Evaluation of sensitivity of the geotechnical parameters in the analysis of slope stability

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ABSTRACT
A slope stability project can not be done efficiently without an accurate report of the physical and mechanical properties of the soils involved. If the designer is working with inaccurate results would not be a successful response to existing conditions. Attempts to analyze different results obtained by performing direct shear tests on submerged and natural condition samples given by laboratories and thus determine the degree of reliability offered by these results. Perform a geotechnical study conducted on a slope and the participation of three well-known soil laboratories, we are looking to obtain results to assess the impact of undrained shear strength of soil in the analysis of slope stability. With all of this, the purpose is to know the levels of uncertainty that has the geotechnical engineer when making any assessment or corrective to the stability of a soil mass.

PRESENTACIONES TÉCNICAS
Un proyecto de estabilidad de taludes no puede efectuarse de forma eficiente, sin que el proyectista tenga un reporte certero de las propiedades físicas y mecánicas de los suelos involucrados. Si el proyectista trabaja sobre resultados "imprecisos", no estaría brindando una respuesta acertada a las condiciones existentes. Se busca analizar qué tanto varían los resultados que se obtienen al realizar los ensayos de corte directo en condición sumergida y natural entre distintos laboratorios, y así conocer el "grado de confiabilidad" que ofrecen dichos resultados. Mediante la ejecución de un estudio geotécnico realizado en un talud y la participación de tres reconocidos laboratorios de suelos, se busca obtener resultados que permitan evaluar el impacto de la resistencia al corte no drenado y el ángulo de fricción interna del suelo, en el análisis de estabilidad de taludes. Con todo esto, se pretenden conocer los niveles de incertidumbre que tiene el ingeniero geotécnico a la hora de realizar alguna evaluación o correctivo a la estabilidad de una masa de suelo.

1 INTRODUCTION

To accomplish a slope stability project should be known in the most accurate way, the properties of the terrain. Furthermore, the laboratory tests results must maintain a direct relation to the real situation under study.

If a project is undertaken based on erroneous results, the engineer can arrive at very different solutions, which fail to respond to existing ground conditions, overestimating the slope conditions, which will have an adverse impact from the economic point of view, or underestimating it, and in this case does not satisfy the necessary requirements for stability.

The variation of the laboratory results could reduce confidence in the decisions and correctives that the designer can implement to a soil mass because the variety of results affects levels of reliability thereof.

To determine the degree of uncertainty of the engineer was proceeded to conduct a geotechnical study for recognition of the study area with the execution of a drilling and laboratory tests. The purpose is to perform the slope stability analysis with the participation of three soil laboratories, the use of the geotechnical software GeoStru Slope and Simplified Bishop method.

2 CASE STUDY AND DATA COLLECTION INSTRUMENTS

The study was conducted in Prados del Este, Baruta, Miranda State. The slope, case study, is located between the streets Isla Larga and Maracaibo, in the green area marked in Figure 1.

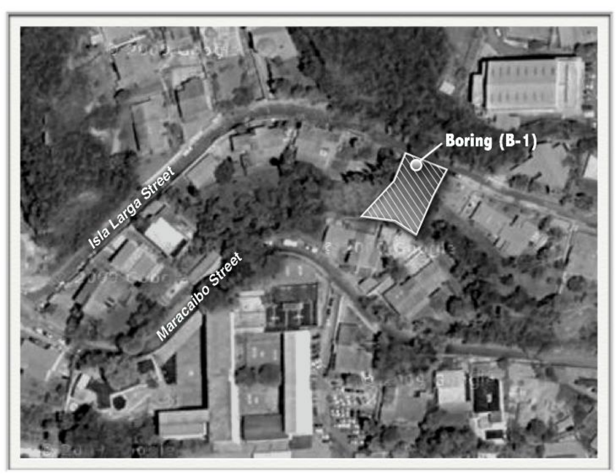

Figure 1. Case study location

Drilling was performed with a continuous sampling, which were extracted three samples per meter of drilling that means each laboratory will have a jar.

