Problematic soils in the western part of Albania

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ABSTRACT: The western part of Albania consists of a large part of the former marshy areas, from alluvium deposits of river deltas, consisting of fine soils with high porosity, high levels of organic matter content and the underground water very close to the natural surface. At these areas we meet problematic soils, which due to a high seismic activity (MSK = 6.2-6.8) tend to put humans' life and economy into risk. Meanwhile, these areas are planned to be very important touristic areas because, tourism is a priority sector of the country economic development. This paper aims to present the studies carried out by ALTEA & GEOSTUDIO 2000 ltd in these areas, where different constructions are foreseen to be built. Our case study is the construction site of Vlora airport. More in detail, this article will present a complete geological-engineering study, with laboratory and in-situ data to explain the hazardous phenomena that may arise in the construction area of the Vlora airport.

Keywords: problematic ground; limit state; laboratory testing; field investigations

1. Introduction

Albania is a small country, which 2/3 rises into mountainous and hills, and 1/3 of the territory into plain and plateaus. The plain territory lays in western part of the country, near the Adriatic Sea.

Part of this territory [4] is composed of marsh, alluvium, lagoon and sea deposits, represented by fine, non-consolidated soils with high porosity, high percentages of organic matter and high level of underground waters. They have very weak mechanical properties. In these zones we have a high seismic activity due to the closeness of the area with the northern boundary tectonic fault of Adriatic and Ionian Sea, (part of the Albanides-Hellenides domain).

Meantime, these zones have a high-rise touristic priority development, as an important branch of the Albanian economy. On these purposes and more, in Vlora city, at Akerni area, it is foreseen to be constructed a new airport.

To realize it's designing it is necessary to know all phenomena linked with the behavior of soils. ALTEA & Geostudio 2000 ltd made a detailed geological and geotechnical study.

The main results of this study are presented in this paper. The zone is composed by problematic soils, which can suffer deformations, and in most severe cases, lose their overall stability.

In this paper we want to present some of our correlations between soils characteristics and finally to determine which might be limit states that the structures' foundations might suffer under static and dynamic loads.

Also, we are going to give recommendations about engineering measures required to improve the situation.

2. Investigations in terrain (in situ)

The study area is situated in the northern part of Vlora city, and western part of Akerni village, see Fig.1.

This area has a flat relief with small differences of quota. It represents the marshy deposits of Narta lagoon and alluvium deposits of Vjosa river.

The thickness of these deposits goes more than 30m at the peripheral areas and about 100m deep in the center of the marsh, right in the place where the study is performed.

A.L.T.E.A. & Geostudio 2000 Company performed 16_bore-holes, 73_SPT test measurements, 90_DCP tests, 73_CPT and CPTU tests and more than 30_geophysical measurements. [5]

Figure 1. Location of the airport of Vlora

From these investigations we obtained the following conclusions:

- In this zone we have a complex and complicated geological situation with irregular layers and frequently of wedge/lens shape, refer to Fig.2.

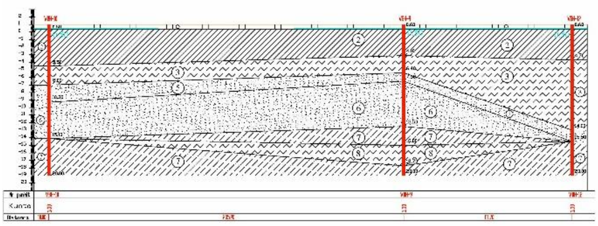


Figure 2. Typical cross-section at Vlora Airport

- Until 20 m deep from natural surface we have found soils with very weak features as you can see by charts compiled of N_{SPT}-h compiled from BH-1, BH-2, BH-3 profile presented at Fig.3. For six different layers evident in boreholes, we have taken the mean value of their thickness and SPT number, see "Table 1.".

