Influence of the migrating stiff layer on building object foundation in the Loess Massif in Podkarpacie Region, Poland

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Abstract: The presented and considered tests prove formation of a stiff layer in the loess massif, also in terraces of the Wislok River, formed of silty soils. From the tests it appears that formation of that layer is the main reason of generation of the foundation settlement, i.e. additional deformations. It is often difficult to find when these settlements formed (see scratches and cracks on the objects of the Old Town in Rzeszow).

The migrating stiff layer changes calculations of settlements under direct foundations. Formation of the migrating stiff layer at the top part of the active zone of the foundation changes conditions of foundation work – the classical Winkler foundation forms where deformations occur above that layer.

Identification of the migrating stiff layer within the active zone under the foundation is very important for calculations and assumptions in computer simulations. For loess, assuming the stiff layer at a given depth is important for the calculated deformations and should be taken into account in management of waters from precipitations and their draining away. From the tests it appears that loess petrification cause increments of strength parameters comparable with parameters of solid rocks.

Résumé: Les analyses présentées et testées prouvent la création de la couche rigide dans le massif de lœss et sur les terrasses de la rivière Wislok, formées sur le fond poussiéreux. Les analyses en question démontrent que la création de cette couche constitue la raison principale de la formation, lors du tassement du fond, de déformations supplémentaires. La déposition de la vase se déroule dans le temps, souvent pendant une période longue et difficile à déterminer, ce que prouvent de nombreuses rayures et fissures sur les bâtiments de la vieille ville de Rzeszow.

La création de la couche migrante rigide dans la partie supérieure de la zone active des fondements change considérablement les conditions de l'évolution du fond ; on observe la formation d'un fond classique de Winkler sur lequel les déformations apparaissent au-dessus de cette couche.

L'identification de la couche migrante rigide au sein de la zone active située sous les fondements a une grande importance pour les calculs et la formulation des principes lors des analyses informatiques. Les analyses effectuées mènent à la conclusion que les processus de pétrification de lœss ont une influence sur le renforcement des paramètres de résistance comparables aux paramètres des rocs compacts.

Keywords: loess, cohesion, collapse

INTRODUCTION

Silty soils prevail at a great area of the Podkarpacie region in the south of Poland. In the middle of that region, the Quaternary loess can be observed, however that soil lost its macroporosity in many places (Figure 1).

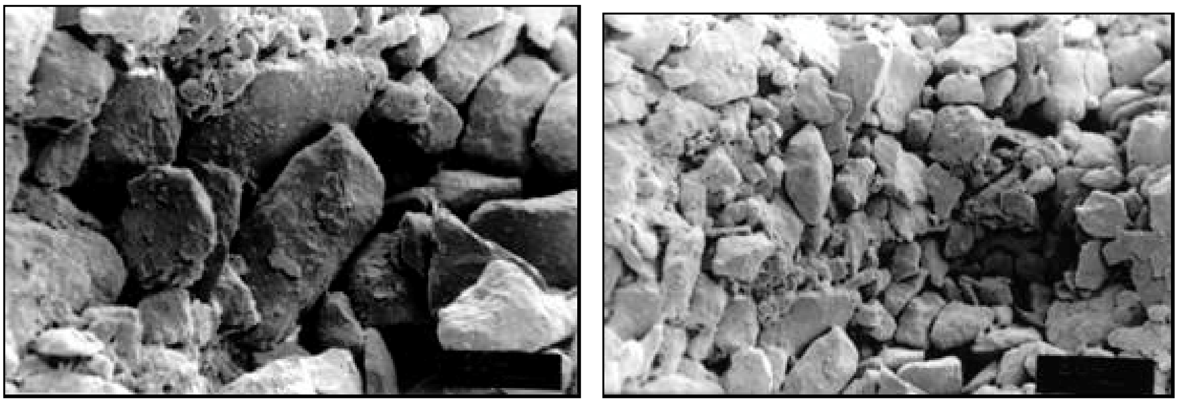

Figure 1. The examples microstructural surface of solid chips from loess soils observed in SEM

The loess is very sensitive to changes of moisture Frankowski (1994). The loess occurring near Rzeszow, a Polish city located in the considered region, was subjected to tests discussed in this paper.

