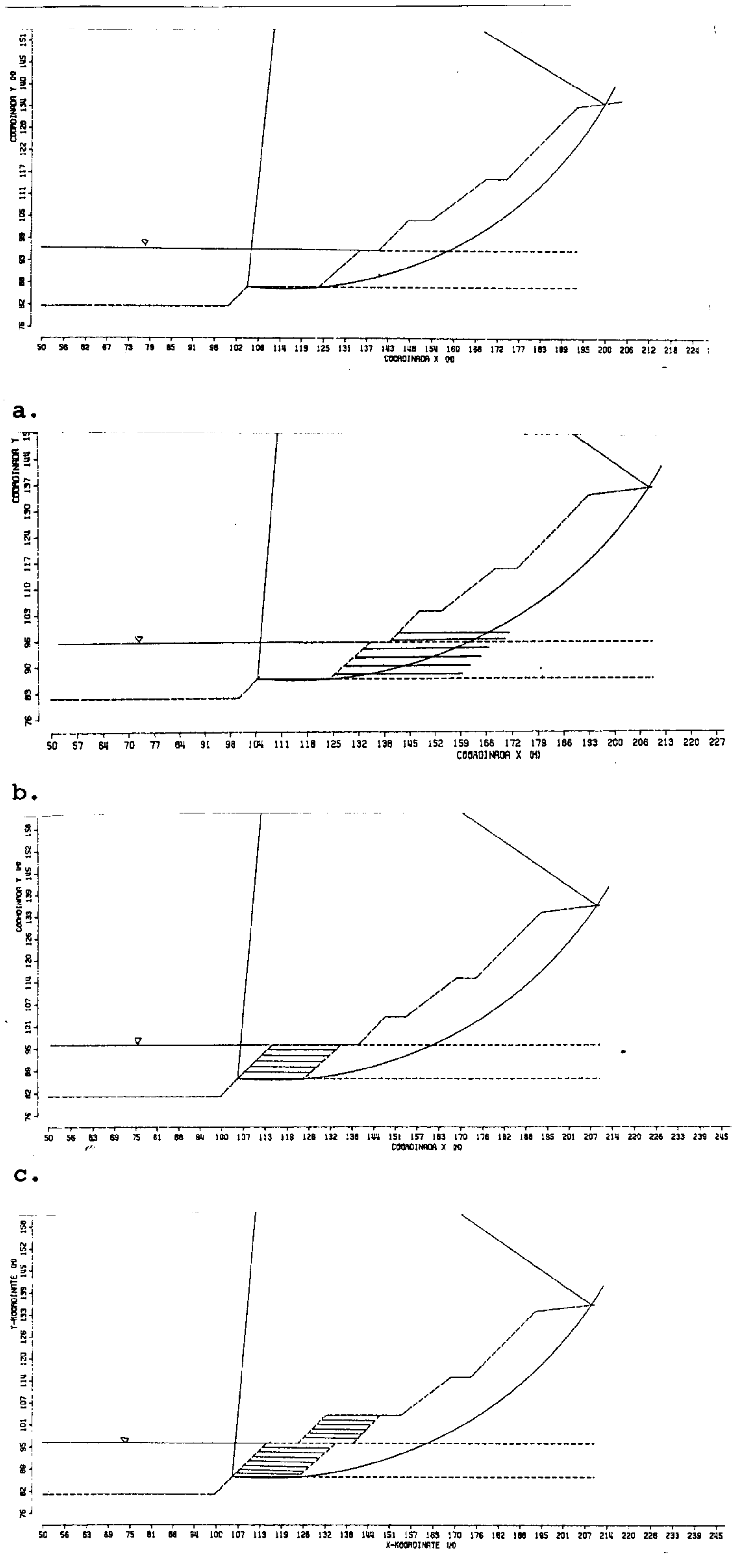

Figure 2 Stability analysis of alternatives for slope stabilization:
a. stepped slope without stabilization measure, safety factor f=0.89; b. slope with anchors, f=1.19; c. slope with one berm, f=1.04; d. slope with two berms, f=1.12

