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Chilean experiences with geosynthetics in embankments

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ABSTRACT: At present every geosynthetics (or geocomposites) application in Chile is being analysed employing functional design procedures. As in many other applications, geosynthetics included in embankments built on soft soil (clay and organic material) and/or on soluble-salt soil, are fulfilling varied basic functions such as *separation, drainage, reinforcement* and/or *impermeabilization*.
New products are being marketed and used prior to the availability of relevant standard testing methods. As result of this state of affairs, too often the engineers find themselves obliged to choose between two alternatives, namely: testing using available but irrelevant standards, or else discarding testing. The present work is supplying useful guidelines covering the knowledge of the actual geosynthetics behaviour in Chilean highway and mining applications and characterization concerning Chilean embankment constructions including geosynthetics, along with recommendations on this subject-matter. These recommendations are providing an up-to-date checking of general principles and subsequent testing procedures and/or requirements regarding highway and mining applications in accordance with Chilean geological and geotechnical realities.

1 INTRODUCTION

Nazca Plate action in the chilean (figure 1), can be considered in relation to the modelling of geomorphological elements and the geomechanical distribution throughout the whole longitudinal extension of continental territory. In addition, the contact between the two tectonic Plates defines a series of seismic strips, or belts, as well as a rejuvenation (or sediment-depositions basins) of local geotechnic.

In view of the above, "life lines" such as ducts, roads, electrical power networks, etc. are interacting with a varied geomorphology and are requiring adjustments of some proper interaction in local subsoils, with an ambiental impact as reduced as possible. Now, very often the foregoing is calling for the inclusion in civil works of geosynthetics designed for sundry mechanical and hydraulical conditions.

The proper modelling of geosynthetics used in mining works (heap leaching facilities) and in highway projects (embankments), considered from the viewpoint of soil *separation/reinforcement*, prior to whatever designs and specifications, requires updated and simplified tests that qualify both the *"synthetic"* aspect and the *"geo"* aspect (foundation subsoil and embankment backfill) taking into a account the building methodology adopted.

2 APPLICATIONS OF GEOSYNTHETICS IN CHILEAN EMBANKMENTS

Figure 2 showing that associated to pluvial conditions and bad drainage in the sediment-depositions basing of the Northern Central Depression, and also due to mining activity in the region, problems are arising in embankments and terraces resting on collapsable subsoils termed as *"soluble"* and constituted by salts forming *"saline crusts"*. Now, the fundamental condition for building embankments on such materials is preserving the humidity degree that is directly affecting their bearing capacity (Paredes 1984). In highway works such as embankments the problem remains limited to preventing that the scarce precipitations may produce some effect through their infiltration into the upper strata. In this case it is considered that the main stressing is caused by layers compaction on the geosynthetic.

In the instance of heap leaching facilities such as those used in copper exploitation, interface pressures are reaching values comparable to those causing geosynthetic rupture, in addition to the presence of lixiviation rubble that may include large clasts that