In his previous papers, the author tested and determined geotechnical parameters of the migrating attenuation layer in marl eluvia occurring in another region of Poland. He also tested chemical and mineralogical composition of those marls Jaremski (1994a, 1997). As in the marls, in the loess massif there is a migrating layer, called "a hardening layer" – it is a layer of compact or half-compact soil occurring at different depths, depending on amount of infiltrating water and thickness of the half-compact layer, being an impermeable layer. Periodical stoppage of infiltration of water coming from precipitation and sloppy roads is strictly connected with formation of that layer, being periodically an impermeable layer. Such extreme states of the loess massif have been described in the author's previous papers, where special attention was paid to influence of percentage of clayey minerals (illite and smectite groups) while silt transition into a typical cohesive soil.

The present considerations concern processes occurring in such a layer of the cohesive soil that passes from plastic states to half-compact and compact states in a consequence of vertical infiltration and water bonding. Existence of the migrating hardening layer is very important for analysis of work of the loess foundation subjected to deformation at time and influence of changes of water content and loading.

The conclusions presented in this paper have been based on the results of extensive tests of geotechnical parameters. The prepared samples coming from the loess massif were tested, and time for registration of reconstruction of cohesion forces and changes of internal friction angle were taken into account.

From the test results it appears that loess solidification leads to increase of their strength parameters, the values of which are comparable with parameters of solid rocks. This process is strictly connected with formation and identification of the migrating stiff layer in the loess foundation within the active zone under the foundation and it influences the future increments of building settlements.

THE TESTS

In the loess massif, continuous physical and chemical phenomena take place at microstructural and macrostructural levels. Thus, an attempt of their reproduction was undertaken with laboratory tests. For the tests described in this paper, prepared samples coming from the loess massif were used. Their water content and loading were simulated, and time for registration of reconstruction of cohesive forces and changes of the internal friction angle was taken into account.

The drawn loess was prepared in the containers, namely it was humidified to the assumed water content. Next, the samples were prepared under the simulated conditions typical for the loess massif. While the tests, the loess behaviour was reconstructed. The loess soils are often classified as soils including some layers, determined as silts or clays. The variable underground water level, registered under real conditions, strongly influences a plasticity level and geotechnical parameters of the impermeable layer of the loess soil. The extreme states of the considered loess massif were discussed in Jaremski (2003). In that paper, special attention was paid to percentage of clayey minerals (illite and smectite groups) while transition of silts into a typical cohesive soil.

Only typical loess from Rzeszow was tested. The elaborated test methods were improved while investigations. Several hundred samples were prepared, their initial moisture contents varied between 10.9% and 25.21%. Difference between particular series of initial moisture was about 1%. Next, the samples were placed in special boxes of the same dimensions as the box in the apparatus for direct shear. Here, the samples were subjected to loading with use of a loading system of oedometers (Figure 2).

Figure 2. Oedometer loading system for consolidation of the loess samples

Then, the formed loess cubes were subjected to continuous loading of 100, 200, 300 kPa (the most often loadings consolidating the soil under standard conditions), consolidation time was varying from 24 hours to 160 and more days. After that time, particular series of samples were put in the apparatus AB-2a and subjected to shearing by the normal method. Moisture of sample shearing varied within 0.66% and 19.73% depending on initial moisture content of the samples and consolidation time.