The advancement of percussion drilling allowed to reach a depth of 10 meters from the initial level of drilling, at this depth was a high rejection, and then proceeded to change the drilling strategy to rotopercussion, which was discarded because recovery volumes were not sufficient for our case study. Thus the length of the survey is 10 meters.

The samples were labelled identically to be sent subsequently to the three laboratories.

The specimens were placed in three boxes properly identified to be transferred to the three laboratories and were delivered under the same conditions.

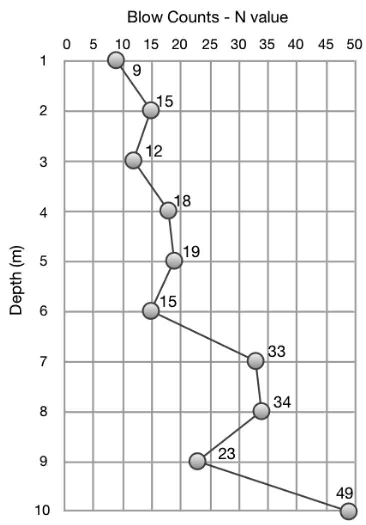

Figure 2. Blow Counts - Standard Penetration Test

Likewise, it were developed and delivered specific instructions to each of the laboratories carrying soil samples. It specifies the parameters and requirements for each test as follows:

- Description of view, in all samples.
- Moisture content, in the samples where the depth of extraction is odd, starting with the first underground drilling.
- Particle size distribution by sieving, in samples where the depth of extraction is odd, starting with the first underground drilling.
- Direct shear test, a sample every three meters from the first underground drilling. Additionally, it requires that samples be tested in both natural and submerged condition.

However, if more than half of the material pass through the sieve No.200 will also be made tests of liquid and plastic limits.

Thus, the laboratories have all appropriate instructions to make the tests under same the conditions.

In order to maintain the anonymity of the participating laboratories were allocated pseudonyms to each of them. Therefore, were assigned the numbers one, two and three, for the distinction of the results provided by them and facilitate information management.

Likewise, were requested the calibration certificates of each of the measuring equipment used in laboratory tests run in this study. The laboratory identified by the number three (3), did not provide the relevant certificates.

On the other hand, was conducted a topographical survey of the slope. The study proceeded to survey the flat area of the crown of the slope, the location of the boring and the face of the slope to the bottom of it. In this survey was necessary to use a total station because at certain points the rugged terrain and dense vegetation did not allow staff access.

3 INFORMATION PROCESSING

With all the information of soil parameters of the study area, we proceed to use the obtained topography to create a soil profile along the axis A-A´ (shown in Figure 3-A). It was selected the most unfavourable slope profile to obtain information on the profile of the worst.

The layers will be different for each model to study, given the different considerations of layers and the results of direct shear tests reported by each of the laboratories.

4 RESULTS OF LABORATORY TESTS

Below are the results of each of the tests carried out by the three laboratories.

4.1 Soil Classification (ASTM D-2487)

The following table reflects the results of the soil description reported by each laboratory (Table 1).

Table. 1 Soil description (ASTM D-2487)