To obtain the necessary slope stability, a retaining berm reinforced by non-woven geotextile was designed. The horizontally will be anchored in the 1 m thick placed fill on top of the geotextile layer. A geotextile was selected instead of a geogrid in order to keep the random fill with its fine grained material in place in the slope of the berm. It will also prevent washing out of the fine grained soil from the random fill in the event of groundwater flow on the slope or during draw down of the reservoir, as the geotextile acts as a filter in the slope surface. Additionally, the horizontal geotextile layers provide improved drainage of the berm.

The main task of the geotextile is to increase the tensile strength of the random fill to provide the necessary stability of the berm. The design of the reinforcement was performed on the basis of stability calculations according to the method established by Rüegger, 1984. A geotextile with a tensile strength of at least 8 kN/m was considered. The reinforcing length was determined to be 6.80 m and the number of reinforcement layers to be 10. This resulted in a requirement for geotextile layers at 1 m intervals over the entire height of the berm.

It was also required to protect the slope surface against UV-radiation, atmospheric influences and the water action in the spillway approach channel by a shotcrete layer. The 5 cm thick shotcrete layer is reinforced with a steel wire mesh. The wire mesh is anchored in the berm with reinforcement dowels. Weepholes are installed for drainage purpose to prevent water pressure building up behind the shotcrete in the event of low reservoir level.

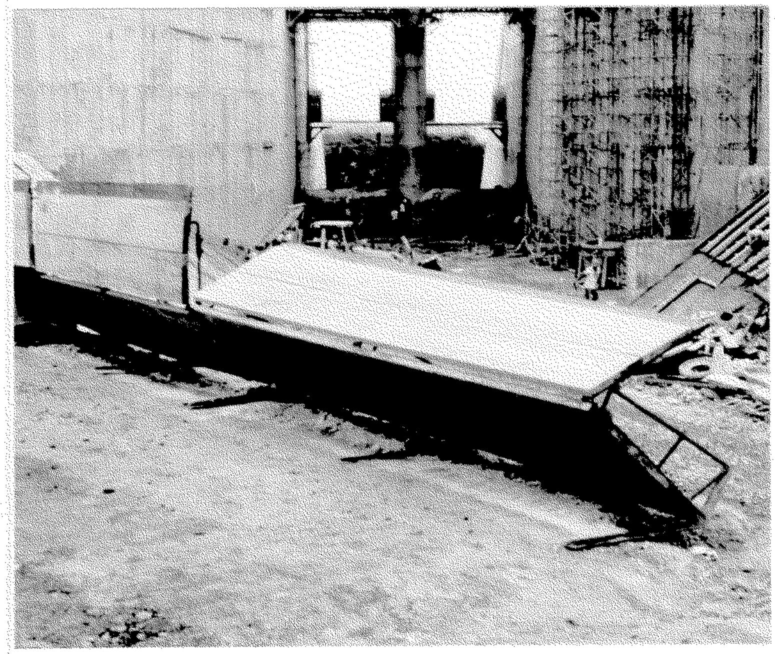

Figure 4 Shuttering for the construction of the geotextile reinforced embankment fill.