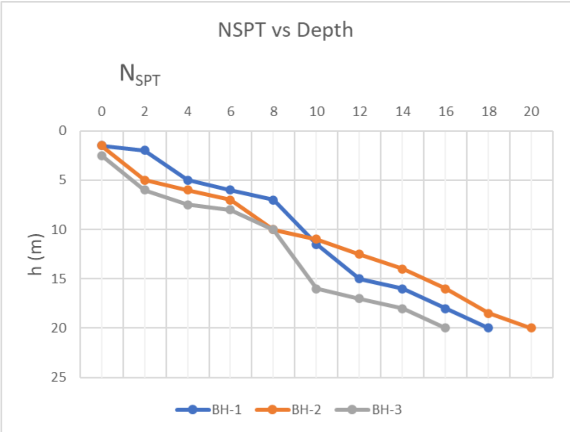


Figure 3. Profile SPT vs depth

Table 1. Medium value of the thickness of layers and SPT value

No. of Layers	Type of layer	Mean N_{SPT} value	Medium thickness of layer (m)
1	Beige to gray, silty clays	9.20	4-4.5
2	Green, grey to black silty clays	3.80	2.45-8.22
3	Loose to medium dense green-gray fine silty sands	13.90	1.8-8.5
4	Medium dense green-gray silty sands	17.80	3.6-6.55
5	Loose green gray clayey sandy silts	10.80	1.5-4.25
6	Soft to very soft, green, gray, clayey sandy silts	6.10	2.1

So, from SPT-h profiles we can observe the same situation as we obtain from boreholes data.

In general, we can divide these very weak soils in 4 categories:

a) SPT<5-6 – very weak layer;
b) SPT=6-12- weak layer;
c) SPT=12-20- medium layer and
d) SPT>21-22 as good layer

These profiles show a very complicated geological composition, which can influence the appearance of the both GEO and STR limit states. From CPT and CPTU tests results, we can see how the cone tip resistance "qc", sleeve friction "fs", friction ratio "Rf" and pore pressure "Pu" parameters change with depth, see Fig.4.

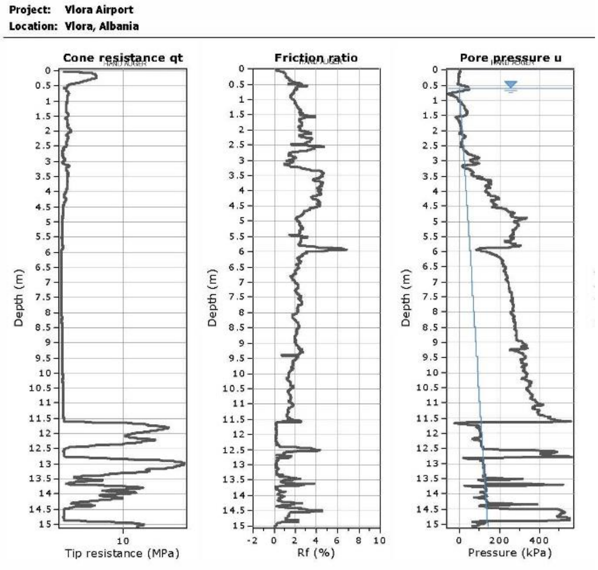


Figure 4. Sample of CPT/CPTu readings

The airport construction site, is composed of very weak soils with low resistance. There are sensitive cohesive soils present, under consolidated conditions and with a very complex lithology.

We see a good concordance between CPT test results and SPT N60 charts versus depth. Using Shmertmann, Robertson and Campanella relations [6] and results of CPT testing, we have determined the mechanical properties of soils. So, we have elaborated a profile relating the coefficient of permeability variations with depth and Young's modulus variations with depth. Please refer to Fig.5.

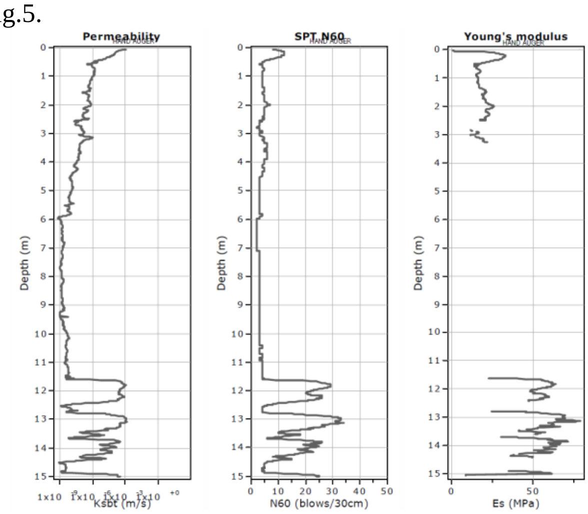


Figure 5. Sample of CPT/CPTu readings (k-h; Es-h relation)

Moreover, from this data we have determined satisfactory accuracy of the relative density parameter "Dr", which results in generally lower 50%, also the friction angle for the non-cohesive soils varying between (35^0 to 40^0).