<table>
<tr><th>DEPTH (m)</th><th>LABORATORY 1</th><th>LABORATORY 2</th><th>LABORATORY 3</th></tr>
<tr><td>1</td><td rowspan="4">Clayey-sand schistic fill, calcareous, with gravel (hard schist and quartz fragments); reddish brown; presence of clay at one meter depth.</td><td rowspan="5">Fill: Sand very silty, brown schistic (material derived from schist). Loose consistency.</td><td rowspan="2">Fill. Sand medium clayey-silt with low gravel content. Rough calcareous with occasional rootlets. Fines of low plasticity. Crumbles, heterogeneous, light brown and gray.</td></tr>
<tr><td>2</td></tr>
<tr><td>3</td><td rowspan="2">Fill. Sand fine to coarse grained, clayey silt with medium fine gravel content.</td></tr>
<tr><td>4</td></tr>
<tr><td>5</td><td>Clayey-sand-silt fill with gravel; yellowish brown.</td><td>Homogeneous sandy clay of medium plasticity with occasional hard fragments. Residual appearance.</td></tr>
<tr><td>6</td><td rowspan="2">Sandy clay(residual soil); reddish and yellowish brown; traces of organic material at six meters depth.</td><td>Topsoil. Dark brown sandy clay. Firm consistency.</td><td>Silty clay some fine sandy with occasional quartz fragments. Light Reddish brown.</td></tr>
<tr><td>7</td><td rowspan="3">Talc very weathered micaceous schist, soft, crumbles. Light yellowish. Weathers as silt very sandy, medium dense with flour texture. Soft touch. Residual soil.</td><td>Fine medium grained very hard sandy clay with fragments of schist.</td></tr>
<tr><td>8</td><td rowspan="3">Soft decomposed clayey sand-silt micaceous schist, presence of veins soft to hard; yellowish brown, red and grayish brown; occasional quartz fragments.</td><td>Soft fractured decomposed schist, crumbles character. Crumbles Sandy silt. Yellowish.</td></tr>
<tr><td>9</td><td rowspan="2">Soft crumbles decomposed weathered micaceous schist, clayey silt very fine sandy.</td></tr>
<tr><td>10</td><td>Finely laminated micaceous schist, soft crumbles. Dun, reddish gray.</td></tr>
</table>

4.2 Moisture Content (ASTM D-2216)

For moisture content, highlighted in bold font, Table 2 shows the values in which there is a discrepancy greater than 60% between them. It should be noted that with 8 meters of depth where can be made comparisons, 5 of them have notable differences.

Table 2. Moisture Content (ASTM D-2216)

DEPTH (m)	LABORATORY 1	LABORATORY 2	LABORATORY 3
1	**3.00**	**4.30**	**6.70**
2	4.00	3.10	
3		**5.90**	**2.90**
4		4.36	
5		2.70	3.50
6	**9.00**	**16.11**	
7		**5.56**	**9.70**
8	**4.00**	**7.01**	
9		4.30	3.50
10		1.46	

The first meter of depth is the only one that allows to make comparisons between the three laboratories studied. It can be seen that the Laboratory 1 differs from Laboratory 2 in 43.40%, and the latter differs from Laboratory 3 in 55.80%. Similarly, and more notably, between Laboratory 1 and 3, there is a discrepancy rate of 123.33%.

Likewise, in the depths 6 and 8 are differences of 79.00% and 75.25% between laboratories 1 and 2; and the underground 7 shows a 74.46% difference in results of Laboratories 2 and 3.

4.3 Particle- Size Analysis of Soils (ASTM D-421, 422)

A summary of the grading done by each laboratory is shown in Table 3 as percentages of gravel, sand and fines from each sample and depth. Bold font highlights the values that have significant differences.

Table 3. Particle size distribution by sieving (ASTM D-421, 422)

	LABORATORY 1			LABORATORY 2			LABORATORY 3		
DEPTH (m)	***GRAVEL %***	***SAND %***	***FINES %***	***GRAVEL %***	***SAND %***	***FINES %***	***GRAVEL %***	***SAND %***	***FINES %***
1	**27.00**	**45.00**	**28.00**				**5.00**	**57.00**	**38.00**
2	41.00	39.00	20.00	42.00	35.00	23.00			
3							15.00	57.00	28.00
4									
5							3.00	59.00	38.00
6	1.00	34.00	65.00						
7				8.00	35.00	57.00	1.00	45.00	54.00
8	15.00	46.00	39.00						
9				**16.00**	**43.00**	**41.00**	**0.00**	**44.00**	**56.00**
10									

It can be seen that at a depth of one meter, the percentage of gravel reported by Laboratory 1, is higher by 440% to the reported by the laboratory 3. However the values of sand and fines kept in close range.

Table 3 also shows that nine meters depth are considerable differences in the percentages of gravel, sand and fines collected. While the Laboratory 2 reported a 16% of gravel, the Laboratory 3 indicates lack of it.

Moreover, the Laboratory 3 gets a percentage greater than 50% fines, while in the grading of the Laboratory 2 dominates the presence of gravel and sand; which could affect future considerations in tests or solutions to geotechnical problems.