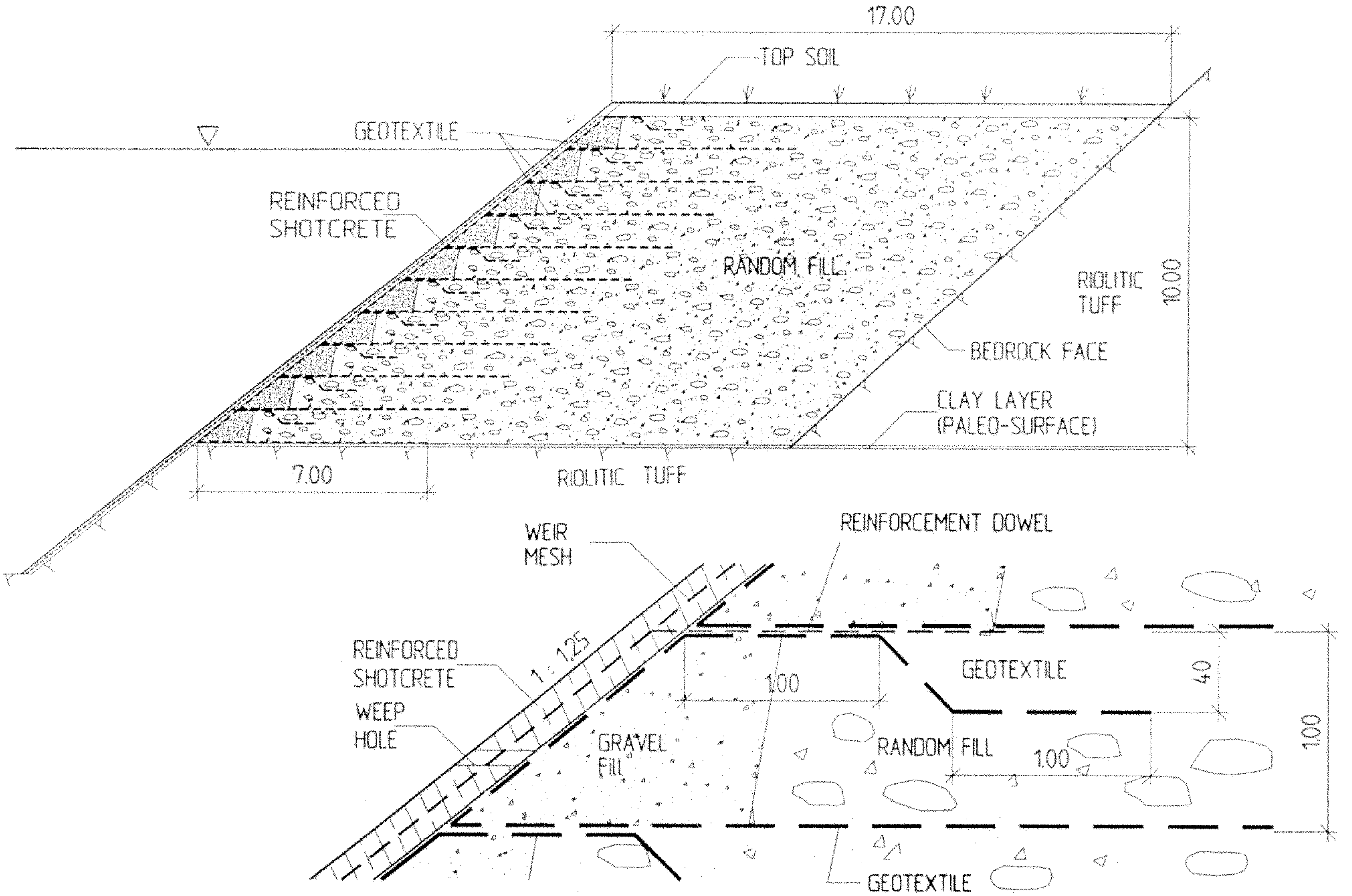

Figure 3 Design of the retaining berm reinforced by geotextile.

4 CONSTRUCTION

Construction of the retaining berm with geotextile reinforcement required special arrangements to install the geotextile at a vertical spacing of 1 m between the embankment fill layers with a loop in the slope surface and to allow dumping, spreading and compacting of the fill material in the slope line of the berm. 2 m long formwork-type units were designed and manufactured each comprising a metal frame with 3 horizontal metal feet 0.65 m long and strongbacks to support a board which is inclined in accordance with the slope of the berm. The board, with a total height of 1.60m, is subdivided in two parts, each 0.80 m high. The strongback support of the board is hinged in order to allow folding of the upper half of the board. A socket coupling fixes the strongback when the board is unfolded (see Figure 4). This enables the dumping, spreading and compaction of the 1 m thick fill between two geotextile layers in two 0.50 m thick layers next to the formwork in the slope.

