XIII ICSMFE, 1994, New Delhi, India / XIII CIMSTF, 1994, New Delhi, Inde

PREDICTION OF COLLAPSE OF LOESS SOIL THICKNESS

LA PREVISION DE L'AFFAISSEMENT DE LA COUCHE DU LOESS

A.A. Grigoryan[1] *Yu.A. Chinenkov*[2]

[1]Professor, Chief of Laboratory, [2]Senior Researcher
Research institute of Bases and Underground Structures, Moscow, Russia

SYNOPSIS: The most reliable way to predict of possible soil collapse under overburden during wetting is the carrying out of experimental field tests. The essence of these tests consist in a long-term wetting of a soil layers in a test place (experimental pit) , followed by direct measurements of the subsidence of the pit bottom. In this paper the results of nine field tests carried out in Rostov Region, Russia and in Ukraine are considered. The results of the experiments are depending on the egineering-geological properties of the soils, on the terms of wetting, on the volume of using water, on the direction of water moving and on the rate of development of the deformations.

A prediction of possible soil collapse under overburden during wetting is one of the must complicated and important problems, arising while designing of structures on thick layers (thickness) of loess soils. Up to the present moment, the most reliable way to determine this collapse was to carry out experimental field tests. The essence of the test was a long-term wetting of a soil layer in a test place (experimental pit), followed by direct measurements of the subsidence of the pit bottom. In this case, the side of the square site was equal to the depth of the collapsible layer.

Engineering-geological structure of the soil thickness and the properties of soils have an influence on the results of the tests. Values of the collapse subsidence thus obtained also depend on the following parameters: rate of water inflow (supply); number of drainage holes; terms and continuity of the wetting process etc. Let us compare the results, obtained while wetting 5 experimental pits in Volgodonsk (the Rostov Region, Russia) and 4 ones in Nikopol (Ukraine) (See Table). The values of the thickness of collapsible layers in both the regions, determined on the basis of the results of engineering-geological survey at the analysed test sites, are close to each other and make 0.21-0.23 m, while soil properties in these two regions are quite different. In Volgodonsk consistency index of collapsible light loam - 12%, density of dry soil - 1.45 to 1.55 tons/m^3, moisture content - 13 to 16%. In the Nikopol test place these values were 6-8%, 1.36-1.46 tons/m^3, and 5.0-6.5% respectively. The average value of the total soil collapse, determined under the laboratory conditions, was 0.3-0.4 m for Volgodonsk and over 0.6 m - for Nikopol.

The collapsible layers in the two analysed regions have different geological structure. The waterproof layer (alluvial clay) lies at a depth of 24-31 m under loess loams of Volgodonsk. In Nikopol the loess soil thickness is underlain by sand. The experiments have shown, that the presence of the waterproof layer largely determines the development of the wetting process, and, therefore, soil deformations. Layers wetting in Volgodonsk led to the appearence of water cupoles and to the rise in the groundwater level.

In order to accelerate the wetting, drainage holes have been drilled in most of the test places. The amount of water spent per 1 m^2 of the wetted soil was 10-33 m^3 in Volgodonsk and 6.8-28.3 m^3 in Nikopol.

The collapse subsidence of the soil surface in the Volgodonsk experimental pits made 0.066-0.46 m, while the predicted values were 0.1-0.7 m. In Nikopol the collapse subsidence value (actual one) was 0.52-1.05 m , the predicted one - 0.5 to 0.8 m.

Thus, in Volgodonsk the actual values of soil collapse in the test turned out to be much smaller than the predicted ones. The situation in Nikopol was quite the opposite. Regularities of soil wetting during the water supply to the pits and the regularities of the temporal dynamics of collapse development were also quite different in Volgodonsk and in Nikopol.

Owing to the presence of drainage holes and huge volumes of water, filtered per unit area (1m^2) of the pit, the rate of groundwater level rise in Volgodonsk was larger than on built-in territory of the plant for which field tests had been carried out. Thus, on site N 4, accordding to the data of V.M.Mamonov, the groundwater

Table 1.