4.4 Liquid Limit, Plastic Limit, and Plasticity Index of Soils (ASTM D-4318)

Concerning to the testing of the limits of consistency are the following reports, as reflected in Table 4.

Table 4. Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils (ASTM D-4318)

<table>
<tr><th></th><th colspan="3">LABORATORY 1</th><th colspan="3">LABORATORY 2</th><th colspan="3">LABORATORY 3</th></tr>
<tr><th>DEPTH (m)</th><th>L.L %</th><th>P.L %</th><th>P.I %</th><th>L.L %</th><th>P.L %</th><th>P.I %</th><th>L.L %</th><th>P.L %</th><th>P.I %</th></tr>
<tr><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td>27.00</td><td>18.10</td><td>8.90</td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td><td></td><td></td><td></td><td>28.90</td><td>20.20</td><td>8.70</td></tr>
<tr><td>4</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td></td><td></td><td></td><td></td><td></td><td></td><td>36.40</td><td>21.20</td><td>15.50</td></tr>
<tr><td>6</td><td rowspan="2">41.00</td><td rowspan="2"></td><td rowspan="2">17.00</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>7</td><td rowspan="3">25.99</td><td rowspan="3">22.92</td><td rowspan="3">3.08</td><td>35.00</td><td>21.70</td><td>13.30</td></tr>
<tr><td>8</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>9</td><td></td><td></td><td></td><td>35.50</td><td>21.90</td><td>13.60</td></tr>
<tr><td>10</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Obtained results showed a significant difference in the plasticity index, being more evident between the Laboratory 2 and the other two laboratories.

4.5 Direct Shear Test

Note that the ASTM standard only conceives the realization of the direct shear test in submerged condition, but due to the investigation the laboratories conducted the tests under submerged and natural condition. This seeks to make the following comparison between the results of the same depth on equal terms with natural and submerged condition. The direct shear tests were performed on remoulded samples.

Analyzing the results of direct shear test of the three laboratories in submerged condition, shown in the Table. 5, the first thing that can be noted is that each of them considered different intervals for the test, based on similarities between layers, obtained from previous tests as grading and visual description.

However, the values that have a greater discrepancy are those of the undrained shear strength “c”, which in all cases at least double the value.

At a depth of one meter, it is noted that the Laboratory 1 differs from 2 and 3 because the latter two take a single interval (from 1 to 5 meters), while Laboratory 1 takes two ranges. For the first meter of depth is observed as the angle of internal friction, reported by each laboratory, shows differences between values but remains close to 27 degrees, ranging up to 5 degrees. On the other hand, in the cohesion arises larger jumps, the Laboratory 1 reported 0.15 Kg/cm^2 less than Laboratory 2; even more what occurred between Laboratory 2 and 3 in which the difference is 0.20 Kg/cm^2.

Table 5. Direct shear test (ASTM D-3080) - Submerged Condition

	LABORATORY 1			LABORATORY 2			LABORATORY 3		
DEPTH (m)	γ (T/m³)	ϕ (degrees)	C (Kg/cm²)	γ (T/m³)	ϕ (degrees)	C (Kg/cm²)	γ (T/m³)	ϕ (degrees)	C (Kg/cm²)
1	1.74	32.00	0.05	1.83	27.70	0.20	1.81	25.00	0.00
2	1.82	31.00	0.10						
3									
4									
5									
6	1.69	34.00	0.20	-	-	-	1.81	24.00	0.00
7				1.94	26.90	0.20			
8	1.80	31.00	0.20						
9									
10				2.08	27.30	0.40			

In the next layer or group proposed by the laboratories, is seen as the Laboratory 3 considers the same soil or with similar characteristics from meter 6 to 10, while the Laboratory 1 divides it into two groups: the first includes the depths of 6 to 7 meters, and the other from 7 to 10 meters. The Laboratory 2 also divided it into two groups, the first from 7 to 9 meters and other at 10 meters.

