INFLUENCE OF SATURATED MEDIUM ON GEOTECHNICAL CHARACTERISTICS OF SOILS

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ABSTRACT: The paper mentions in a real problem happened in the dumping ground, the industrial activity area or coastal area, that is the contamination of pollutant in the ground. The ground contaminated by seawater or chemically polluted water will lead to the changes in construction characteristics of the soils. The testing on influence of waste water on soil deformation was carried out on loess soil and clay paste when they were saturated with pure water, crude oil and detergents. The change of parameters especially compressibility of loess and clay paste when these soils were saturated by pure water, salty water and detergents had been investigated. Besides, undisturbed clayey samples were also tested in saturated condition with salty water. The results of the tests show that the soils saturated by detergents will increase their deformation and compression, however, they become inversely in case of soil saturation by crude oil. When soils saturated by salty water, the change of their parameters is on contrary depending on soil's mineral composition.

INTRODUCTION

The industrial activities of human being on the earth are going strong. Accompanying them is the discharge of chemical pollutants to the neighboring environment. Consequently, the areas around industrial plants are increasingly contaminated as a result of their pollution due to leakages from the sewage network and their appurtenant structures, failure in the various installations and the disposal of chemical wastes on and under the ground surface. Besides, the natural geological hazards such as sea level rise, coastal erosion, flooding near the coast are also made inland area ground gradually intruded by seawater.

The ground that contaminated by seawater or chemical polluted water will lead to changes in constructed characteristics. The knowledge and understanding of geotechnical increasingly enabling the constructions can be located at any conditions of ground. The study of variations of geotechnical characteristics of soils being contaminated by different substances in the interaction with the structures is taken into account.

INFLUENCE OF WASTE WATER ON SOIL DEFORMATION

The authors pay at tension to the studies on influences of one of the most frequently encountered pollutants of the subgrade in industry on the deformation properties of loess and clayey soils, namely the industrial waste water containing surface-active substances.

In clays and generally soils with low permeability, it is difficult for solution of chemical substance to penetrate through the specimen tested in the laboratory. For that reason a test apparatus was used which represents a closed airtight oedometer allowing the penetration of a liquid through the soil specimen in upward or downward direction. The apparatus is designed for determining both the permeability and the deformation properties of soils.

Before the studies, the mineral compositions of soils tested were determined with electronic microscopic and X-ray crystallographic analysis. The geotechnical testing on these soils were also carried out with twin specimen (cut from one disturbed sample). Their parameters are given in table 1.

Table 1. Physical characteristics of loess and clay tested [Kirov B., 1993]

	γ	ρ_S	e	W	W_L	W_P	Particle size distribution (%)		
	g/cm^3	g/cm^3	%	%	%	%	$2 \div 0.05$	$0.05 \div 0.005$	<0.005
Loess soils	1.67	2.74	0.87	14.5	22.0	28.0	25.0	73.0	2.0
Clay paste	1.76	2.70	1.17	41.5	20.0	42.0	23.0	67.0	10.0

Deformation of clay paste (remolded clayey specimen)

Mineral composition of clay paste includes chlorite, hydromica, kaolinite, quartz and feldspar. Quantitative prevailing is quartz, hydromica, chlorite and kaolinite respectively. Least found are feldspars.

For making the test, specimens fully saturated with 2% water solution of detergent by upward penetration was carried out. Subsequent step these specimens were compressed with oedometer test. Simultaneously oedometer tests were executed with non-polluted condition for paste clay by saturated with distilled water.

The compression curves obtained for the clay paste specimen are plotted in figure 1, where curve 1 is for soil specimen saturated with distilled water, and curve 2 is for specimen processed with a 2% solution of detergents. The comparison between curves 1 and 2 shows a considerable reduction of the oedometer modulus. For example, in case of a loading of 0,2 MPa the oedometer modulus of the clay is reduced by 15%.

