The Geotechnical Properties, on Water Sensitive Soils, Loess

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Abstract. This article presents the geotechnical characteristics of loess, water sensitive soil. A comparison of loess from around the world is made (Romania, China). These soils are of quaternary age, are found just below the topsoil and most buildings are founded on them. Problems can arise when the foundation on these lands is softened with water from different sources, permanent or casual. The appropriate parameters of geotechnical solutions for improvement will be presented.

1 Introduction

The article has appeared as a result of the fact that lately there is a globalization of information and workforce. Some international consortia, having activities in different parts of the world, are sending specialists to work on building objectives.

Especially in the field of constructions, a very important problem is the behavior of soils, so comparisons between the same type of soil found in different parts of the world are made.

Loess and loess-like sediments are quaternary soils and cover 10% of Earth's land surfaces.

In Romania, loess and loess-rich soils occupy an area representing about 17% of the territory, and in China the occupied area is 631 000 km^2. In China it is the greatest bulk accumulation of loess on Earth (Liu 1985) and here loess has the greatest thickness.

It is considered that the loess is a soil derived from unstratified wind deposits, the majority of it being comprised of dust. Due to potential collapsibility, loess can be considered as one of the most difficult foundation soils.

Numerous studies and analyses have been done to explain the microstructure, determine the mineralogical composition and geotechnical properties in order to understand the mechanisms leading to its collapsibility.

As there is easy access to information, based on analogies, geotechnical data obtained from different targets in different parts of the world can be used. Although a problematic soil, due to the increased development in the field of construction it is sometimes necessary to build objectives of high importance on loess-rich soils, which are water sensitive.

In order to forecast its behavior when certain initial conditions are changed (accidental damping of the land, earthquakes etc.), knowing and establishing a database of geotechnical parameter values is recommended.

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Figure 1 shows the location of loess in China (a) Distribution of loess deposits in China and location of the study region of the Central Shandong Mountains. CLP refers to the Chinese Loess Plateau. (b) Chinese Loess Plateau and location of some of the sites mentioned in the text. (c) Location of the studied loess sections in the Central Shandong Mountains (Pingyin — PY; Zibo — ZB; and Qingzhou — QZ) and location of the sediment samples obtained from the lower reaches of the Yellow River (YR). Figure 2 shows the area covered by loess in Romania.

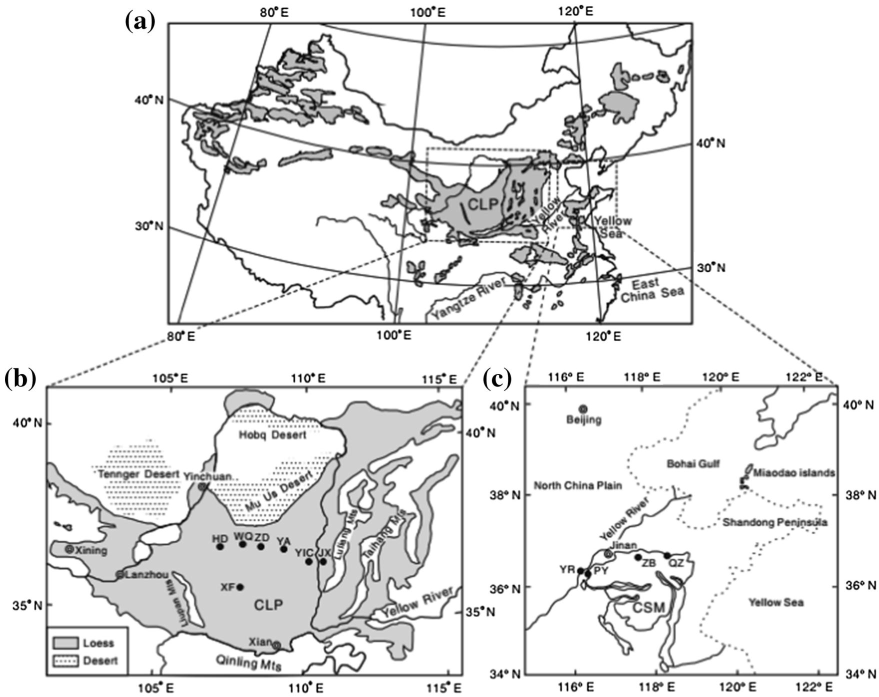

Fig. 1. Loess in China (after Shuzhen et al. 2016)

2 Characteristics of Loess

Loess is a cohesive, high porosity, unsaturated, low humidity soil, which undergoes sudden and irreversible changes of the internal structure when its moisture rises. These changes lead to additional settlements, collapsing, and a decrease in the geotechnical parameter values.

