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The Geological Setting and Dynamic Properties for Soils in Tartous area (Syria)

(Submitted by academician E. Y. Khachian 24/XII 2003)

1. Introduction. In the past centuries many disaster earthquakes have been taken place in the western part of Syria. These earthquakes are connected to the main Fault system called Dead Sea Fault System (DSFS). To minimize the loss of casualties caused by such natural disaster, microzonations studies are much needed in northern western side of Syria. Tartous region is conducted to zone no.IV (PGA = 0.4g) by Syrian code. The aim of this study is to adjust the Syrian code and make it more accurate for Tartous region. Therefore studying the local soil behaviors under earthquake forces are very important. To study soil characteristics more than 29 reports have been chosen from different engineering previous work. These reports provided us with basic elements like Deformation Modulus (E) Density (ρ) and (μ) passion Factor for each borings. The other dynamic properties (Vs and Ts) were calculated based on Khachian-Okomoto assumptions. Different layers have been used to classify the area of Tartous like Geology map, Geomorphology, Structural map and the results obtained from borings. Finally classified image has been generated for Tartous City, which recognize among 4 types of soil.

2. Location of study area and past geological studies. Tartous area is located North West Syria in the coastal plain. It covers an area about 1000 Km^2. The coastal area studied by several scientists like M. Blanckenhorn (1891) [1], L. Dubertret (1958) [2], A soviet geological team (V. V. Kozlov, A.V. Artyemov and A. F. Kalis, 1966) [7], and M. Mouti (1976) [4], [5].

3. Geomorphology of the Study area. The Coastal Mountain extends in the two areas of Tartous and Safita. Generally, the slopes dip gently toward the Mediterranean Sea. The Coastal area are divided into four geomorphological units.

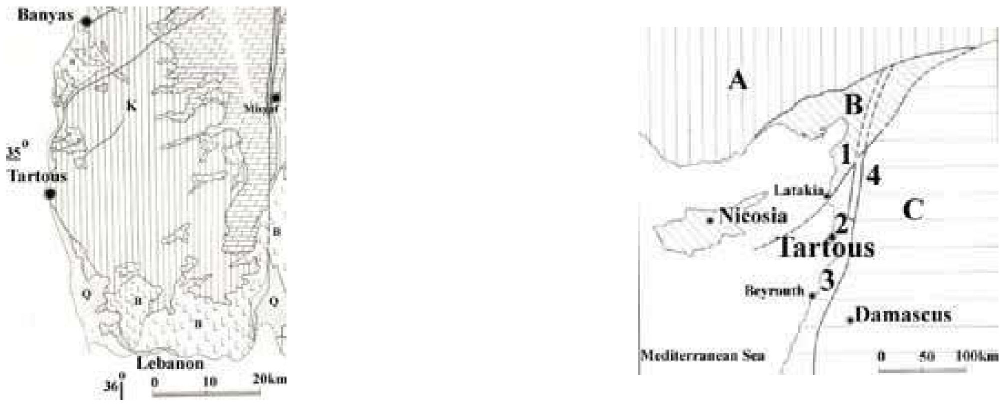
3.1 Deeply dissected Carbonate terrain. This area is cut by many valleys. The soil cover is shallow and carbonated soils, partly colluvial enriched by clayey matrix. Sinkholes and karst fissures are common in this unit.

3.2 Moderate Dissected Carbonate terrain. In the contrary to unit 1 the maximum relief is much less Gentle slopes prevail and most of the tops of the hills are flat. On gentle slopes and on plains a soil is developed composed of brown colored clayey material mixed with boulders of flint.

3.3 Hilly country. The area is an old plain modified by young erosional processes. The terraces and the flat area are covered by soil composed of brown colored carbonated clay.

3.4 Coastal Plain. The coastal plain is located on the shore of the Mediterranean Sea. Flat areas gently incline to west. The width of coastal plain is up to 4 km, but in general about 1 km only.

4. Regional Geology and Tectonics. The coastal Mountains are located on fringe of Arabic platform, bordered by the Mediterranean Sea basin in the west, Ghab Rift (northern extension of Gulf of Aquaba Dead Sea Rift) in the east, and Lebanon Mountains in the south (Fig. 1,). It is horst structure. The area may be determined as an oblique horst dipping to west and southwest in general (V. P. Ponikarov (1963) [6]) (Fig. 1,b). Limited numbers of faults occur in the north-east of the area. They are extension of the faults that occur in Qadmous-banyas area. The main trends are NE-SW and SE-NW. The Geology map of Tartous area is shown in Fig. 1,a.



a

b

Figure 1. (a) Geological map of Tartous area. (b) Geological-stuctural map of the western part of Syria. A: Alpine Orogene. B: Transition Zone. C: Arabic Platform. 1: Bassit Block. 2: Coastal area. 3: Lebanon Mountains. 4: Ghab rift. (Shabo, 1980) [8].

