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COLLAPSE SETTLEMENT SENSIBILITY ANALYSIS OF LOESSOID SOILS

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Abstract:

Collapsibility of the loess is strongly governed by water content and the magnitude of applied stress. Under an increasing load, the critical pressure at which collapse started to occur was greater for the loess with lower water content. At natural water content the critical pressure was greater than the overburden pressure. The greatest problem with collapsible soils arises when the existence and extent of the collapse potential are not recognized prior to construction. Settlements associated with development on untreated collapsible soils usually lead to expensive repairs. A comparative study between natural undisturbed and compacted samples of collapsible soils was performed. An attempt was made to relate the collapse potential to the initial moisture content.

Key words*: leossoid soils; collapse behaviour; settlement analysis*

INTRODUCTION

Loessoid soils are also known in the scientific literature as collapsible soils. The expression ‘‘soil collapse’’ is used to describe a wetting-induced deformation in collapsible soils (Figure 1). These soils have an open structure as the particles are held together by a temporary bonding. If the loess becomes saturated, the material structure collapses and records large supplementary settlements. (Ciobanu, 2014)

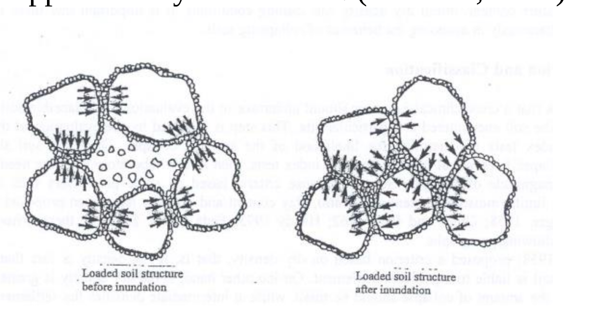

Figure 1. The collapse occurred after inundation of the soil (Al-Rawas, 2000)

Supplementary settlement to wetting (Im) is defined by vertical deformations occurred with the growth of humidity, leossoid soils reports much higher values compared to soils based on clay or sand in natural form under the same values of stress. Supplementary settlement to wetting is influenced by the weight of the sheet (I_{mg}) and under the compressive load transmitted by foundations (Imp). (Siminea, 2006).

MATERIALS AND METHODS

In order to calculate the settlement we have to take in consideration the type of the soil.

For normal soils the settlement is calculated according to STAS 3300-77, using the method of summing the elementary sheets. In this algorithm the soil is separated into elementary sheets until the required depth, where $\sigma_z < 0{,}2\sigma_g$ (in this case it is necessary to find the depth of active area and the value for σ_{gz} - geological load for specific sheet - Figure 2).

On vertical axis, at the limit of sheets we determine the vertical pressure exercised by the net pressure from the base of the foundation calculated with the following relation:

$$\sigma_z = \alpha_0 \text{ x } p_n \quad (1)$$

Where:

α_0 index for distribution of vertical efforts toked from table based on L/B and z/B reports

L the length of the foundation (m)

B the width of the foundation (m)

z the depth of the layer from the separation limit to the base of the foundation

p_n the pressure on the base of the

foundation calculated with the relation:

$$\mathbf{p_n} = -\frac{\mathbf{P} + \mathbf{G_f}}{\mathbf{A_f}} - \gamma\, \mathbf{D_f}$$
(2)

In our case:

P = the pressure exercised by the foundation kN

$\mathbf{G_f}$ = the weight of the foundation (kN)

$\mathbf{A_f}$ = LB = the area of the foundation (m2)

γ = the specific weight of the soil (kN/m3)

Df = the depth of the foundation (m)