The soils' behavior under the influence of various factors depends on granulometric composition, mineralogical composition and geotechnical parameter values.

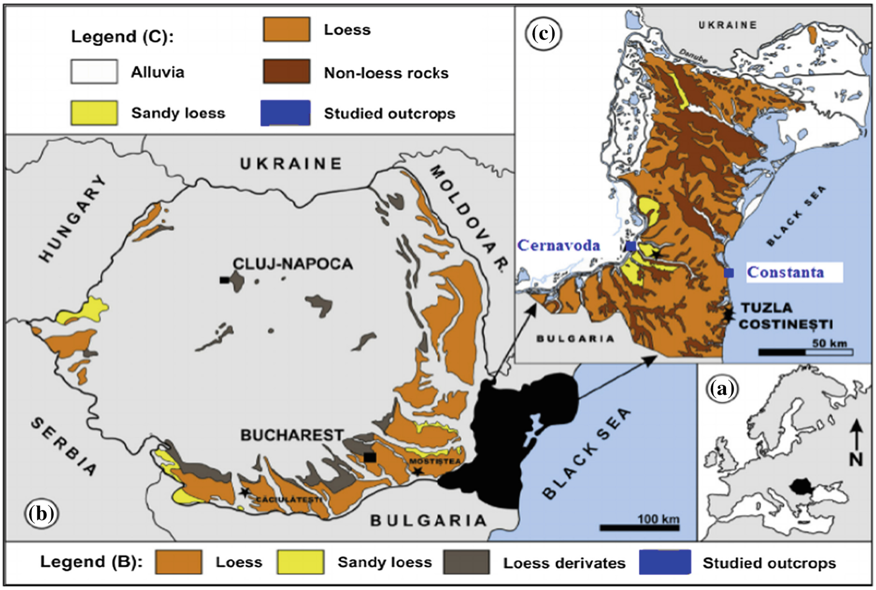

Fig. 2. Loess in Romania (after Constantin et al. 2014)

Table 1. Geotechnical parameters of soils

	Clay <0,005 mm (%)	Silt 0.005—0,05 mm (%)	Sand >0,005 mm (%)	w_L (%)	w_p (%)	Ip (%)
China	36	54	10	29.53	18.02	11.51
Romania	25	65	10	37	15	22

Although coming from different parts of the world, comparisons can be made between two soils of the same type.

Data presented from remolded Lishi Loess Q2, middle Pleistocene, China and loess of quaternary age obtained from Constanta area, Romania, was used.

Table 1 represents the average geotechnical parameters of the loess.

It is considered that a soil can be customized by considering the granulometric values and plasticity values (which are influenced by granulometry, mineralogical composition, the content of humus). "This can be done using a simple figure called the print".

Definition of the "print" – in order to define the soil nature, the print A applies to Casagrande chart in the 1st dial (point P_1) and a part of the granulometric curve in the 3rd dial; thus for the cohesionless soils we attribute in the granulometric curve the part between the efficient diameter d_{10} (point P_{10}) and d_{90} (point P_{90}), and for the cohesive ones the part between point P_{90} and the 2_{μ} diameter (point $P_{2\mu}$). In the 2nd dial it may also be represented the integral curve of pores distribution on dimensions both for the soil considered and, eventually, for the geotextile with which it comes in contact.

The 2^{nd} dial is established to represent soil activities, the position of point P_2 indicating, by the slope of the line P_2 O, the activity index $I_A = I_{\rho/x\ 2\mu}$ defined by Skempton, or the activity fields established by Van de Merwe (1975) under the observation of the behavior of the constructions built in areas with expansive clay.