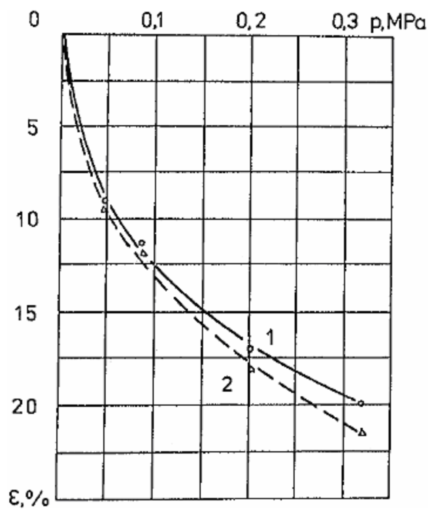

Figure 1. Compression curves of a clay paste without (1) and after processing with a 2% solution of detergents [Kirov, B., 1993]

Deformation of loess soils

Petrographical composition of loess soils tested is divided into sand–silt and clay fraction. Mineral composition of sand and silt fractions includes quartz, mica, feldspar and carbonates, and that of the clay fraction is hydromica, montmorillonite and kaolinite.

The testing procedures were executed similar to the above for loess soils. However, beside the saturation with distilled water and detergent solution, the effect of crude oil and petrol on loess was also studied, since they can penetrate in the soil in case of accidents in petrochemical plants and stores for oil products or oil spill in the rivers, around the islands or a long the coast. The tests with crude oil was carried out applying the same pattern as with the detergents, whereby after a loading of 0,28 MPa was reached, solution was let to penetrate upwards through the specimens. In a parallel oedometer test with loess at natural water content, after a loading of 0,28 MPa was reached, first petrol was let to penetrate upwards and then water (see figure 2).

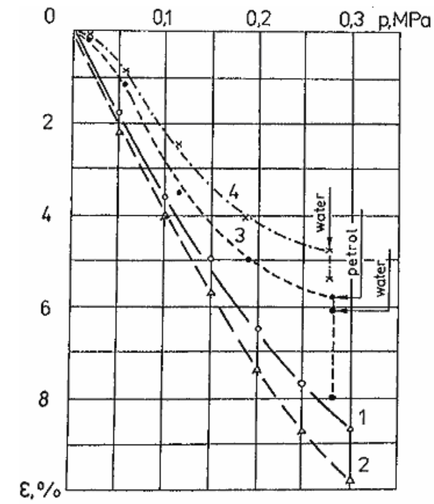

Figure 2. Compression curves of undisturbed twin loess specimen; saturated with distilled water (1), with 2% solution of detergents (2), with natural water content (3), with crude oil (4) [Kirov, B., 1993]

The test results given in figure 2 indicate that curves 1 and 2 which are corresponding to specimens saturated with distilled water and with polluted water show a significant reduction of the oedometer modulus. Thus for example, in case of a loading of 0,2 MPa the oedometer modulus is reduced by 20%.

The results of loess soils saturated with crude oil give an inverse situation. The collapsibility reduces up to 4 times and the oedometer modulus raises up to 40% (see curves 4, 3 and 1). When the loess is wetted with petrol a comparatively limited collapse (0,3%) is obtained, and after a subsequent wetting with water the loess completely preserves its collapsability (see curves 3 and 1).

The comparison of curves 3, 1 and 2 after the well known method of the two curves shows that the collapsibility due to the 2% solution of detergents (see curves 2 and 3) is increased up to 1,5 times compared to 3the action of the distilled water (curves 3 and 1).

INFLUENCE OF WASTE WATER ON SOIL CONSOLIDATION

This study outlines the influence of the industrial waste waters (mainly from the chemical industry) on the process of consolidation of soils, taking the time factor in mind. An investigation is carried out on the one-dimensional strain state of thick soil samples with an oedometer, which eliminates the lateral friction.

Loess soils and clay paste which have absolutely the same characteristics as those of the above study are investigated objects. Four sets of tests were conducted on the influence of detergents and salty waters on the collapsing of loess. The first set was executed on sample with natural water content (curve 1, figure 3) and the others on samples which were saturated upwards with distilled water (curve 2), with 10g/l water solution of NaCl (curve 3) and with 2% water solution of detergents (curve 4) after which the tests were continued under full saturation.

The comparison of compression curves and the coefficient of macropores n_{mp} shows that the deformation of the saturated loess decreases under the action of salty waters and increases under the action water containing surface active substances.