The construction sequence was as follows:

- installation to the required slope of several units of the formwork with the upper board folded for one embankment lift;
- placing of the geotextile in a 7 m width horizontally and folding the geotextile slope loop and anchor strip around the formwork;
- placing and compaction of a 0.50 m thick lower layer of gravel fill next to the formwork in a strip appr. 2 m wide and of random fill between the gravel fill and the abutment slope;
- folding back of the upper part of the board with the geotextile;
- placing and compaction of an o.50 m thick upper layer of gravel fill next to the formwork and of random fill between the gravel fill and the abutment slope;
- anchoring of the geotextile in the previously placed upper fill layer in a trench, refilling of the trench and compaction of the material;
- removal of the shuttering units.

This construction sequence was repeated for each 1 m lift of the embankment fill with one geotextile layer. Following the placement of the embankment lifts, the anchor dowels, wire mesh reinforcement and shotcrete were installed in the slope face.

Spreading of the dumped fill material was carried out by a dozer and compaction by a 15 tonne static load vibratory drum roller. Gravel fill was placed in the slope area to prevent damage to the geotextile by sharp edged stones and boulders and to obtain a high degree of compaction in the sloping berm surface. Despite the high degree of compaction of the fill between the geotextile layers no ballooning occurred to the slope face.

Geodetic displacement measurements did not indicate movement of the reinforced retaining berm during first reservoir impoundage and initial project operation.

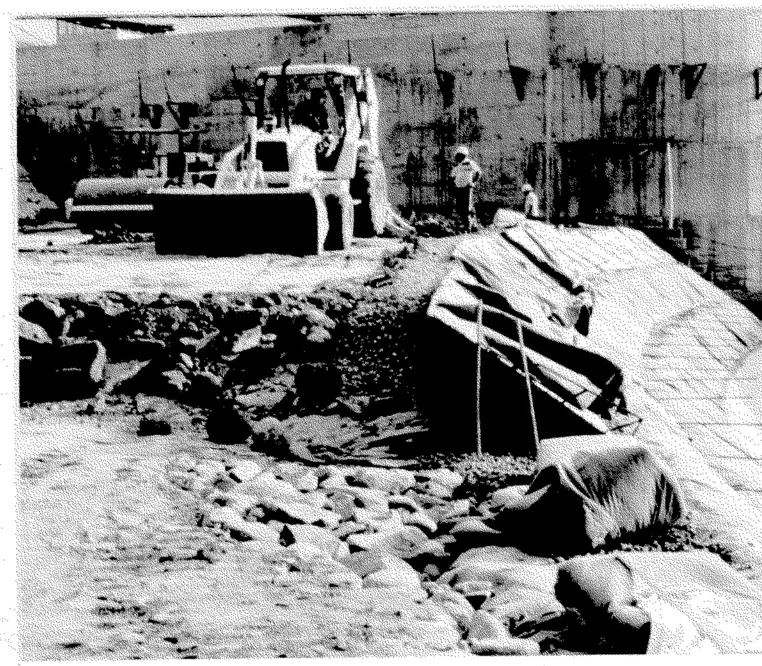

Figure 5 Construction of the retaining berm with geotextile reinforcement.

Figure 6 Completed retaining berm in the upper part of the left slope of the spillway approach channel.

REFERENCES

Rüegger, R (1984)Berechnungen der Zugkräfte in Polsterwänden, *Das Geotextil-Handbuch, Schweizerischer Verband der Geotextilfachleute*