5. Different Soil types located in Tartous area. The area is differentiated into eight classes of soil indicated by the following characterization.

Class 1: it is characterized by: hard and medium hard Jurassic limestone or dolomite.

Class 2: the soil described as: alternation of limestone, dolomite and marl.

Class 4: the Geology and soils described as: soft marly siltstone, marl and medium hard sandstone and conglomerate.

Class 5a: the soil characterized as hard and soft fine grained marine sandstone with intercalations of gravels covered by consisting of clayey, highly porous.

Class 5b: soil characterized as Gravel and boulder beds of Pleistocene time.

Class 6: the soil characterized as Sand, silt, gravel, pebble and boulder beds.

Class 7: soil characterized as eolian fine – and medium grained sand deposits.

Class 8: soil characterized as friable, strongly weathered basaltic lava and tuff.

6. The Mechanical & Physical soil Properties. This paper presents the results obtained from 29 data sets collected over Tartous area. We have used over than 29 reports prepared by different engineers in Syria. These reports provided us with the basic engineering properties, after that we calculated the needed other factors like G (t/m^2), Vs (m/sec), and the density ρ (ts^2/m^4). The lithological changes with depth have been discovered using the data from many borings.

We have created a map to show the location for each point in Tartous region. The soil properties have been calculated and adopted in tables which contains the most important factors like, Natural water content w(%), Bulk density γ b (gr/cc). Dry unit weight γd (gr/cc), Relative Density Gs, Porosity η (%), Degree of saturation Sr (%), Angel of internal friction (Φ. deg), Cohesion C (kg/cm^2), Deformation Modulus E (t/m^2), Shear factor G (t/m^2), Shear wave velocity Vs (m/s), Period of soil Ts (sec), Liquid limit LL (%) , plastic limit PL (%),Plasticity Index PI (%), passion Factor (μ), and soil type St. To calculate the dominant period Ts we have calculated the shear wave velocity for each layer in each boring using equation (4). During calculations we didn't consider the surface layer characteristics, which are described as disturbed layers. The periods of soil Ts (sec) have been calculated based on the equations: (6) developed by Edward Khachiayn (Khachiyan, 2000) [9], (1), (2), and (3). This equation is given as follows: In case we have only one layer so the period Ts calculated using following formula:

$$T_{01} = \frac{4H}{v_s} \quad (1)$$

For n layers Ts can be calculated using the following formula (Okomoto, 1980) [10]:

$$T_{01} = \sum_{k=1}^{n} \frac{4H_k}{v_{sk}} \quad (2)$$

Or it can be calculated by using the following equation [9]:

$$T_{01} = \frac{4H}{v_s} \quad (3)$$

While Vs is the averaged velocity as shown in equation (7) H represents total depth. Shear wave velocity:

$$v_{sk} = \sqrt{\frac{G_k}{\rho_k}} \quad (4)$$

Shear factor calculated using this formula [9]: G = E / 2(1 + μ).

$$T_{01} = 4H\sqrt{\frac{\sum_{k=1}^{n} \rho_k \left[H_k + \frac{H}{\pi}\left(\sin\frac{\pi h_k}{H} - \sin\frac{\pi h_{k-1}}{H}\right)\right]}{\sum_{k=1}^{n} \rho_k v_{sk}^2 \left[H_k - \frac{H}{\pi}\left(\sin\frac{\pi h_k}{H} - \sin\frac{\pi h_{k-1}}{H}\right)\right]}} \quad (6)$$

While, $h_0 = 0$, $h_k = \sum_{i=1}^{k} H_i, h_n = H$

ρ_k Is the density, H is the total depth, Hi is the layer thickness, and n is number of layers. The following equation used to calculate average velocity

$$\bar{v}_s = \frac{\sum_{k=1}^{n} H_k}{\sum_{k=1}^{n} \frac{H_k}{v_{sk}}} \quad (7)$$

The soil changes with depth for each boring have been shown and described with their thicknesses in tables for each point. All Factors needed have been calculated and adopted as seen in the following examples: **Point No. 1** is Located in the southern part of Tartous city at Thawrah street, south of Alghamkah Bridge. 6 boring have been given the lithological changes with depth. It covers an area about 1000 m^2 as shown in diagram 1. The periods Ts, calculated in 4 different equations 1, 2, 3, and 6. In this paper we calculated the average velocity as described in equation (7). Finally we calculated the average velocity and period for each boring and for each point. The resulted values don't show big differences among them, which are related to the following reasons: shallow depth used, and low numbers of soil layers presented in the same point. By integrating data collected from different layers (Geological, Geomorphological, Structural and Engineering properties), the resulted image has been created for Tartous City. In this map the area has been divided into four zones represent different soil types.