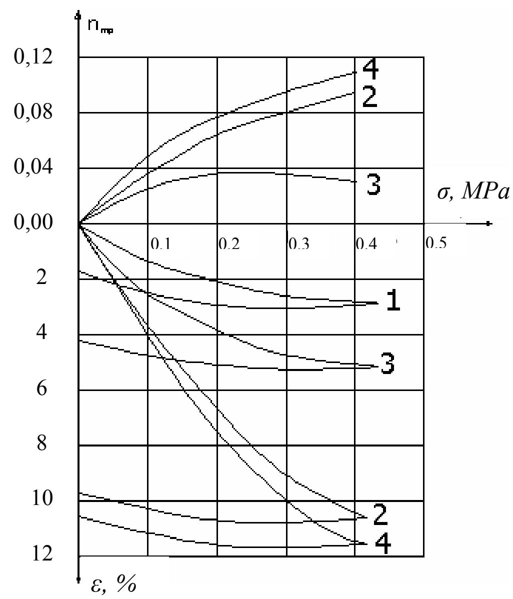

Figure 3. Compression curves (b) and collapse curves (a). Natural water content (1); saturated state with pure water (2); with salty water (3); and with water containing detergents (4) [Germanov T., Kirov B., 1989]

Tests for investigation of deformations from creeping under compression of saturated loess and clay paste were conducted. There investigations are necessary for predicting the changes in the settlement of constructions during their operation. The results from the laboratory tests show that the diagrams $\varepsilon = f(\lg t)$ are consolidation curves of a classical type, i.e. after dissipation of the pore pressure the strain grows proportionally to the lg t (figure 4).

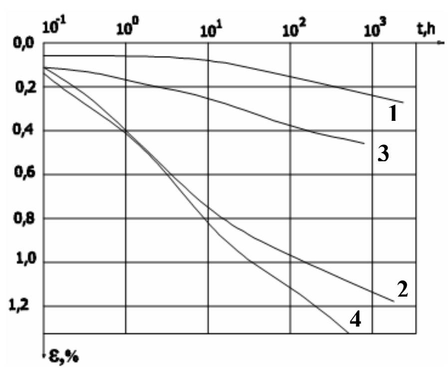

Figure 4. Rheological curves showing the consolidation of loess (σ = 0,2 - 0,25 MPa): in a natural state (1); saturated state with pure water (2); with salty water (3); with water containing detergents (4) [Germanov T., Kirov B., 1989]

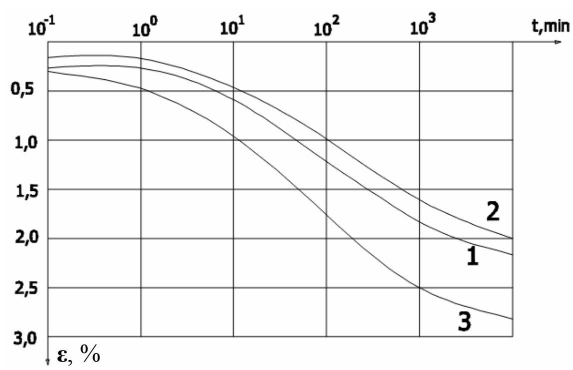

Figure 5. Rheological curves showing the consolidation of clay paste 20mm high in an oedometer under full saturation with pure water (1); salty water (2); and water containing detergents (3) [Germanov T., Kirov B., 1989]

The deformations of soils with such diagrams can be described comparatively well with the theory of hereditary creeping. The relation between stress, deformation and time can be expressed with the following integral equation (Germanov, Ter-Martirosyan, 1980):

$$e_o - e(t) = m_o\sigma'(t) - \int_o^t \sigma'(t)\frac{d}{d\tau}m_v(t,\tau)d\tau \qquad (1)$$

where: e_0 and e(t) are respectively the primary void ratio and that changing with time;

σ' - effective normal stress;

$m_v(t,\tau)$ - coefficient of volume change, which can be defined from the equation:

$$m_v(t,\tau) = m_o + m_i\{1-\exp[\eta_i(t-\tau)]\} \qquad (2)$$

where: m_0 – and m_i are coefficients of instantaneous and secondary creeping consolidation;

η_i - rate of creeping;

τ - coordinate of time.

The parameters of creeping of the soils tested are defined according to the methods elaborated by Germanov (1978). They are shown in table 2.