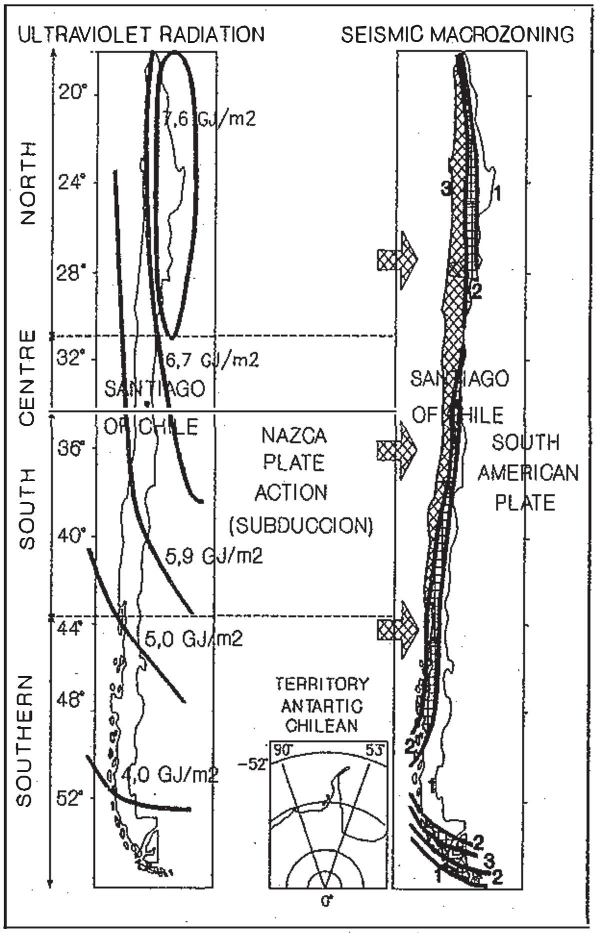

FIG. 1. Tectonic action, seismic zoning and ultraviolet radiation along and across the chilean territory.

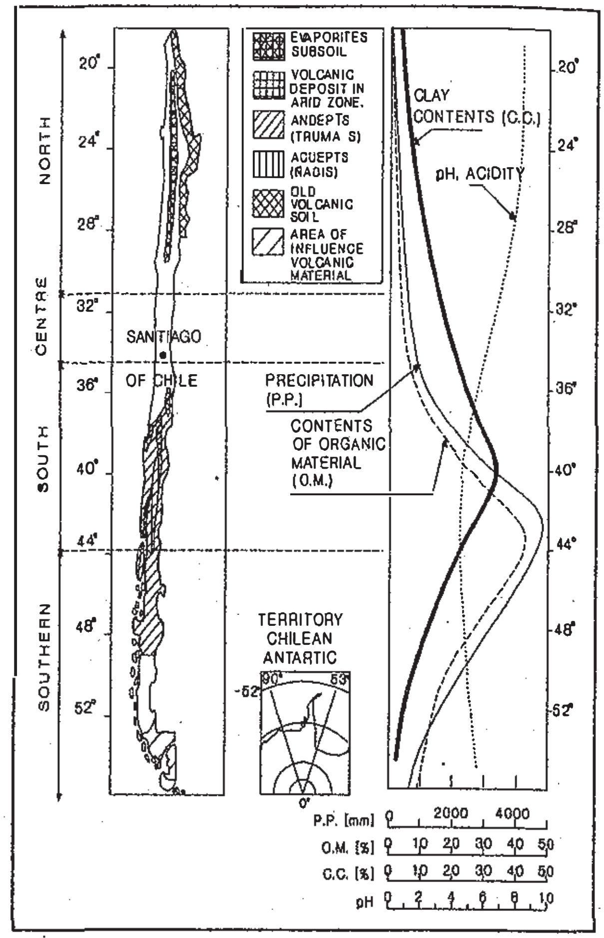

FIG. 2. Variation of properties along and across the territorry related to soil geographic distribution derived from volcanic materials and evaporites.

increase stressing and affect soil/geosynthetic interface through their weight and sharp edges. Some filtration of operation liquid towards the collapsable foundation subsoil would cause settlements that the geomembrane must absorb (Smith and Welkner, 1994). Thus these reasons are leading to the recommendation of providing the *protection* and *reinforcement* by means of a geotextile placed onto and/or under the membrane. In other words, it is recommended to design some optimum geocomposite in keeping with the requirements of the work.

Figure 2 is pointing out the soft subsoil areas existing chiefly in the Chilean far South, inasmuch as subsoils existing in the more northern region are principally granular and/or with better drainage conditions, excepting localized sectors of hydrographic basins that are descending stepwise (figure 1).

In sectors of highways extending on weak subsoil (South of Chile, figure 2), and normally resting on embankments less than 3 meters high, the same include geosynthetics (non-woven geotextiles) to act as a means of *separation/filter-stabilization*, mainly in order to improve the conditions of constructive operations (reducing foundation-seals remoulding, and maintaining design-bases thicknesses), as well as to ease the consolidation that improves sub-grade resistance during the passing of time.

3 SOIL-GEOSINTHETIC INTERACTION MECHANISM ASSOCIATED WITH FUNCTIONS AND PROPERTIES OF REINFORCEMENTS USED IN CHILEAN EMBANKMENTS

Figure 3 shows that the more habitual applications of geosynthetics in Chilean highways are corresponding to the positions 1 and 2, i.e. to low embankments (less than 1 meter high) that are having slopes below 25°. However, some situations (new embankements, widening and/or repairs ones) are corresponding to position 3 and even to position 4 (sustainment/containment structure). Anyone of the above situations involves the same concept with diverse mobilization degrees of soil-geosynthetic interaction through friction or shearing when passing from position 1 to position 2, from position 2 to position 3, and from position 3 to position 4, i.e. when increasing the embankment height and/or slope (Gourc 1993).