The measurements from CPT and CPTU data gives us the possibility to draw same conclusions, which are similar as per SPT tests.

It is important to mention that in this area we have the presence of the non- cohesive soils, very porous, containing organic matter, and cohesive soils, very sensitive and under consolidated conditions. [5]

These layers are placed irregularly through the site. So, we can say that the objects constructed in this site should suffer at least the serviceability limit state.

During earthquakes a dangerous phenomenon can emerge, therefore it was a must to perform geophysical measurements. In Fig.6. we have presented a typical profile compiled from shear wave velocity towards the depth.

The results show the presence of problematic soils, with values of shear wave velocity Vs = (120-200) m/s until 15m depth.

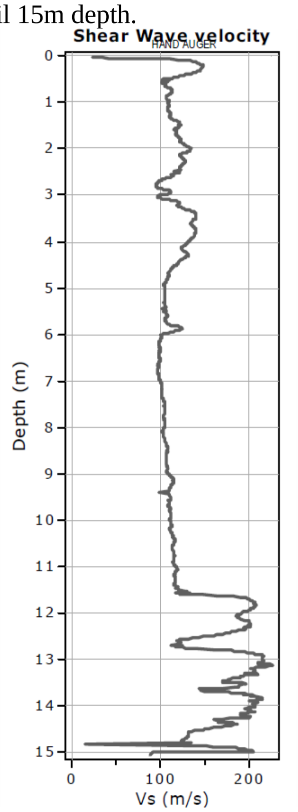


Figure 6. Sample of CPT/CPTu readings (Vs-h)

From these data, we have calculated the constrained modulus “M”, shear modulus “Go”, remolded resistance “Su”, and compiled the respective profiles, see Fig.7.

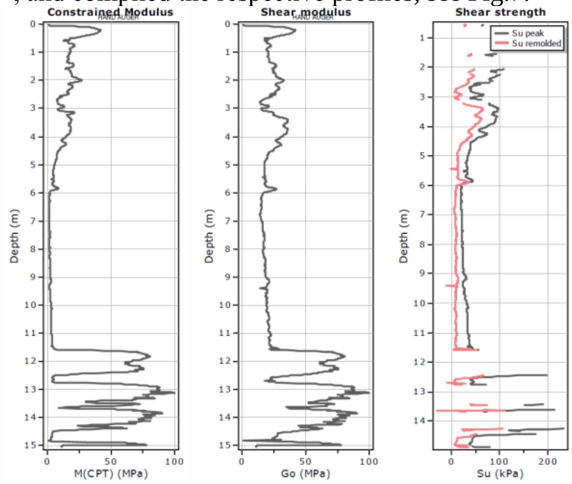


Figure 7. Sample of CPT/CPTu readings (M-h , Go-h , Su-h)