Table 2. Parameters of creeping of the soils tested [Germanov T., Kirov B., 1989]

Soil	Chemical influence	Parameter of creeping		
		m_0 $(MPa)^{-1}$	**m_i** (MPa)-1	η_i (h-1)
Loess soils	Natural state	0,0095	0,0684	0,0021
	Pure water	0,0297	0,4666	0,0026
	Salty water	0,0168	0,1504	0,0032
	Detergents	0,0210	0,5062	0,0034
Clay paste	Pure water	0,0502	0,7588	0,0384
	Salty water	0,0376	0,6704	0,0377
	Detergents	0,0588	0,8335	0,0405

INFLUENCE OF SALTY WATER ON COMPRESSION AND PERMEABILITY OF SOILS

To assess objectively the basic characteristics of soils, hundreds of undisturbed samples were collected and tested. They are taken from six different regions in Red River Delta, Vietnam, where the potential of sea level rise and salty intrusion of ground is increasingly severe. The samples are determined clay and silty clay (see table 3).

Table 3. Research areas in the Red River delta

Region	Position	Description
Hanoi	Nhan Chinh, Thanh Xuan dist.	Clay
Ha Dong	Mo Lao, Ha Dong City	Silty clay
Hai Duong	Thanh Binh, Hai Duong City	Clay
Thai Binh	Vu Thu District	Silty clay
Nam Dinh	Nam Truc District	Silty clay
Hai Phong	Minh Tan, Kien Thuy dist.	Clay

The change in compression characteristics of soil

Study on the change in compression characteristics of soil was carried out by one-dimensional compression test on Oedometer device concurrently for two cases of tube water and brine in order to compare the variations in compressibility of soil. Mechanical specifications of soils taken into considerations were the general module E_0, compression index Cc and coefficient of compression a_{1-2}.

The average compression curves of soils from each region within the study areas derived from the laboratory tests are shown in figure 6. Based on these compression curves, it was easy to observe a remarkable change in mechanical characteristics in 6 research areas of the Red River delta in two saturated conditions. After soil specimens are saturated with salty water, their compression curves were almost below the compression curves when they were saturated with tube water.