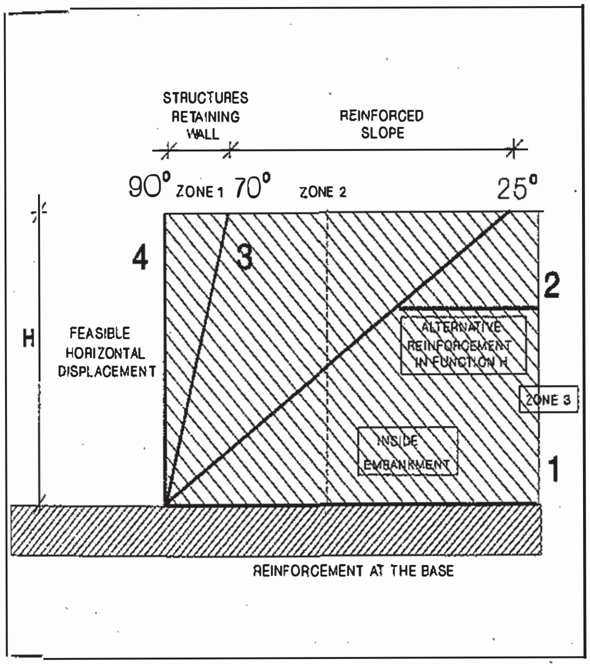

FIG. 3: Habitual applications of geosynthetics in chilean embankments and terraces.

Hence the contribution to strength through friction and/or connection generated in soil-geosynthetic interface develops and interaction where the reinforcement will not reduce settlements magnitude through consolidation (occurring in clays in the medium ter), or through secondary consolidation (occurring in organic clays and micaceous sands in the long term). In order words, by insuring pore-pressure dissipation in the subsoil, the reinforcement would rather control the remaining differential settlements. Considering the *separation, stabilization* and *reinforcement*, functions, we it follows that a given subsoil exhibiting a CBR < 3% can be reinforced; however, the *filtration* function does not loose its importance because the response of ttheload-embankment-geosynthetic-subsoil system is strongly influenced by the geometry and rheology of each component thereof. Of course stress/strain and stress/strain gradient responses of the soil are depending on permeability and on boundary condition modifications such as drains of backfills, and they are also depending on the velocity of application of dynamic loads onto the base and of the mainly static load onto the foundation seal of embankments.

4 CHARACTERIZATION OF FOUNDATION SUBSOIL OF EMBANKMENTS THAT HAVE BEEN IMPROVED AND/OR REINFORCED BY MEANS OF GEOSYNTHETICS

The necessity of some adequate characterization of foundation subsoil is due to the fact that the national practice adopted in Chile by inspectors examining the work in situ is essentially empirical because they are considered as unnecessary the using of geosynthetics when subgrade CBR is above 3%.

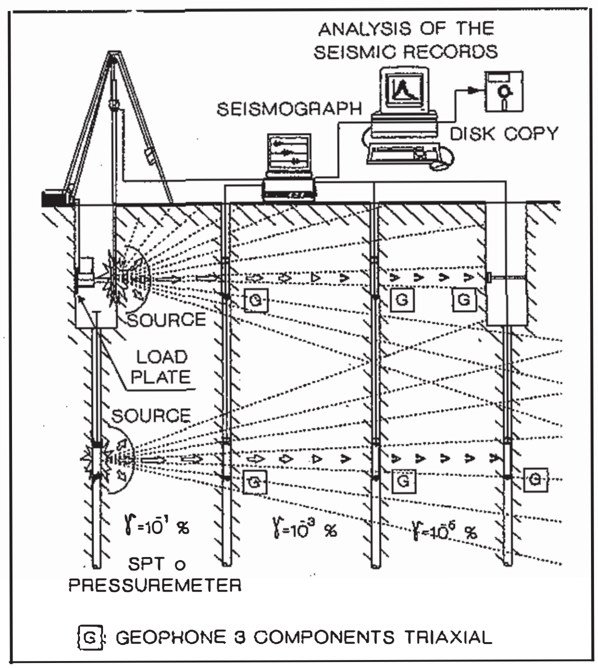

FIG. 4: Crosshole testing. Set up of equipments employed to determine subsoil dynamic properties of reinforced structures with geosynthetics.