NN of test place	Depth, m				Calculated collapse, m	Collapse subsidence of pit bottom, m	Maximum rise of soil surface, m	Rate of soil subsidence, m/day
	of collapsible thickness	of compressed soil layer by field test	of maximum collapsible layer by laboratory tests	of maximum compressed soil layer by field test				
				Volgodonsk				
1	20–22	8–20		11–14	0.16	0.236		
2	23	13–21	16–20	17–20	0.6–0.8	0.098	0.038	0.002
3	16–17	6–16	12–15	13–16	0.05–0.15	0.066	0.029	0.001
4	24–27	10–30		15.5–19.5	0.36–0.69	0.460		0.004
5	22	8–18	8–12	8–12	0.14–0.3	0.322	0.02	0.002
average	21	9–21	11–17	13–16	0.34	0.24	0.03	0.002
				Nikopol				
1	20	6–20	15–18	15–18	0.8	1.05	–	0.04
2	20	9–20	15–18	12–15	0.5	0.7	–	0.02
3*	26	6–18	7–13	6–9	0.55	0.53	–	0.021
4*	26	0–22	7–13	9–12	0.55	0.52	–	0.025
average	23	6–20	7–18	11–14	0.6	0.7	–	0.027

* – without stabilisation of collapse

level rose by 37 m during one month and reached the soil surface, whereas on the plant's territory in the place of most intensive water inflow, the groundwater level rose by 15 m during 15 years, which corresponds to a depth of 6.5 m from the soil surface.

It is important to note, that during the soil wetting via test pits in Volgodonsk and during the groundwater level (GWL) rise, not the soil collapse, but (on the contrary), soil layers rise occured. The soil layers rise was not observed on the built-in territory of the plant (Fig. 1 a, b). The layers rise occurs at a depths of not more than 24 m, reaching 20–38 mm (Fig. 2). This phenomenon can be explained by the fact, that during intensive wetting and quick groundwater level rising the pore pressure in the soil increases. Under the impact of this, pore pressure in the soil, which has no possibility to expand downwards and sidewards, move upwards.

The soil collapse subsidence together with buildings on the built-in territory begins as a result of soil wetting in the downwards direction, accompanied by groundwater level rising (Fig. 1, b). On the test sites soil compaction occurs only during groundwater level fall and stops when another wetting starts (Fig. 1, a).

The maximum rate of the soils collapse at the experimental sites turned out to be considerably higher than on the built-in territory and reached 2.3–4.2 mm/day. This rate of the collapse was observed immediately after the wetting was stopped. Then it began to fall gradually.

At the test sites the upper soil layers (6.0–13.4 m thick) were not compacted. Moreover, owing to the soil hanging, the collapse subsidence at a depth of 8 m in the pit N 5 turned out to be larger then the collapse subsiddence of the soil surface. It should be noted, that collapse began only at a certain depth (10–16 m) on the built-in plant's territory, i.e. deeper than at the test sites.

On the built-in territory of the plant practically everywhere in the places of the maximum of collapse the soil compaction occured both within the limits of the collapsible thickness and lower, at a depth of 20–35 m/1/. At the Volgodonsk test sites the compaction occured within the limits of the collapsible thickness whereas the exception was site N 4, where underlying noncollapsible soil layers were compacted to a depth of 30m. The Volgodonsk test have shown, that the wetting of test places does not reflect the peculiarities of soil deformation observed under real structures during the time of their operation. Short terms of the tests, great consumption of water, spent for the wetting, making of drainage holes – all this largely increases the rate of water inflow into the soil and, in the presence of the waterproof, modifies the regularities of wetting which, in the end, affects not only the rate of the soil compaction in the massif but its intensity too.

The soil collapse in the experimental pits and built-in territories of Nikopol develops in accordance with the general regularities. It begins about 1 month after the beginning of wetting and occurs mainly during the period of the water inflow to the soil. At the first time the collapse occurs basically due to the compaction of soil layers, lying at small depths (6–8 m),