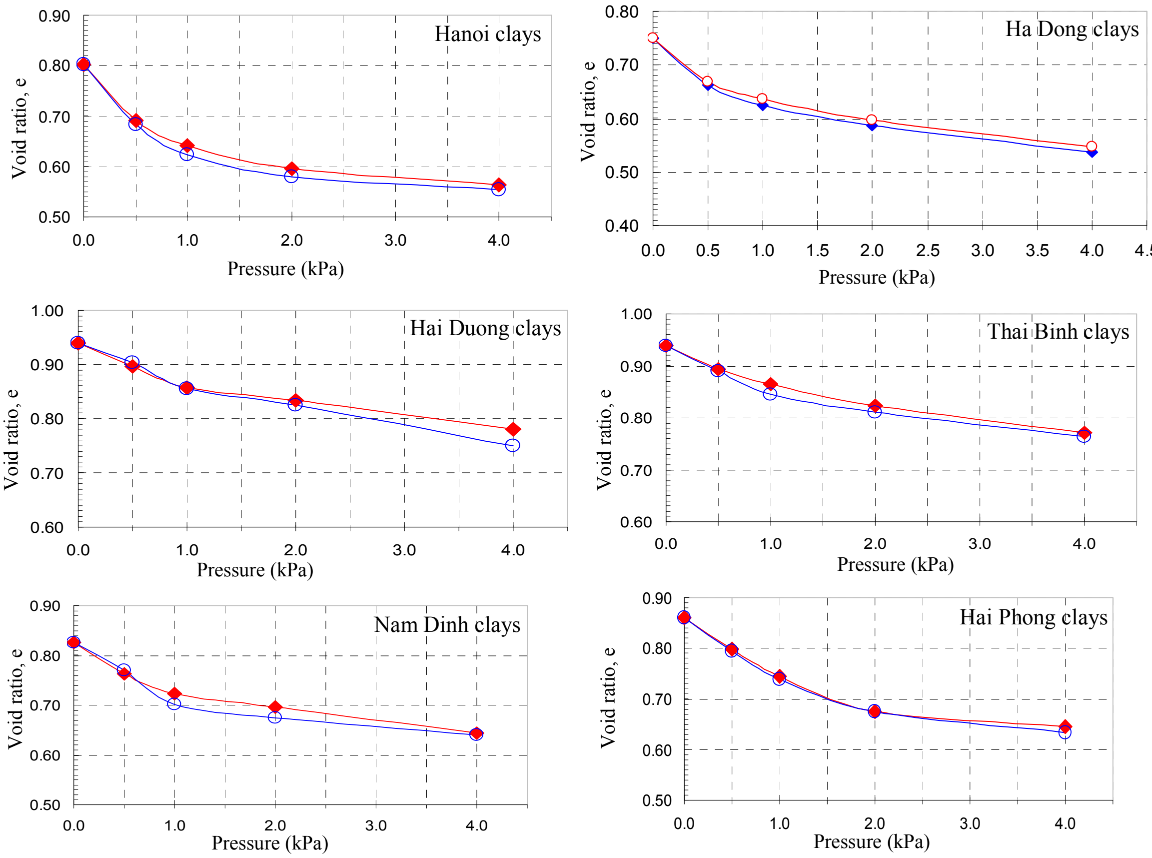

Figure 6. The average compression curves of soils at 6 regions within the study area
(saturated by brine, saturated by tube water) [Truc N. N., Granie R. J., 2008]

For the parameters that specify compression characteristics of soils, coefficient of compression a_{1-2} was decreased once the soil is saturated with salty water. The attenuation ratio fluctuates from 2.56 % to 17.07 %, reaches 6.93 % on average. Compression index Cc of soils was also changed significantly with two saturated conditions, fresh water and brine water. Compression index of brine-saturated soils at 6 research locations decreased by 6.94% on average when compared with saturated with tube water. General module of soils E_0, were decreased by similar amounts i.e from 0.5 to 12.0%. This means once the soils are intruded by salt the compressibility decreases. All derived results from the laboratory tests on undisturbed specimens are shown in table 4.

Table 4. Change in significant specifications of compression of soil at six research areas, ((*) saturated with brine water) [Truc N. N., Granie R. J., 2008]

	Coef. of compression, a_{1-2} (cm^2/kG)	**Coef. of compression, a_{1-2}*** (cm^2/kG)	**Change rate** $a_{1-2}*/a_{1-2}$ (%)	**Compression index** Cc	**Compression index** Cc*	**Change rate** Cc*/Cc (%)	**General module** E (kG/cm^2)	**General module** E* (kG/cm^2)	**Change rate** E*/E (%)
Hanoi	0.045	0.043	- 4.44	0.136	0.114	- 16.17	1.658	1.638	- 12.06
Ha Dong	0.039	0.038	- 2.56	0.094	0.086	- 8.50	0.129	0.123	- 4.65
Hai Phong	0.060	0.057	- 5.00	0.104	0.101	- 2.88	1.63	1.62	- 0.61
Hai Duong	0.031	0.030	- 3.20	0.201	0.189	- 10.00	0.104	0.101	- 2.88
Nam Dinh	0.028	0.026	- 7.14	0.131	0.127	- 3.053	1.72	1.70	- 1.16
Thai Binh	0.041	0.034	- 17.07	0.150	0.143	- 4.667	1.86	1.85	- 0.54

Change in permeability of soil

Permeability of soil is characterized by its hydraulic conductivity represented by *k* and determined on the basis of Darcy's law. It is generally expressed in cm/sec or m/sec in SI units. The hydraulic conductivity of soil depends on several factors: fluid viscosity, pore-size distribution, void ratio, roughness of mineral particles, and degree of soil saturation. In clayey soil, structure plays an important role in hydraulic conductivity. However, another factor which is considered more specifically in this study is the assessment of dependence of permeability of soil due to the difference in soil saturation caused by brine and fresh water. Determining hydraulic conductivity k in laboratory for clayey soils is based on the inconstant head test.

To study the change in permeability of soils due to salty intrusion, we have carried out in laboratory for soil specimens collected from the six research areas (table 3). Experiments have shown that the change in saturation of tube water and brine is inconstant. In these six research areas, five cases the hydraulic conductivity *k* are increased when they were tested with brine and one decreased.