Comparing the results of the first laboratory at a depth of 6 to 7 meters with the third laboratory results, is seen as the Laboratory 3 has a cohesion of 0.00 Kg/cm^2 when Laboratory 1 gives a value of 0.20 Kg / cm^2, which is the same result reported by laboratory 2. However, in the internal friction angle the largest variations are 10 degrees between the Laboratory 1, which reflects about 34 degrees and the Laboratory 3 that gets as a result only 24 degrees.

The last layer of comparison arises to a depth of 10 meters, in which the three laboratories delivered results. In this last group can be seen that the friction angle does not shows a big difference between the Laboratory 2 and the other two remaining, it varies only 4 degrees. However, when comparing the results between Laboratory 1 and Laboratory 3, there is a difference of 7 degrees.

Likewise, in the values of cohesion can be observed a considerable discrepancy, because it does get a 100% variation between the values reported. Such is the case of Laboratory 1 and 2, in which the cohesion value is doubled from 0.20 to 0.40 Kg/cm2 Kg/cm^2, or in the case of the Laboratory 3 which gives a value of cohesion 0.00 Kg/cm^2 and have differences of 0.20 Kg/cm^2 and 0.40 Kg/cm^2 with laboratories 1 and 2, respectively, in this last layer.

Regarding the direct shear tests conducted in natural condition, which can be seen in Table 6, in the first meter shows that the results of angle of internal friction have a great resemblance to each other and vary from 35 degrees in the Laboratory 1 to 32 degrees in the Laboratory 3.

Furthermore, it can be observed that the Laboratory 1 gets a cohesion value of 0.20 Kg/cm^2 and the Laboratory 3 considers that there is not cohesion, reflecting a value of 0.00 Kg/cm^2 of it. Very similar, occurs in layer from 2 to 5 meters depth where the friction angle values differ only one degree between them, but instead the laboratory 1 reported an increase of cohesion of 0.40 Kg/cm^2 in this stratum; raising the difference between the two values of cohesion in these laboratories to 0.40 Kg/cm^2.

From 8 to 9 meters of depth, it can be compared the results of all laboratories studied. In these meters can be seen as the angle of friction has almost the same among with the three laboratories being almost equal between 1 and 3, but varying in only 0.9 degrees from the Laboratory 2.

Table 6. Direct shear test - Natural Condition

	LABORATORY 1			LABORATORY 2			LABORATORY 3		
DEPTH (m)	γ (T/m³)	ϕ (degrees)	C (Kg/cm²)	γ (T/m³)	ϕ (degrees)	C (Kg/cm²)	γ (T/m³)	ϕ (degrees)	C (Kg/cm²)
1	1.74	35.00	0.20	-	-	-	1.81	32.00	0.00
2	1.82	31.00	0.40						
3									
4									
5									
6	-	-	-	-	-	-	1.81	34.00	0.00
7				1.97	34.90	0.50			
8	1.80	34.00	0.65						
9									
10				2.04	33.90	0.75			

In contrast, with respect to cohesion, there is a difference between the Laboratories 1 and 2, and the Laboratory 3 that maintains a zero cohesion while the other laboratories report cohesions of 0.65 Kg/cm^2 and 0.50 Kg/cm^2 respectively. As well it occurs at meter 10, where the internal friction angles vary only by 0.01 degrees while cohesion values have a discrepancy much larger. Laboratory 1 and 3 have their previous values while Laboratory 2 increases cohesion to 0.75 Kg/cm^2, ie increase over 0.25 Kg/cm^2 from the previous value, reducing the gap to Laboratory 1 in only 0.10 Kg/cm^2 but increased it from the Laboratory 3 at 0.75 Kg/cm^2.

5 RESULTS OF SLOPE STABILITY ANALYSIS

The stability analyses are reflected in Figure 3, as the topography and the profile along the axis A-A´of the area of study.

In the figure of the results of stability analysis, obtained with the software Geostru Slope, is the differentiation of the layers for each model to study that corresponds to reports of direct shear testing by each laboratory.