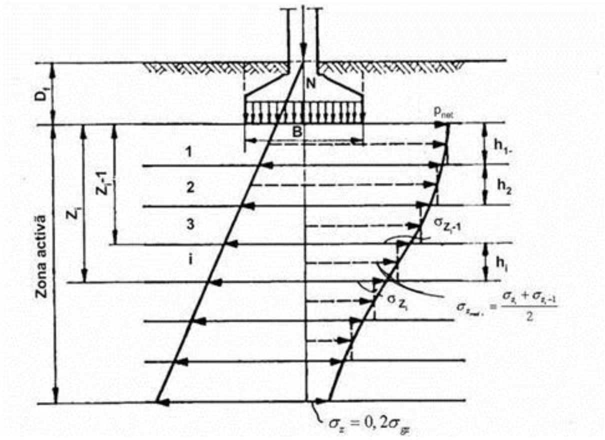

Figure 2. The calculation of the settlement

The settlement is calculated with the following formula

$$\mathbf{s = 100\beta \sum_{1}^{n} \frac{\sigma_{zi}^{med} \cdot h_i}{E_i}} \qquad (3)$$

where

β = correction index = 0.8

σ_{zi}^{med} medium vertical stress in the elementary sheet calculated with the next formula:

$$\sigma_{zi}^{med} = \frac{\sigma_{zi}^{sup} + \sigma_{zi}^{inf}}{2} \text{ (kPa)} \qquad (4)$$

$\mathbf{h_i}$ = the thickness of the elementary sheet

$\mathbf{E_i}$ = the linear deformation module (kPa) (Atanasiu, 1983)

From 2014, the method for the determination of settlement, for leossoid soils, is made using a different algorithm.

The hypothesis for determination of settlement is built on the assumption of direct foundation on saturated loessoid soil.

The calculations were made according to Romanian normative in force (NP 124/2014). This normative calculate the settlement according to European legislation in Civil Engineering (EUROCOD 7).

In order to calculate the settlement, the following characteristics were taken into consideration.

I_{mg} – Supplementary settlement to wetting under own weight (geological action)

I_{mp} – Supplementary settlement to wetting under the action of loads tran smited by foundation (for compression loads)

s = The total of supplementary settlement from wetting $s = I_{mg} + I_{mp}$ (5)

Calculations uses the results of compressibility test in laboratory and on field (if is possible)

The supplementary settlement to wetting, under geological load is calculated on entire thickness sensible to wetting ($i_{m3} \geq 2$ %) with the relation:

$$I_{mg} = \sum_{1}^{N} i_{mg} \cdot \boldsymbol{h_i} \qquad (6)$$

where:

N = the number of elementary sheets

hi = the thickness of the elementary sheets

i_{mg} =the index of supplementary settlement from wetting of the elementary sheet under his own weight and it can be obtain with the duble edometer test with the following relation: ,

$$i_{mg} = \varepsilon_{gi} - \varepsilon_{gn} \qquad (7)$$

where:

ε_{gi} = the specific deformation of wetted soil (calculated with volumetric weight of saturated soil)

ε_{gn} = the specific deformation of natural soil (geological pressure accorded to the middle of the sheet calculated with the volumetric weight of natural soil)

The supplementary settlement to wetting from geological load I_{mg} represent a criteria for a classification to group A (I_{mg} < 5cm) or group B (I_{mg} > 5cm) and it has to be calculated into the first phase, no matter what situation that will occur after.

The supplementary settlement from wetting under the load transmitted by foundation (I_{mp}) is calculated from the depth of foundation (D_f) for all deformable areas with the following relation

$$I_{mg} = \sum_{1(D_f)}^{N} i_{mp} \cdot \boldsymbol{h_i} \qquad (8)$$

Where:

N' = the number of elementary sheets in the deformable area from the soil

h_i = the thickness of the sheet

D_f = the depth of foundation

i_{mp} = the index of specific settlement from wetting under the load transmitted by foundation, it can be obtain from the double edometric test with the following relation:

$$i_{mp} = \varepsilon_{pi} - \varepsilon_{gi} \quad (9)$$

Where

ε_{pi} = specific deformation for wetted soil using the relation:

$$p_i = \sigma_{gi} + \sigma_z \quad (10)$$

σ_{gi} = specific deformation of wetted soil for ε_{gi},

ε_{gi} = the specific deformation of wetted soil (calculated with volumetric weight of saturated soil)

σ_z = the vertical stress from the foundation load in the middle of the sheet according to NP 112/2004.