In the exploration of embankment subsoils there are used CBR laboratory tests affording the advantage of being generalized (and relationships). But these tests have the disadvantages of being usually carried out in the laboratory and of supplying results that are being questioned where CBR < 3% and/or where geosynthetics are more required for acting as membrane-type reinforcement primarily (under high stresses occurring during the construction work). If the geosynthetic is mainly subjected to the load induced by the embankment, then the subsoil has a CBR < 1% and inasmuch as failure modes are associated with stratigraphic profile and with shearing resistance (S_u) of subsoil foundation, it is proposed here that the characterization be determined in situ by Vane shear test (or torsion) correlated with other laboratory test (triaxial).

The complementation of seismc macrozoning (figure 1) considering the Chilean regional geologic information along with local microzoning, is modelling embankment foundation subsoils as geomechanical horizons of unconsolidated deposits, and of saline, organic, or residual soils taking account the boundaries defined by the geological units and their accidents using static and/or cyclic tests such as Load Plate, Pressuremeter, SPT (Standard Penetration Test) that impart local validity and, in addition, allow bi and tridimensional modelling of a given area using Crosshole techniques of the geotomographical kind (Acevedo, 1987), inasmuch as they are inducing dynamic deformations in the geomechanical medium.

Consequently, in order to ascertain in situ the dynamic properties of large heap leaching facilities subsoil that give rise to small and large deformations (similar to those induced by seisms), it is proposed here that both subsoil prospecting and embankment monitoring be undertaken employing the equipments shown in figure 4 (Acevedo, Martínez and Rebolledo, 1993) implemented by the Geotechnics Section of the IDIEM (i.e. the Institute of Investigations and Materials Testing, of the University of Chile. These equipments are allowing to analyse microseismical waves in order to get dynamic profiles (*"P"* and *"S"* wave velocities as well *"E"* and *"G"* deformation modules and damping *coefficient* *"α"*) in depth below embankment foundation seal.

5 CHARACTERIZATION OF GEOSYNTHETICS USED IN EMBANKMENTS AND TERRACES

Since the requirements concerning geosynthetics properties are different in the short term in order to survive to installation processes, and in the long term in order to insure the efficient duration or the design, the tests conducted must totally reflect the ambience to which these materials are going to be exposed before, during and after their installation, for instance resistance to ultraviolet radiation both during the placing in the embankment and during and eventual exposition thereof, depending on the geographical location. That is to say, it is necessary

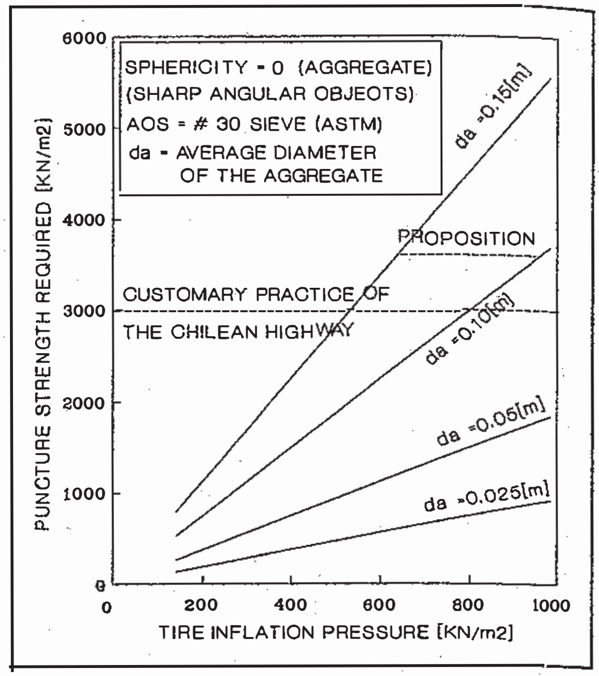

FIG. 5: Proposal of requirements for geotextile puncture strength used in road works of soil stabilization.