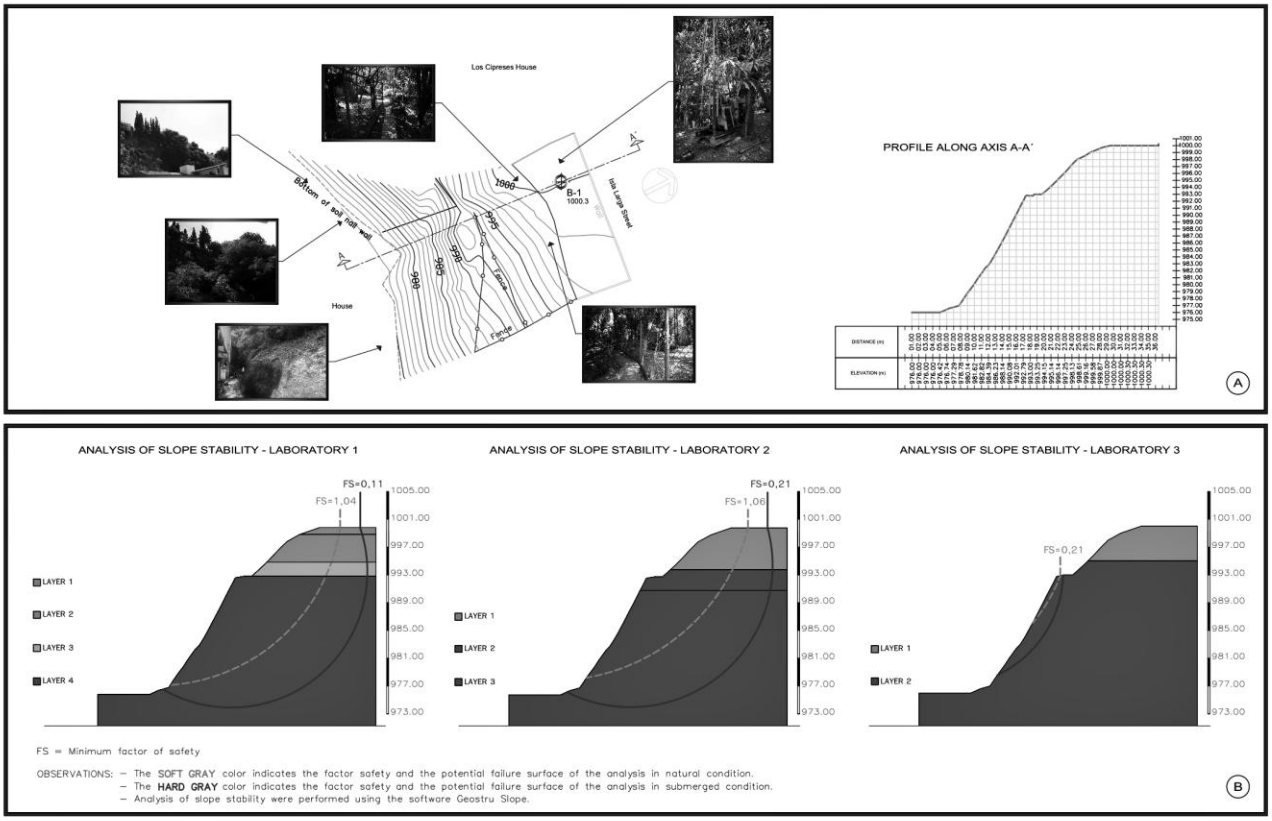

Figure 3. (A) Topographical survey, Profile along axis A-A´ (B) Results of slope stability analysis

The layers were separated into 3 groups which are represented by the following colors: medium gray for the fill, light gray for sandy clay and dark gray for the weathered mica schist. The slip surfaces were placed in light gray with dotted line for analyses in natural condition and dark gray with continuous line for submerged condition.

Contemplating the acceleration of the ground under study and the stipulated by the standards COVENIN 1756:2001-1, has been considered as normative values, the safety factors greater than 1.2 for stable slopes under dynamic conditions.