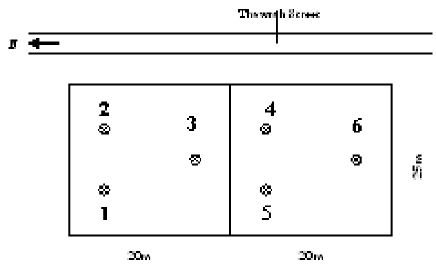


Diagram No. 1 shows the location of borings at point No. 1.

Zone 1 represents layer characterized by low density, high porosity, not stable under earthquake forces like sandy silty clayey soil, low velocity value. Zone 2 represents layer characterized by medium dense soil lying over hard limestone with presence of soft layer in different places low to medium Shear Wave Velocity value. Seismically this layer considered more stable than first layer. Zone 3 represents layer characterized by medium to hard limestone, with medium velocity value. This layer seismically, considered as stable layer. Zone 4 represents hard limestone or dolomite layer characterized by medium to high velocity. The most stable seismically in this region, but unfortunately this layer located very close to major tectonic fault called Dead Sea Fault System (DSFS) which should be taken in our future calculations.

Table 1: lithological changes and soil description over Boring No.1

Layer. No.	***thickness m***	***Soil description***
1	4.5	Surface layer
2	2	Clay with silt and gravel saturated with water
3	1	Sand with Clay and high content of grey to white Silt
4	2	Alluvial gravel with different sizes
5	4.5	Clay with Sand and gravel
	H =14	Ps. Ground water has been noticed at depth = 5 m Layers after 4m it is not stable under earthquake forces.

Table 2: lithological changes and soil description over Boring No.2

Layer. No.	***thickness m***	***Soil description***
1	4.5	Surface Layer
2	1.5	Clay with silt and gravel saturated with water
3	2.5	Sand with Clay and high content of Silt
4	5.5	gravel with different sizes with Sand and clay
	H =14	Ps. Ground water has been noticed at depth = 5 m Layers after 4m it is not stable under earthquake forces.

Table 3: lithological changes and soil description over Boring No.3

Layer. *No.*	*thickness* *m*	*Soil description*
1	3.5	Surface Layer
2	5	Gravel with Sand and fine clay and silt. At depth 5m thin layer of clayey white calcite.
3	5.5	Sand with Clay and silty clay with few gravels
	H =14	Ps. Ground water has been noticed at depth = 5 m Layers after 4m it is not stable under earthquake forces.

Table 4: lithological changes and soil description over Boring No.4

Layer. *No.*	*thickness* *m*	*Soil description*
1	4	Surface Layer
2	0.5	Gravels with sand and silty clay
3	4.5	Gravel with marine Sand and fine clay and silt.
4	5	Sand with sandy clay with gravels
	H =14	Ps. Ground water has been noticed at depth = 5 m Layers after 4m it is not stable under earthquake forces.

Table 5: lithological changes and soil description over Boring No.5

Layer. *No.*	*thickness* *m*	*Soil description*
1	4	Surface layer
2	0.7	Sand and silty clay with gravel substances
3	4.30	Gravel with marine Sand and fine clay and silt.
4	5	Sand and clay with presence of gravel substances
	H =14	Ps. Ground water has been noticed at depth = 5 m Layers after 4m it is not stable under earthquake forces.

Table 6: lithological changes and soil description over Boring No.6

Layer. *No.*	*thickness* *m*	*Soil description*
1	3.3	Surface layer
2	5.7	Gravel substances with Sand and sandy clay
3	5	Clay and sand with presence of gravel substances.
4	H =14	Ps. Ground water has been noticed at depth = 5 m Layers after 4m it is not stable under earthquake forces.