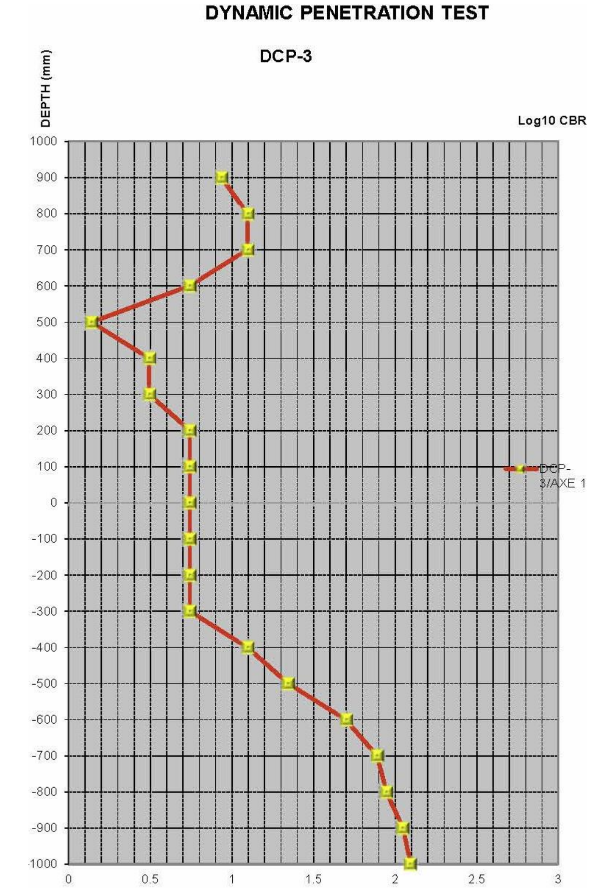
These profiles allowed us to draw the following conclusions:

- The zone which might suffer considerebale deformations lays between 1m to 11m deep, refering to the values of Dr<50%; Go<25MPa; Su<10MPa.[1]
- From DCP tests, refer to Fig.8., we can see that the first layers where should be placed the concrete slabs of the airport's roads have low resistance and bearing capacity (N= 4-8). It is only in some of the layers that it can get up to N=20-22.

There was also calculated the dynamic resistance in different points “Rd” which ranges from 13-25 kg/cm^2; 40-50 kg/cm^2 and in the depth Rd = 100-130kg/cm^2.

We have calculated also the CBR strength parameter, which ranges from 4% to 6% in the first layer and goes up to (80-100) % in specified depths.

The DCP data confirm the same conclusions as CPT, CPTU and SPT tests.



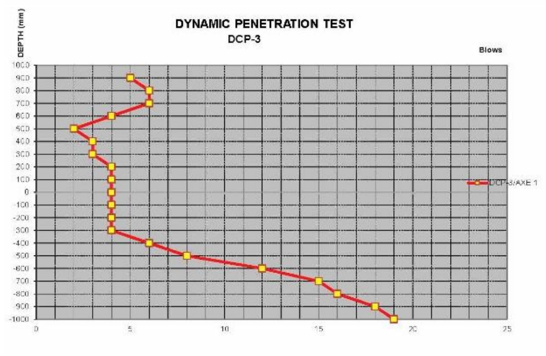


Figure 8. DCP test and profile of CBR vs. depth and No. of blows vs, depth

- According to the trial pits data, until the first 3metres, it results a low bearing capacity of the soils, judging from the pocket penetrometer measurements. It varies from 45 kPa to 60 kPa.
- The geophysical tests results show small velocity of "Vs" and "Vp" as shown at Fig.6.
- These tests demonstrate that the area under study, until 11-12m depth is composed of very weak and problematic soils with representative parameters Go<25 MPa, M= (10-40) Mpa, Su<10Mpa and Dr<50%.

3. Laboratory investigations

Samples taken on the construction site for testing purposes are tested at ALTEA's laboratory premises. [5] Different physical, classification tests and mechanical tests were executed. We analyzed the oedometric tests, direct shear and triaxial tests results, refer to Fig.9.

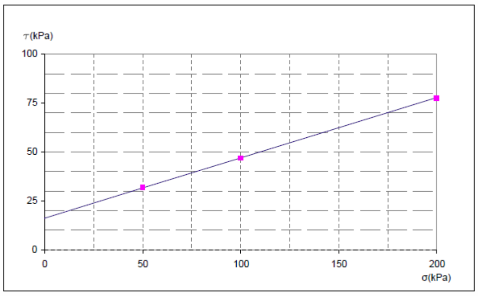


Figure 9. Direct shear test sample[5]

The "Table 2" and "Table 3" [5] show the representative results, of physical-mechanical properties and the parameters obtained from geophysical tests and CPTU tests.

The data from laboratory tests completed the image for the kind of the soils where we are going to lay the objects of the airport, in Akerni village, Vlora area.