Table 7. Safety Factors resulting in both conditions

	SUBMERGED CONDITION	NATURAL CONDITION
LABORATORY 1	0.11	1.04
LABORATORY 2	0.21	1.06
LABORATORY 3	0.09	0.21

Laboratory 1 did not provide results on the sixth and seventh meter deep in natural condition, and Laboratory 2 from first to fifth. In order to have comparison results in both conditions and with each of the laboratories, it will be assumed the values provided for the submerged condition, taking into consideration that these results should be higher in natural condition, meaning that the safety factor will be lower by such considerations.

First, in submerged condition resulted that all raised models were unstable, but the safety factors obtained do not have a significant difference between them, even though the cost to stabilize the slope with the results of Laboratory 1 and Laboratory 2 can be a considerable difference.

These results showed how the factor of safety obtained by the software's help Geostru Slope by the Modified Bishop method, according to data supplied by the Laboratory 2 was resulting in the higher safety factor 0.21, while with the Laboratory 1 report gives a factor of only 0.11. Moreover, note that the software for the results of laboratory 3 provided an error resulting in a safety factor out of range, so it could be assumed as a limitation of the software for the parameters used. Thus, it was decided to use another software of slope stability analysis to verify the values that would have the safety factor, with the results of Laboratory 3 in submerged condition.

Using the software Rocscience Slide to check what safety factor would associate the software with the terms, we obtained the results as reflected in Figure 4, with a safety factor of 0.09, being this value the lowest of all.

Moreover, under natural conditions there are major differences between the safety factors obtained by the laboratory results.

From these results it can be found large discrepancies such as Laboratory 3 in which is appreciated that there is a difference in the safety factor of 0.83 to its nearest value which is the laboratory 1. This difference is large when we remember that the minimum safety factor for a stable slope considering a dynamic analysis is 1.2, ie this difference is equal to slightly more than half a minimum factor.

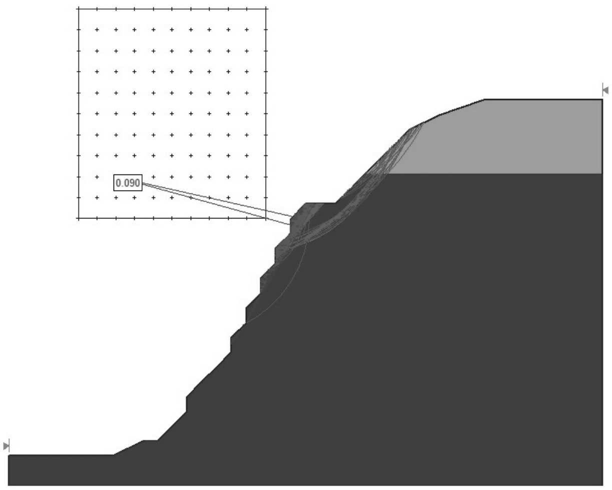

Figure 4. Result of slope stability analysis in submerged condition - Laboratory 3 (Using Rocscience Slide Software)

However, it is important to consider the factors of safety and the resulting failure surfaces with the parameters provided by Laboratories 1 and 2 are pretty close.

If the results now are analyze in both conditions, arise graphs as shown below in Figure 5, and clearly indicates the significant difference between the assessment of slope stability of the natural condition and under the parameters established by the ASTM - 3080 in submerged condition.

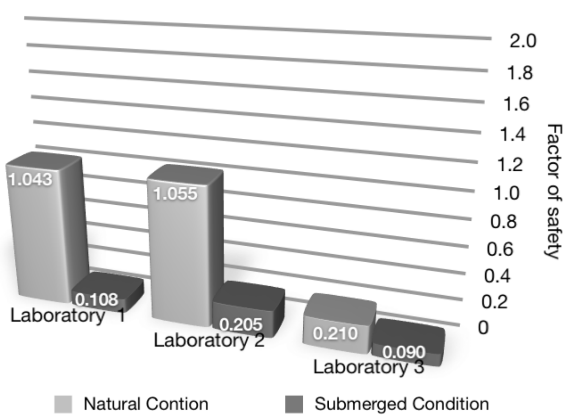

Figure 5. Comparison of the safety factors of each laboratory in both conditions.