In the 4^{th} dial the point P_4 is represented and it has a abscissa equal to the upper plasticity limit w_L (%) and the ordinate line related to d_{10} for the non-cohesive soils, or of d = 2μ for the cohesive ones.

By the union of the points $P_{1,}$ $P_{2,}$ P_{90} or $P_{2\mu,}$ according to each case, P_4 and $P_{1,}$ the print A is obtained which form and sizes depend on the common parameters used for characterizing the nature of given soil (Andrei, Athanasiu 1981).

A reference circle is used so the form of the print be independent of the representation scales, the circle having the center in O origin of the coordination axes and a 100 unit diameter, that passes through the points $w_L = 50\%$, $I_\rho = 50\%$, $X_d = 50\%$, d = 1 mm and which has an area of 7854 mm^2.

Considering the fact that any change in the soil nature (solid phase, and the absorption complex), may be interpreted by modifications which occurred in the form and dimension of the print, a global characterization of the material nature may be made to the related area.

A_r = print area/reference circle area

$$A_r = (185 + I_\rho)\,(W_L + 0,5_{X2\mu} + 45)/7854 \quad (1)$$

The value of the print for the Chinese loess is 2.27, while the value is 2.47 for the Romanian loess.

An image of the prints obtained for the soils to be analyzed is shown in Fig. 3.

3 Comparison Between the Parameter Values of Shear

Soil behavior is heavily influenced by shearing parameter values, which are used to calculate pressure, the settlement of constructions, the stability of banks etc. Loess-rich soils cause the most problems for the stability of buildings when they are unsaturated and porous.

In This Article, a Parallel Is Drawn Between Soils with Similar Print Values and Mechanical Properties

4 Cohesion

The values for soils with moistures of 10%, 13%, 16% and 18% and dry density values between 1.50 g/cm^3 and 1.70 g/cm ^{3}(3) were considered.

Figure 4 shows the values of cohesion depending on moisture and dry density of loess from both China and Romania (wc – moisture China, wr – moisture Romania).

By all accounts, the cohesion parameter values increase along with the percentage of clay, the increasing dry density and with the decreasing of moisture values.

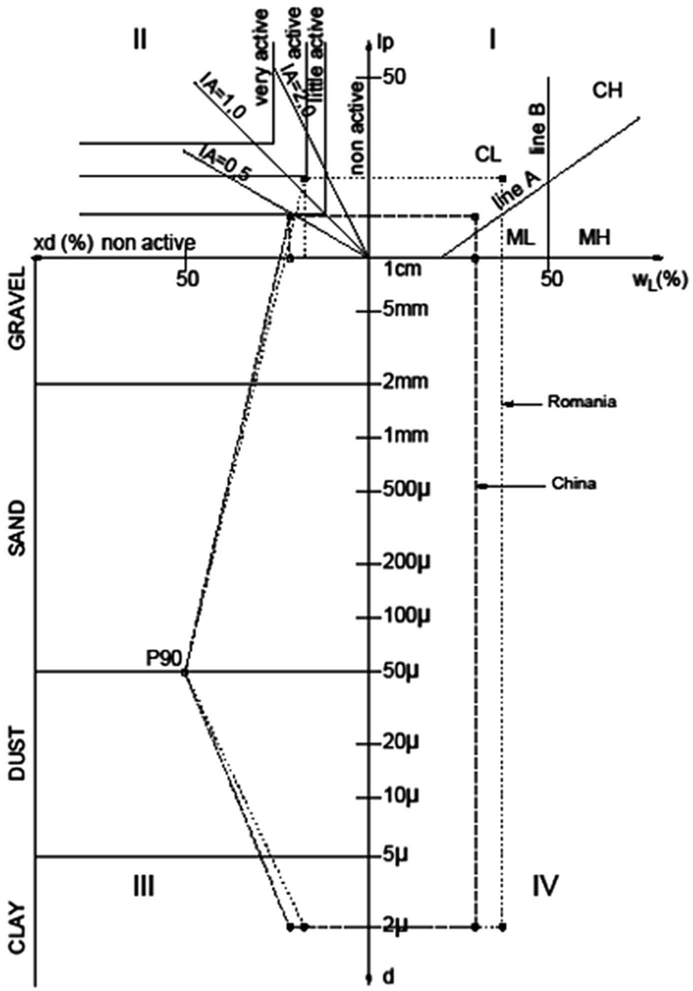

Fig. 3. "Print"soils

Although the soils have approximately equal relative area values, the cohesion values are higher for Romanian soils, although the percentage of clay is higher in Chinese soils.