The supplementary settlement from wetting is calculated with

$$s = I_{mg} + I_{mp} \quad (11)$$

The settlement is realized for deformable areas from the soil. (NP 124/2014)

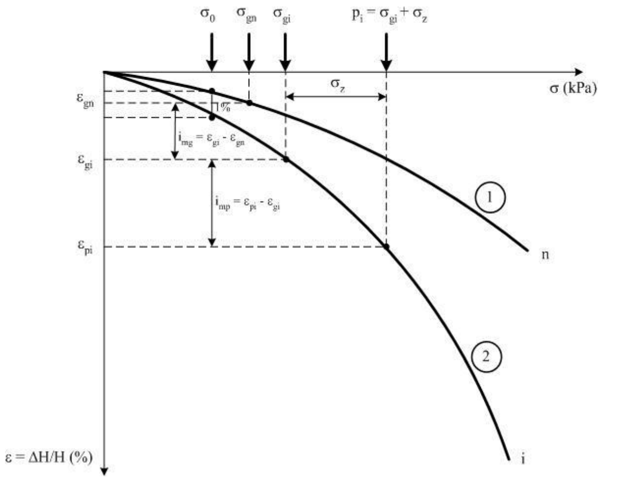

Figure 3. Curves of compression for unmodified sample: with natural humidity (curve 1) and initially saturated (curve 2)

RESULTS AND DISCUSSIONS

In order to calculate the settlement for a non collapsible soil and for a leossoid soil the dimension of foundation are considered: L = 2.5 m B = 2.5 m and D_f = 1.5m.

For a non-collapsible soil, we used the following values: specific weight γ = 20 kN/m^3, the pressure exercised by the foundation P = 1500 kN, the linear deformation module E_i = 20000 and the pressure exercised by the foundation was calculated and resulted p_{med} = 239.32 kN/m^2.

To realize the settlement calculation, the specific deformation for every sheet, σ_z and σ_{gz}, was extracted from the Figure 4 (first one realised for a natural sample of soil wetted at 300kPa vertical load and the second curve was made for a initially saturated sample of loessoid soil).

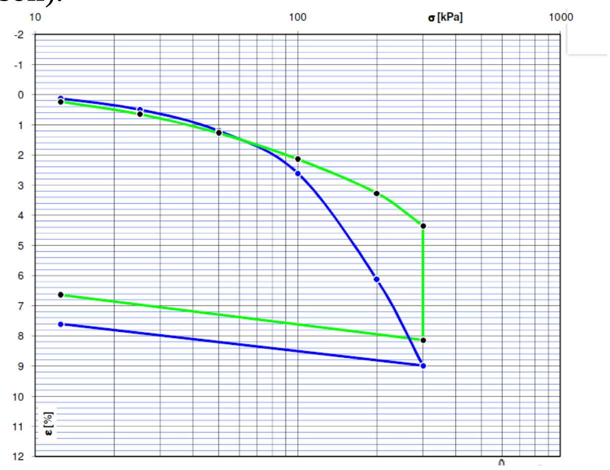

Figure 4. Curves of compression on a loessoid soil (green curve – for a sample with natural humidity and blue curve – for a sample initially saturated) (NP 124/2004)

The difference between settlements, depending on the type of the soil, can be seen in the Figure 5.