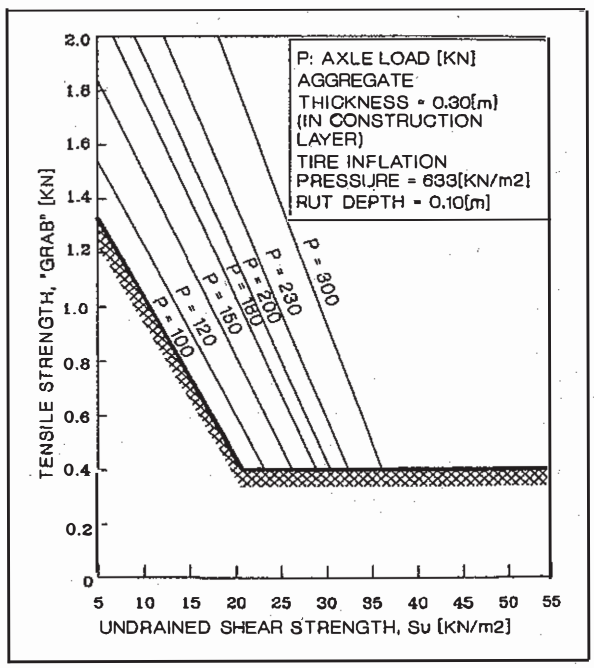

FIG. 6: Proposal of requirements for geotextile tensile strength used in road works of soil stabilization.

to include in a schematic and comparative fashion those factors of greater influence in some Chilean regions, partitioning the country into at least three sector (figure 1). In addition, the grade of geosynthetics must be determined through soil reinforcement material tests of the *direct shearing* and *pullout* types seeing that the factors and parameters that are to be included in quality control tests of the synthetic material are verified during the fabrication process of such industrial items, habitually considered as being reliable.

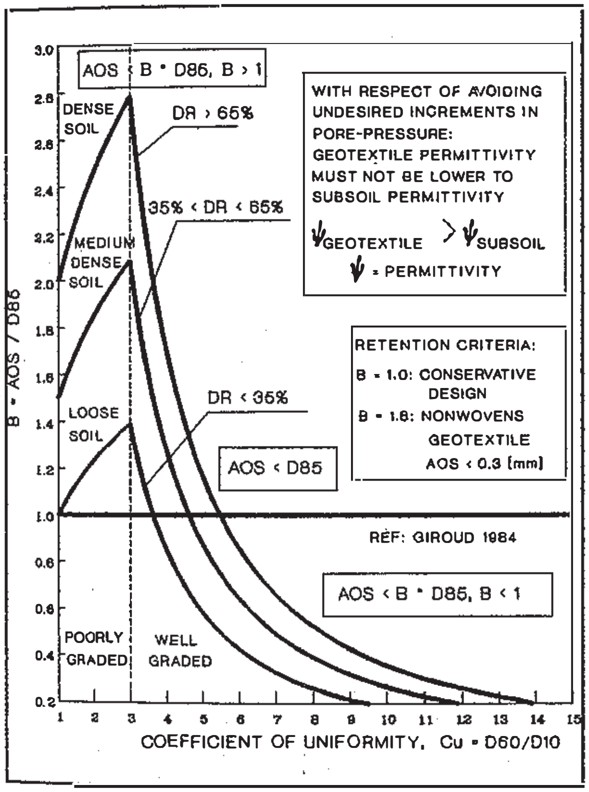

FIG. 7: Proposal of requirements for geotextile apparent pore opening used in road works of soil stabilization.

In addition to fulfilling separation, stabilization and reinforcement functions, the geosynthetics are acting as *filters* and they are easing the drainage and, in justified instances, they compensate the properties of low-grade aggregates. The foregoing requires the implementation of some equipment allowing to analyse geosynthetics deterioration through *clogging* in the transcourse of time, taking into account the kind of fine material, the hydraulic gradient as well as more complex phenomena due to bacterias, and to ferric calcareous concretions.

Then geosynthetic parameters will be determined by their specific application and by conditions, as well as by the sundry functions fulfilled. Thus; for *separation/reinforcement* functions the parameters are principally mechanical (resistance to traction, elongation to rupture, and punching, considereing durability/creep); for *filter/drainage* functions the parameters are predominantly hydraulic (permitivity, transmissibility, apparent pores opening, and durability); and for the *protection* function the parameters are mechanical with index properties (mass per unit area and thickness), inasmuch as the foregoing requires determining the coupled secondary function along with its associated parameters.