Cohesion is influenced by the water absorbed by submolecular particles.

It is worth noting that, from a mineralogical point of view, the soils are different, which also results from the fact that the plasticity upper limit of loess in China is lower at a greater amount of clay.

In Romania, for a soil which has in its composition 36% clay and 10% sand, it is defined as dusty clay and the liquid limit values are 47% and plastic limit values 18.6%.

Forecasting the cohesion values and the internal friction angle was tried, using some relations obtained by Chenchen et al. (2017) for China loess.

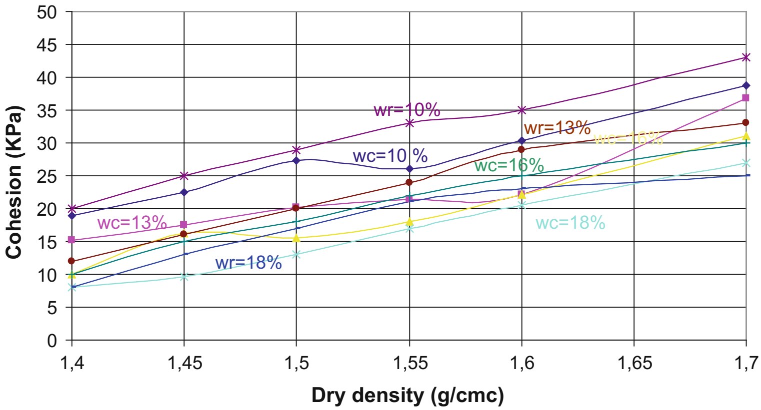

Fig. 4. Variation of cohesion values

Table 2. Relations between the values of cohesion and moisture content

Humidity w (%)	Corelation for cohesion
10	$c = 53.41\rho_d^2 - 102.95\rho_d + 58.98$
13	$c = 228.78\rho_d^2 - 645.72\rho_d + 473.09$
16	$c = 227.81\rho_d^2 - 655.32\rho_d + 486.93$
18	$c = 36.65\rho_d^2 - 39.16\rho_d - 10.55$

The formulas are based on moisture values and the dry density values are taken into account in calculations. They are presented in Table 2.

It is noted that there are differences between −6 kPa and +4 kPa, the large differences are obtained when the loess is dry and stocky, the other values do not differ very much.

For the same loess from China, a relation was found to determine the parameters of resistance, but in calculating it both the values of moisture and the dry density values are taken into account. The formula is shown and denoted by (2).

$$c = 0.035w^2 + 115.921\rho_d^2 + 1.337\rho_d w - 4.361w - 312.217\rho_d + 251.502 \qquad (2)$$

Calculating with this relation, the differences obtained between forecasted parameters and actual parameters for loess in Romania are much lower, ranging between ±3 kPa.

Figure 5 shows the obtained differences between the geotechnical parameter values in Romanian loess and the forecasted relationships of Table 2 (Fig. 5a) and the ones forecasted by formula (2) - Fig. 5b.

It is of note that the differences are smaller if the forecast cohesion takes into account the moisture and dry density values.

Large differences, in both cases, are recorded when the moisture is low, w = 10%, and the dry density is around 1.55 g/cm^3.