The test results that determined the hydraulic conductivity *k* at 6 regions of the study area are indicated in table 5. From the average values of those areas, we can easily observe that the hydraulic conductivity has moved up after saturated with salt water. It occupies the rate of 83.33 % of research areas. Meanwhile it goes down only at the rate of 16.67 % of research areas. The highest increase of 7.73% was observed in Hai Phong soil samples. Hydraulic conductivity k only reduces for soil in Ha Dong with the rate of k/k^* at 6.0%.

Table 5. Change in permeability at six research area, ($^{(*)}$ saturated with brine water) [Truc N. N., Granie R .J., 2008]

	Hydraulic conductivity K (cm/s)	**Hydraulic conductivity** K^* (cm/s)	**Change rate** K/K^* (%)
Hanoi	1.73×10^{-5}	1.743×10^{-5}	+ 0.764
Ha Dong	5.6×10^{-5}	5.264×10^{-5}	- 6.00
Hai Phong	7.56×10^{-8}	8.193×10^{-8}	+ 7.73
Hai Duong	4.526×10^{-5}	4.634×10^{-5}	+ 2.00
Nam Dinh	4.424×10^{-5}	4.594×10^{-5}	+ 3.70
Thai Binh	1.646×10^{-5}	1.654×10^{-5}	+ 0.483

Increase in permeability of soil due to salty intrusion implies the possibility of increased underground erosion and reduction in load bearing capacities due to washing away of materials. This challenges the stability of construction's foundation, particularly for the embankment.

SOME DISCUSSIONS

By the obtained results, one can be realized that, generally, after soils saturated by crude oil the deformation properties are improved significantly. In other words, deformation properties of soil reduce or soil becomes better in crude oil. On the contrary, both clay paste and loess are downgraded when saturated with surface active substances as detergents. After the oedometer tests the specimen were submitted to electronic microscopic and X-ray and crystallographic analysis again. For the specimen processed with detergents, no deviation from the above mentioned mineral composition was observed and no trace of chemical interaction was established. This indicated that the interaction has occurred on the basis of adhesion, cohesion and over the external surface of the basalt without any penetration of ions, molecules or micelles in the interlayer space of the minerals.

An outstanding event in testing is the compression results of clay paste and undisturbed samples be opposite with each other. The deformation properties of clay paste reduce and soil become 'better' after saturated by salty water, then the results for undisturbed clayey samples in the Red river delta are inverse. The reality of the deformation when soils saturated with salty water is not to depend absolutely on their disturbance. They depend mostly on the mineral composition also the formative condition of those soils. Clay paste is a kind of continental soil with prevailing mineral composition of quartz, hydromica, chlorite and kaolinite respectively. Meanwhile the undisturbed samples are taken in the Red river delta mainly formed by deposition in quiet lakes (lacustrine soils) and deposition in the sea (marine soils), predominated by montmorillonite, illite and kaolinite. The changes of parameters of soil due to salty intrusion depend very much on its mineral composition [Komine H., 2006]. When soil is predominated by clay mineral of montmorillonite and group, the changes occur negatively and soil is degraded by brine water.

These studies show that under the above considered interaction significant changes of the deformation properties of the soils occur. It should be taken into account in the design of structures erected under these conditions that undesirable additional settlement and collapse of the subgrade might occur in the course of their operation.

CONCLUSION

These studies are simulated the fact that chemical wastes in the industrial plants caused the penetrations and seepages into ground and salty intrusion of river mouth and coastal areas as well, brought about variation of geotechnical properties of ground and subsequently impacted on structures located on it. The testing results on the change of deformation, compression and permeability of clayey soils and loess due to the development of saturated environments were carried out reliably. They were shown a significant variation.

For loess, the deformation of the saturated one decreases under the action of salty waters and increases under the action water containing surface active substances. They have the same trend for both loess and clay paste when investigating the creeping under compression. Soils saturated with crude oil are “better” than those in saturation of detergents or distilled water but soils saturated with distilled water are “better” than those in saturation of detergents. The comparison of compaction and permeability tests for clayey soils in Red River delta, Vietnam, when saturating with tube water and salty water is given results inverse in the above soils. The compressive parameters of clayey soils are decreased and hydraulic conductivity increased with brine. These researches will contribute to establish the constructed methodologies in the regions acted by industrial waste water or highly potential regions of salty intrusion to the ground.

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