We see that the first 10-11m of the site are prone to very deformable soils, with values of E= (3.3-5.5) MPa.

Table 2. Physical characteristics of layers

No. of Layers	Type of layer	Particles >0.075 %	OC %	LL %	PL %	PI	γ KN/m3	e	γ0 KN/m^3	W %
1	Soft to firm, beige, silty clay	58-84	2-4	30-65	18-30	11-34	18-19.5	0.6-0.91	25-26.8	21-35
2	Very soft, grey to black, silty clay	64-71	4.8	30-60	15-31	18-29	16.-19.6	0.85	25-27	26-56
3	Soft to very soft, green, grey, clayey, sandy silt	33-58	2.3-3.9	12-28	13-19	5-9.7	18.7	0.78	25.8-27.1	20-32
4	Silty, fine sand, loose to medium	23-46	3.	2.4	18	6	19.1	0.7	26-27	13-33
5	Silty sand, medium dense	17-23	0.5	-	-	-	19.3	0.69	26.5-27.5	10-23
6	Loose, clayey, sandy, silt	46-52	-	31	18	12	18.7-19.2	0.74	26.6-27.4	21-31
7	Soft, green, grey, silty clay	41-63	-	27.2	19.9	8.09	19-19.2	0.74	27-27.1	23-31

Table 3. Mechanical characteristics of layers

No. of Layers	Type of layer	E*10^4 kPa	CV*10^{-8} m^2/s	φ°	C kPa	Cuu kPa	K cm/s	Vs cm/s	Vp cm/s	qc cm/s	fs cm/s
1	Soft to firm, beige, silty clay	0.35-058	1.3-17.5	18	23	26-38	1.05*10^{-7}	164	267	0.68-1.33	12-49
2	Very soft, grey to black, silty clay	0.34	41.9	15-17	14-16	21.26	1.05*10^{-7}	369	602	1.1-12	11-28
3	Soft to very soft, green, grey, clayey, sandy, silt	0.45-0.55	-	28	12.2	-	1.03*10^{-4}	383	626	0.6-1.99	10-17
4	Silty, fine sand, loose to medium	0.84-0.96	-	27-32	4-16	-	1.02*10^{-3}	383	626	3.6-5	14-16
5	Silty sand, medium dense	0.99-1.13	-	28-31	7-11	-	(2.08-3.0) *10^{-3}	444	726	14.8-17	35-39
6	Loose, clayey, sandy, silt	0.6-0.62	-	14-28	13-24	-	1.65*10^{-4}	369	602	3.8-7.5	29-33
7	Soft, green, grey, silty clay	0.54-0.74	-	26	19	11.2	(1.05-2.3) *10^{-8}	538	878	2.65-7.1	21-45

The settlements might take a long time to develop, more than 5-7 years referring to their permeability coefficient K = 1.05.10^{-7} m/s. [2]

These layers have very low mechanical resistance, friction angle (15^0 -28^0); cohesion (12- 20) kPa. They have very low resistance in case of an earthquake event (Vs = 100-200m/s). The organic matter content varies (OC = 2.3%-4.8%), fine material (FM = 40%-80%). They are encountered below underground water level surface. The high percentage of organic content and fine material (according to the Albanian Norms), augments the settlements and aggravate the permeability of the soil layers.

4. Correlations

The correlations are purely graphical, using reliable parameters values derived from in situ and laboratory testing of soils samples from the investigated area. Here are presented some relations charts linking the number of SPT to the deformation modulus, SPT–E; fine material content in percentage, cohesion, friction resistence, tip resistence with material greater then 0.075mm grain, and the shear wave velocity with the shear modulus and constrained modulus. Please refer to Fig.10 up to Fig.15 below. SPT-%FM; SPT –C; SPT – Rf; qc - % particles>0 075mm and Vs – G0 , Vs – M.