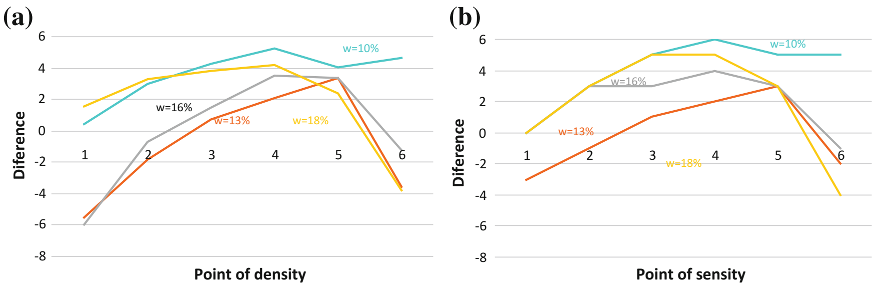

Fig. 5. XXX

It is confirmed that the cohesion parameter values increase along with the percentage of clay, the dry density and with the decrease of moisture values.

4.1 Internal Friction Angle

For the analyzed loess-rich soils, friction angle values based on the moisture and density were obtained, and are shown graphically in Fig. 6.

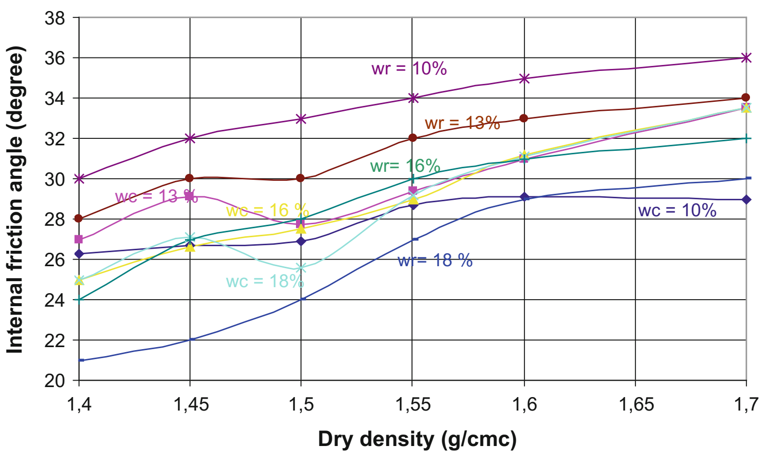

Fig. 6. Variation of internal friction angle value

It is found that for the loess in Romania the angle of internal friction values are between 21% and 36% and between 25% and 34% for China.

For the analyzed loess from China, the friction angle values are lower, due to higher clay percentage from the granulometric composition.

If the same value of density of the soil in the dry state is considered, having 10% moisture values, the angle of friction values for loess in Romania are about 30 degrees and an increase of the moisture lowers the values to 21 degrees.

An attempt was made to verify the relations obtained by Chenchen Huo et al. and are presented in Table 3. The values of the angle of internal friction will only be determined by the moisture of the soils.

Table 3. Relations between the values of the angle of internal friction and dry density

Density ρ (g/cm^3)	Corelation for cohesion
1.5	$\theta = -0.10w^2 + 2.68w + 10.1$
1.6	$\theta = -0.05w^2 + 1.65w + 17.6$
1.7	$\theta = -0.25w^2 + 7.25w - 18.5$

For the Chinese loess analyzed, a correlation to determine the angle of internal friction value has been determined, to which the moisture and dry density values are analyzed, formula 3.

$$\theta = -0.093w^2 + 10.997\rho_d^2 + 2.303\rho_d w - 0.878w - 45.597\rho_d + 54.601 \qquad (3)$$

Although there are differences in terms of the variation of the angle of internal friction according to the moisture and dry density values, the relations used have resulted in large variations of up to 7 degrees, only on the low moisture soils of Romania, otherwise variations were up to ±2 degrees.

5 Conclusions

Two soils, with relatively close print values, although from different places on Earth, may have similar mechanical properties.

When no data on geotechnical parameter values exists: either not available, undisturbed samples could not be obtained or some were damaged, existing analogies between soils can be used.

Loess-rich soils are water sensitive and can sometimes have settlements of about 10 cm/m in the case of its moistening without being burdened by a building.

Therefore in the design stage it is important to foresee their behavior under changes to the initial conditions.

In addition to the "in situ" data obtained for objectives achieved in certain areas, data from specialty literature from other areas of the world may be used.

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