6 METHODOLOGIES RECOMMENDED FOR DESIGN AND CONSTRUCTION

Figures 5, 6 and 7 are showing the results of an investigation conducted by the authors of the present work at the Geotechnics Section of IDIEM Institute belonging to the University of Chile. This investigation formulates proposals covering the requirements for the geosynthetics (geotextiles) used in highway embankments taking into account subsoil type along with design and constructive methodologies customarily employed in Chilean highway projects.

Hence, normally the objective characterization of geosynthetics is based on representative interaction test that are qualifying both the *"synthetic"* and the *"geo"* aspect thereof and is also based on methodologies that are compatible with the totality of products present on Chilean market, at least for the properties denominated as indexes or of short term.

As regards the constructive methodologies, the same must adopt procedures taking into consideration the conditions of work and the properties of materials used (subsoil, geosynthetic, and backfill material provided in the embankment) and that are affecting the constructive strategy and hence the time periods and costs of the project.

7 CONCLUSIONS

In accord with the foregoing and in view of Chilean geological and geotechnical realities, the desing and constructive methodologies shown in figure 8 are allowing an adequate modelling from the standpoint of embankment separation/reinforcement. Prior to whatever design and specification, these methodoligies require the undertaking of supdated tests that qualify both the *"synthetic"* aspect as well as the *"geo"* one (of foundation subsoil and of

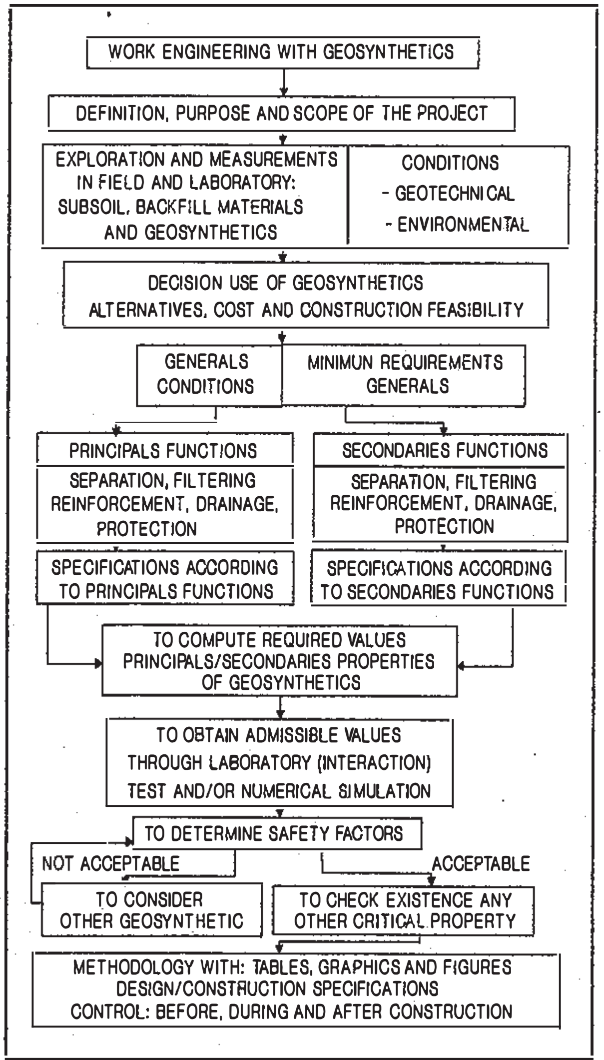

FIG. 8: Design/constructive methodology by means of the definition of geosynthetic functions.

backfill materials included in the embankment) in conformity with Chilean regional requirements.

Consequently, the properties of geosynthetics used in mining works (heap leaching) and in highway projects (embankments) must be necessarily analysed considering activities associated with a series of tests (of the direct shearing, pullout and clogging types), as well as considering modelling requirements that include quality-control testing, interaction-properties testing, and in situ and monitoring testing.

Furthermore the *numerical modelling* (Finite Elements Method) is a critical tool in the interpretation that may reveal properties details many times difficult to be measured (Medrano, 1986), and that may also confirm whether the simplifications proper to whatever design are adequately reflecting the actual behaviour of the embankment in situ.

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