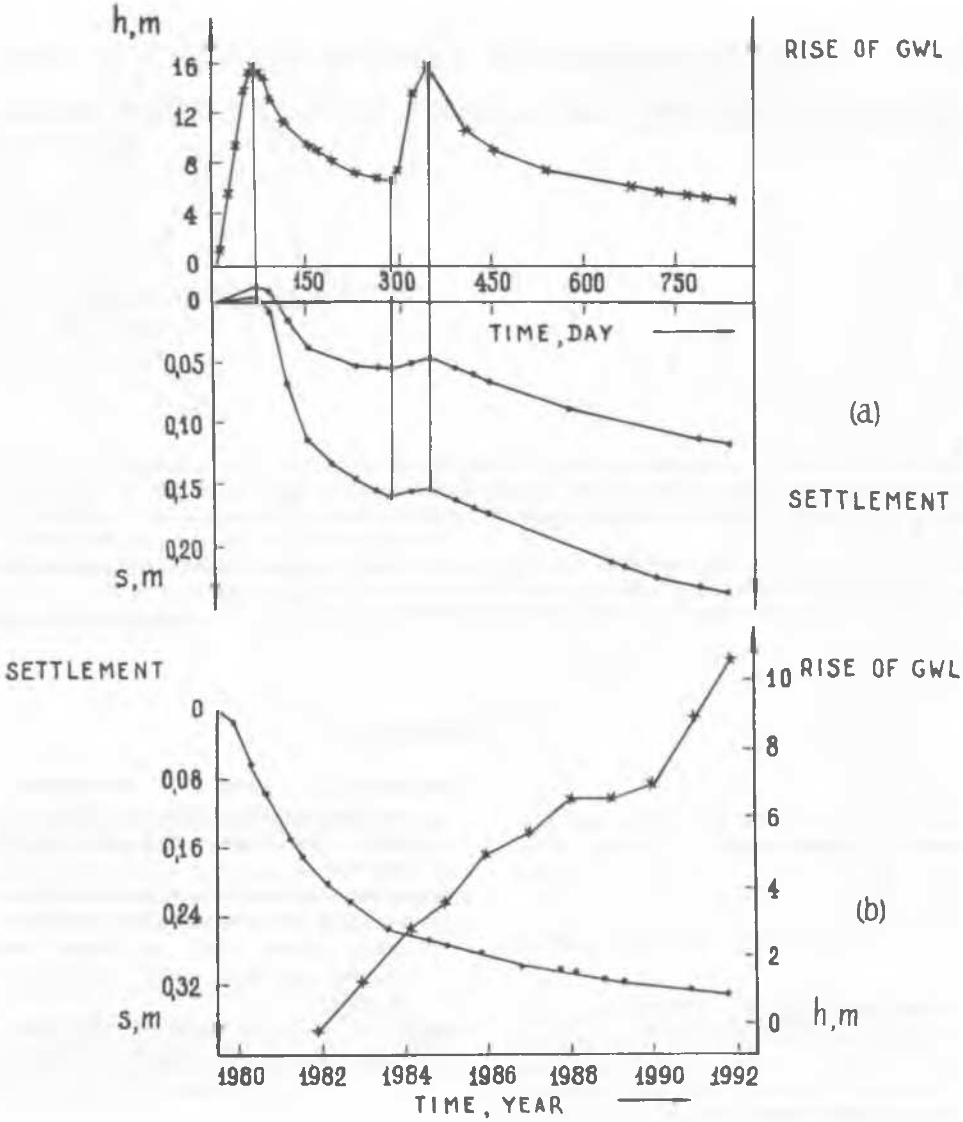

Fig. 1 Changing of groundwater level (h) and collapse subsidence (s) during the time
a - at the test site N 5,
b - at the built-in territory;
-×-×- - changing of groundwater level,
-·-·- - soil subsidence.

and then deeper layers (12-18 m) begin to compact gradually .

For some time after the wetting is over, soil collapse continues but its rate begins to fall gradually. The maximum collapse during the wetting of experimental pits in Nikopol was 0.51-1.05 m, i.e. close to the data of laboratory experiments. The calculation of possible collapse made on the basis of laboratory test data is as follows. The collapsible thickness is divided into elementary layers not more than 2 m thick. The total collapse from overburden of the upper layer during wetting is calculated in the designing practice as a sum of all the collapses in every elementary layer. The latter is determined under the overburden, acting at a considerable depth:

$$S_{sl} = \sum_{i=1}^{n} \varepsilon_{sli} h_i ,$$

where ε_{sli} is a relative collapsibility of the i-th soil

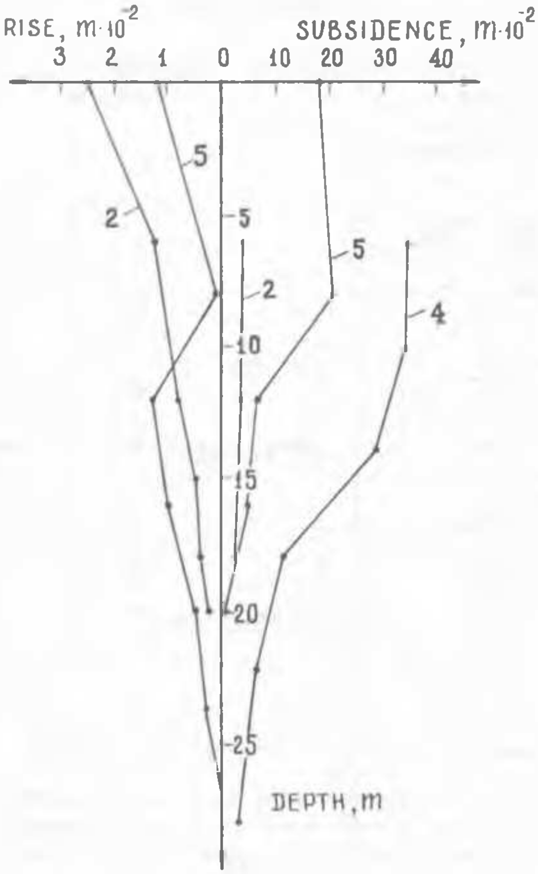

Fig. 2 Subsidence and raising of soil layers at the test sites 2, 4, 5 of Volgodonsk

layer; h_i - thick of the i-th layer.

The above simplified formula does not take into account the fact, that the collapse deformation should be considered as a spatial task, not as a one-dimensional one (Fig. 3). However, more accurate solutions are given only for certain particular cases, e.g. in /2/.

Soil field tests made for predicting the collapse have shown, that their results largely depend on the structure of the thickness, properties of soils, regime of wetting and some other factors. Therefore, the technique of such field tests cannot be common for various conditions. Under the most widespread conditions (such as the Nikopol conditions) with more light category of soils one can use the technique envisaging the wetting during about 1 month /3/. Under the conditions similar to the Volgodonsk ones we recommend a longer wetting (for about 1 year) under slow rise of the groundwater level. Such wetting regime gives the results closer to actual ones for the processes occuring in soil thickness and for the determination of possible soil collapse under overburden.

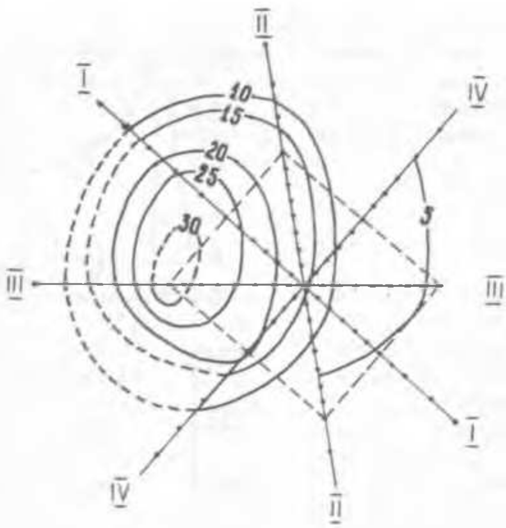

Fig. 3 Equal collapse subsidence lines at the test site N 5

- boundaries of the test site

REFERENCES

1. Grigoryan, A. A. (1989) Deformation phenomena in collapsible soils. Proc of 12th Inter. Conf. on Soil Mech. and Found. Eng., Rio de Janeiro, Vol. 1, pp. 607-609.
2. Grigoryan, A. A. and Ivanov, Yu. K. (1968). Prediction of the collapse of soil thickness during wetting from a small area with a depth spring. J. Bases, Foundations and Soil Mechanics, Moscow, N 6: pp. 31-34.
3. Manual in designing bases of buildings and structures (1986) Moscow, Stroyisdat: pp. 220-221.