7. Conclusion. The study of soil properties is very important for earthquake engineers. These kinds of study show us the behavior of soil under earthquakes forces. Actually knowing the soil periods show what kind of building or project we have to construct, and sometimes save a lot of souls and money. Microzonation studies only can give us a clear idea about the area under investigations. For carrying out such study which is much needed, we must collect a lot of samples and calculate their characteristics especially Deformation Modulus, Passion Factor, Velocity and soil period. These kinds of study will give a clear view for future work and city development. With the help of Geology, geomorphology, structural and the soil properties calculated we could create a classified image for Tartous city. This image recognize among 4 classes of soil.

Table 7: The calculated and estimated factors for each boring over point No. 1

Boring No.	*Layer No.*	*Thickness m*	*ρ ts^2/m^4*	*E t/m^2*	*μ*	*G t/m^2*	*Vs m/s*	*By using equations(2), (3), (6), (7)*			
								T_{01} sec (2)	T_{01} sec (6)	$\overline{V}_s$ m/s (7)	T_{01} sec (3)
	2	2	0.204	750	0.4	267.86	36.23				
	3	1	0.21	880	0.38	318.84	38.96				
	4	2	0.198	950	0.4	339.3	41.4				
	5	4.5	0.20	800	0.4	285.7	37.8				
1		H=9.5						0.99287	0.99667	38.27	0.99294
	2	1.5	0.196	920	0.4	328.6	40.94				
	3	2.5	0.22	850	0.38	307.97	37.4				
2	4	5.5	0.206	800	0.4	285.71	37.24	1.0047	1.02315	37.82	1.005
		H=9.5									
	2	5	0.219	1850	0.3	711.54	57				
	3	5.5	0.216	1200	0.35	444.4	45.36				
3		H=10.5						0.8356	0.89	50.25	0.836
	2	0.5	0.196	950	0.4	339.3	41.6				
	3	4.5	0.218	2400	0.35	888.89	63.85				
4	4	5	0.206	1300	0.35	481.5	48.4	0.7432	0.7643	53.82	0.74321
		H=10									
	2	0.7	0.185	725	0.4	258.93	37.4				
	3	4.3	0.225	2280	0.3	876.92	62.43				
	4	5	0.22	1800	0.35	666.67	55.05	0.71368	0.7048	56.05	0.71364
5		H=10									
	2	5.7	0.193	1450	0.3	557.69	53.75				
	3	5	0.206	2100	0.35	777.78	61.45				
6		H=10.7						0.74965	0.69968	57.09	0.7497
The averaged Ts & Vs values for each boring								0.83995	0.84643	48.883	0.84008
Total Average Ts and Vs for point 1						$\overline{V}_s$ *(total)* = 48.888 m/s			T_s *(total)* = 0.84215 sec		

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Ռ. Ա. Ահմադ

Տարտուս քաղաքի (Սիրիա) տարածքի երկրաբանական առանձնահատկությունները և գրունտների դինամիկական բնութագրերը

Բերվում են անհամասեռ բազմաշերտ հիմնատակերի դինամիկական բնութագրերի ուսումնասիրությունների արդյունքները Տարտուս քաղաքի տարածքում շինարարական հրապարակի սեյսմիկ վտանգի աստիճանը գնահատելու նպատակով՝ կախված ինժեներա-երկրաբանական պայմաններից: Նկարագրված են տարածքի գրունտների տիպերը և հորատման միջոցով ստացված խորքային ապարների ֆիզիկա-մեխանիկական բնութագրերը: Ալիքային տեսության տարբեր եղանակներով որոշված են անհամասեռ հիմնատակերում լայնական ալիքների տարածման արագության միջին արժեքը և գերակշռող պարբերությունների մեծությունները, որոնք ըստ ժամանակակից պատկերացումների հանդիսանում են տվյալ տարածքի սեյսմիկ միկրոշրջանացման և գրունտային հիմնատակերը ըստ սեյսմիկ հատկությունների դասակարգման հիմնական պարամետրեր:

Р. А. Ахмад

Геологические особенности и динамические свойства грунтов территории г. Тартус (Сирия)

Приводятся результаты исследований динамических характеристик структурно-неоднородных многослойных оснований для оценки степени сейсмической опасности территории прибрежного города Тартус в зависимости от инженерно-геологических условий площадки строительства. Описываются типы грунтов территории города. Исходя из физико-механических характеристик глубинных пород, полученных в результате бурения, различными методами волновой механики определены средние значения скоростей распространения поперечных волн и преобладающие периоды колебания многослойного основания, которые, по современным представлениям, являются основными параметрами для микросейсморайонирования территорий и разделения грунтов на классы по сейсмическим свойствам.