The figure 5, presented above, shows how the factors of safety for laboratory vary with submerged and natural conditions in which the ordinate (y) represents the safety factor as the abscissa (x) represents each laboratory.

It is worth mentioning that the safety factor obtained from the geotechnical parameters provided by the Laboratory 2, even in submerged condition, this value is equal to that obtained under natural conditions for the Laboratory 3.

Also Figure 6 shows how with the results of each laboratory arise factors of safety so diverse.

In natural condition, all laboratories have angles of internal friction similar to each other in layers considered, but values of cohesion variables, being very similar for Laboratories 1 and 2, and radically different for the Laboratory 3. This discrepancy in the cohesion is directly reflected in the stability of the slope because the factors of safety associated with each laboratory report are easily influenced by this parameter. Then emphasizes the closeness between the factors of safety obtained by the results of Laboratories 1 and 2, and the vast distance between them and the factors obtained by the laboratory 3.

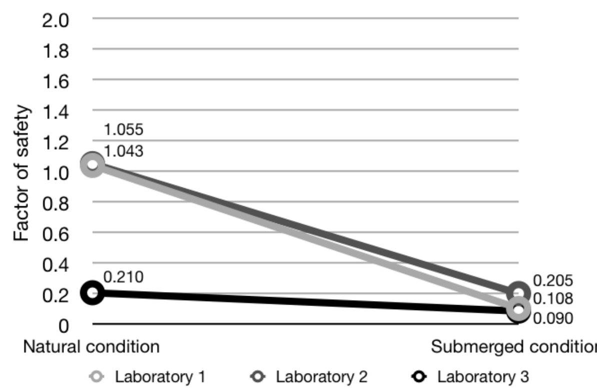

Figure 6. Trend of the safety factors of each laboratory in both conditions.

In submerged condition, obtained values converge a bit more than in natural condition, results in the stability analysis with the reports of the Laboratories 1 and 2 are quite similar. On the other hand, with the Laboratory 3 could not be established comparison because the Software GeoStru Slope did not show a value in this case. It may be mentioned that the Software has limitations in this regard. Presumably the factor of safety could be so small that the software can not report it. It can be stated because under natural conditions, this value was 0.21, and in submerged condition must be substantially lower.

6 CONCLUSIONS

Through conducting this research it can be seen the great difference between the laboratory results under natural and submerged conditions. However, studies performed in natural conditions are more difficult to assess because there are no specific testing standards that regulate it, as with tests performed in submerged condition. The parameter that was most affected was the cohesion, in some cases this increase amounted to as much as 400% between natural and submerged condition. The largest increase reported in the internal friction angle was 20%.

Nevertheless, it should be noted that there is a significant discrepancy between the results of analysis of slope stability with the reports of the laboratories. These results are so different between them that, in most of the analyses, at least one of the laboratory results drastically adjusts the factor of safety.

It should be emphasized that the stability calculations were performed with the Software GeoStru Slope, which presented an error or deficiency analyzing the slope in submerged condition for the results of Laboratory 3; it showed a factor of safety out of range. This error could be visualized analyzing the slope, with the same data, but with RocScience Slide Software and obtaining a safety factor of 0.09, which is much more consistent for the data provided.

We know that the geotechnical is not an exact science but this situation is quite alarming. These results lead us to consider not only how these values influence the stability of a slope, but how these differences affect all calculations and decisions that must be taken by the designer.

There are no intentions to judge the quality of laboratories, in fact what is sought is to determine the level of uncertainty facing the designer when calculating or proposing solutions in a project. The above brought us to ask how a design engineer can make decisions if does not have the certainty that his calculations are based on reliable parameters.

It is difficult to be indifferent if we can not guarantee the safety of civil works projects because we directly depend on information provided by others.

This puts the engineer in the disjunctive of having to penalize the works with very high safety factors, which makes the projects less accessible to their customers. Or maybe the engineers should stop looking for practical and effective solutions to become someone who only deal with oversize their projects, without being assured that safety is not compromised.

These factors can be applied to slope stability and by extension to a large number of civil works such as the calculation of piles, design of dikes and dams, filler material loans, etc.

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