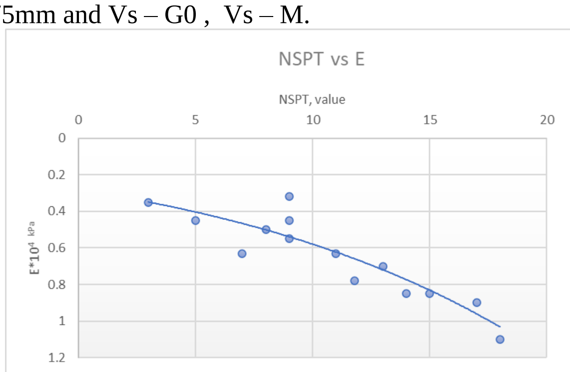


Figure 10. Relation between SPT and modulus

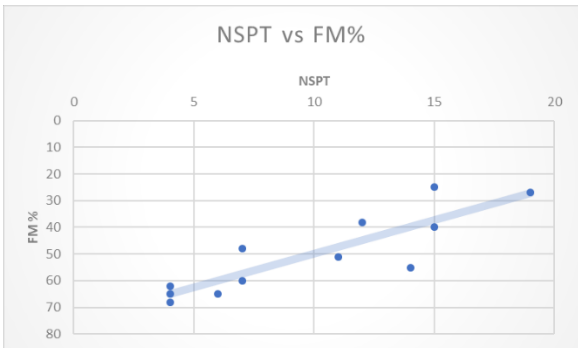


Figure 11. Relation between SPT and fine material percentage

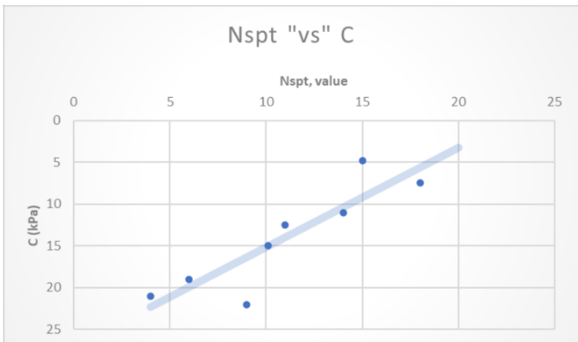


Figure 12. Relation between SPT and cohesion

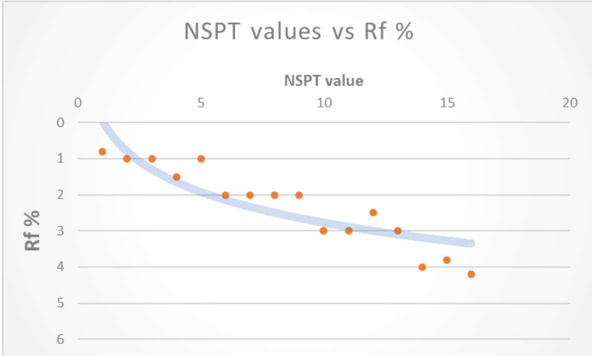


Figure 13. Relation between SPT and friction ratio Rf

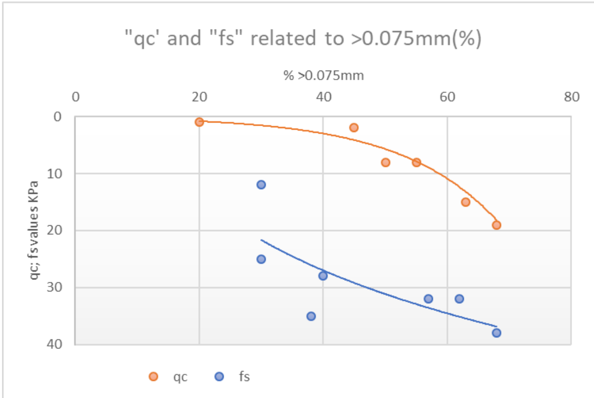


Figure 14. Relation between qc/fs versus material fraction %>0.075mm

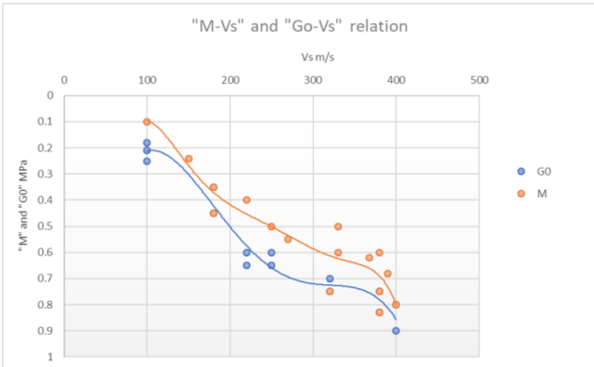


Figure 15. Relation between Vs and shear modulus and constrain modulus

From these correlations we can take some interesting conclusions as:

- SPT has a non-linear relation with modulus of deformation of the soil, though the augmentation of “E” leads to augmentation of SPT number.
- SPT number and the fine material content in percentage have nearly a linear relation.
- The augmentation of the cohesion due to the presence of silt particles leads to diminution of the SPT and the relation between them is linear.
- Between SPT and Rf(from CPTU) we see a non- linear behaviour, the augmentation of “R_f“ leads in an augmentation of SPT
- “qc” and “fs” from CPTU tests are closely tied with the percentage of sandy fraction (>0,075mm). The augmentation of this

percentage leads to augmentation of these two parameters, but “fs” has a rapid increase.
- The relations between “Vs”, “G0” and “M” display two interesting phenomena. Both graphs have the same trend, but “M” has more rapid augmentation then “G0”. These charts show the evidence of three phases:

a) the first phase is for values of Vs<250m/s, where we have easy augmentation of the two parameters,
b) the second phase is for Vs=(250– 350)m/s, where the two parameters keep nearly constant values,
c) the third phase is for Vs>350m/s, where we have very rapid augmentation of the “G0” and “M” values.

5. Problems and recommendations for the improvement of the situation

The area where the new airport of Vlora will be constructed, is composed of problematic soils. In these conditions we except significant deformations which can lead the objects of the airport embeded here, suffer the serviceable limit state, or ultimate limit state. [3]

The presence of silt particles in high percentages; fine sand, organic matter, high underground water level (-0.5m), and non-consolidated silty clays are all negative factors, which affect the behavior of the basement deposits.

Also the potential of frequent earthquake events should make us(designers) very careful when designing the optimal solutions for the construction of the objects of the new airport.

We think it is necessary to make interventions in these basements before the construction with the intention to improve the soil condition.

We recommend two possible solution:

1. pre-consolidation (constructing a temporary embankment) and
2. using stone or gravel piles.

The second method is more favourite because the gravel piles can play also the role of vertical drainage and can serve as damper of pore pressure, which augments the effective stress.

These two methods can make the soils less deformable, more resisting and their behavior under static and dynamic loads will be satisfactory.

For all calculations we recommend the use of geotechnical model presented here below, see Fig.16.

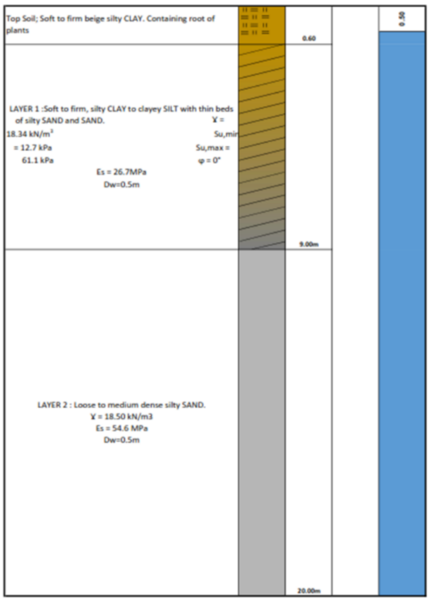


Figure 16. Geotechnical model for the geotechnical calculations

6. Conclusions

Soils in the zone of Akerni – Vlora are very problematic.

Their existence makes possible the exceedance of the limit states in the ground and in the structures constructed over it.

There exist many correlations between the data from in situ and in laboratory testing.

In the future these correlations can help designers predict and evaluate with accuracy the problems related to ground settlements and stability.

It is necessary to improve the ground conditions before the construction of the objects of the Vlora airport.

The engineering means and methods must be chosen in function of the type of objects needed to be constructed and the ground conditions, or the dangerous phenomena raised.

Acknowledgement

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