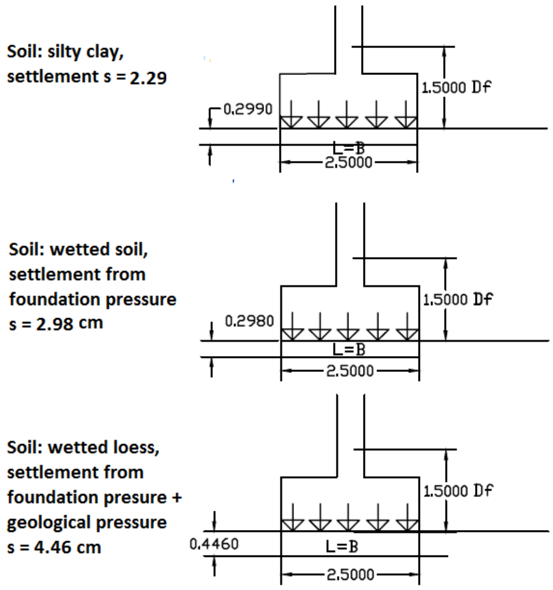

Figure 5. The difference of settlement for differet soil types

The calculations conducted to determine the settlement are shown in Table and Table 2.

Table 1. settlement determination for normal soil

H	n=L/B	z/B	á0	pn	Ϭz	Ϭgz	0.2Ϭgz	Ϭzi med	E	s
m				kN/m^2	kPa	kPa	kPa	kPa	kPa	mm^2
1.5	1	0	1.00	239.32	239.32	30.00	6.00	215.39	20000	8.62
2.5	1	0.4	0.80	239.32	191.46	50.00	10.00	149.58	20000	5.98
3.5	1	0.8	0.45	239.32	107.70	70.00	14.00	84.96	20000	3.40
4.5	1	1.2	0.26	239.32	62.22	90.00	18.00	50.26	20000	2.01
5.5	1	1.6	0.16	239.32	38.29	110.00	22.00	32.31	20000	1.29
6.5	1	2	0.11	239.32	26.33	130.00	26.00	22.74	20000	0.91
7.5	1	2.4	0.08	239.32	19.15	150.00	30.00	16.75	20000	0.67
									Total	22.88

Table 2. settlement determination for leossoid soil

sample with natural humidity					sample initially saturated							
ϒ kN/m^3	pn kN/m^2	$Ϭ_{z}$ kPa	$Ϭ_{gz}$ kPa	0.2* $Ϭg_{z}$	$ϒ_{sat}$ kN/m^3	pn sat kN/m^2	$Ϭ_{z}$ kPa	$Ϭ_{gz}$ kPa	0.2* Ϭgz	I_{mg}	I_{mp}	s
16.80	243.80	243.8	25.2	5.04	20.00	240.92	240.92	30.00	6.00	0.46	5.40	5.86
16.80	243.80	195.0	42.0	8.40	20.00	240.92	192.74	50.00	10.00	0.84	5.00	5.84
16.80	243.80	109.7	58.8	11.76	20.00	240.92	108.41	70.00	14.00	1.40	4.20	5.60
16.80	243.80	63.4	75.6	15.12	20.00	240.92	62.64	90.00	18.00	1.90	3.80	5.70
16.80	243.80	39.0	92.4	18.48	20.00	240.92	38.55	110.00	22.00	3.00	3.80	6.80
16.80	243.80	26.8	109.2	21.84	20.00	240.92	26.50	130.00	26.00	3.00	3.80	6.80
16.80	243.80	19.5	126.0	25.20	20.00	240.92	19.27	150.00	30.00	4.20	3.80	8.00
									Total	14.80	29.80	44.60

CONCLUSIONS

The determination of settlement for leossoid soil is according to the normative NP 124/2014.

The algorithm for calculation of the settlement for leossoid soils compared to the algorithm for calculation of settlement for normal soils is more complicated and it’s include more information, using the hypothesis of supplementary settlement from geological weight and foundation weight.

The settlement of a leossoid soil is almost double compared to a normal soil which is not sensible to wetting, the phenomenon being caused by the collapse of the leossoid soils.

For minimization or elimination of the collapse phenomenon caused by the wetting of the soil we must stabilize the soil using improving methods.

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