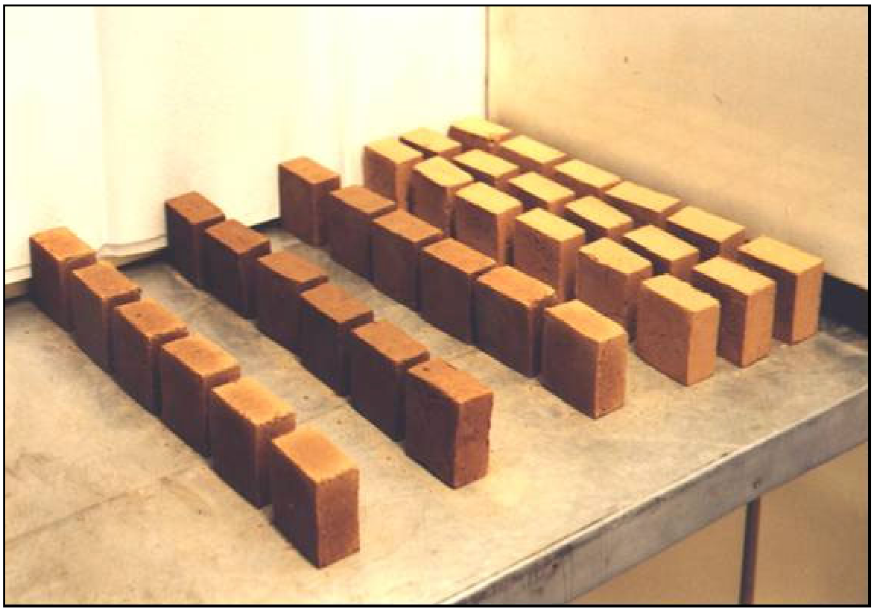

Figure 3. The samples formed from loess of 14.5 %, 20% and 25.18% moisture content and subjected to free dying over time

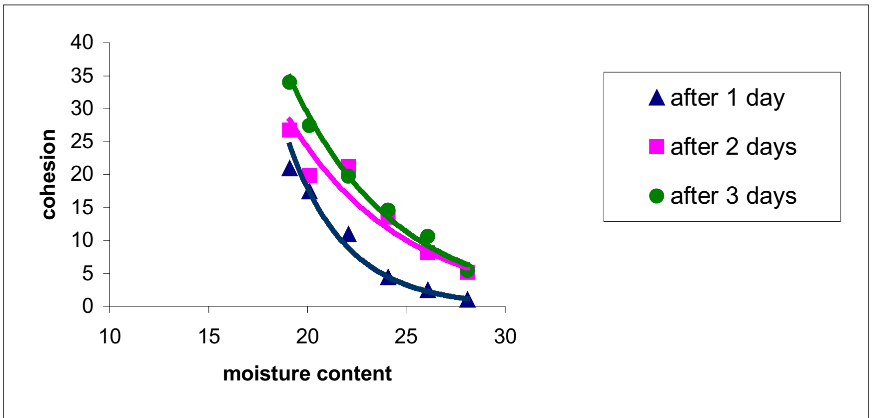

Figure 4. The exemplary dependences of cohesion (in kPa) on moisture content (%) of loess samples sheared by means of the AB -2a direct shear apparatus

Some other samples were not subjected to loading; they were subjected to shearing after some free drying (Figure 3). Many tests were performed in order to find if the migrating impermeable layer could be determined as a stiff layer. Thus, relations between the angle of internal friction, coherence and initial water content were analysed, taking time and loading into account (Figures 4-8).

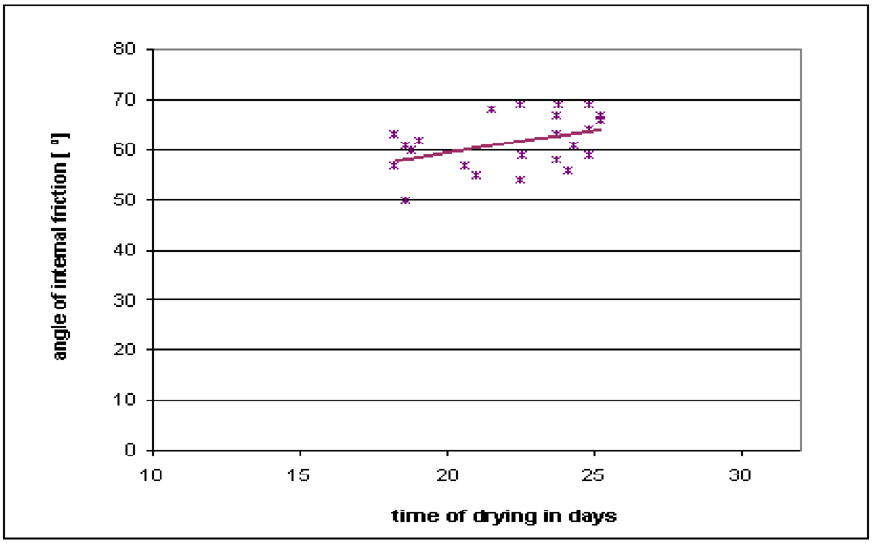

Figure 5. The graph of dependence of internal friction angle on time of drying for samples of loess sheared by means of AB -2a direct shear apparatus

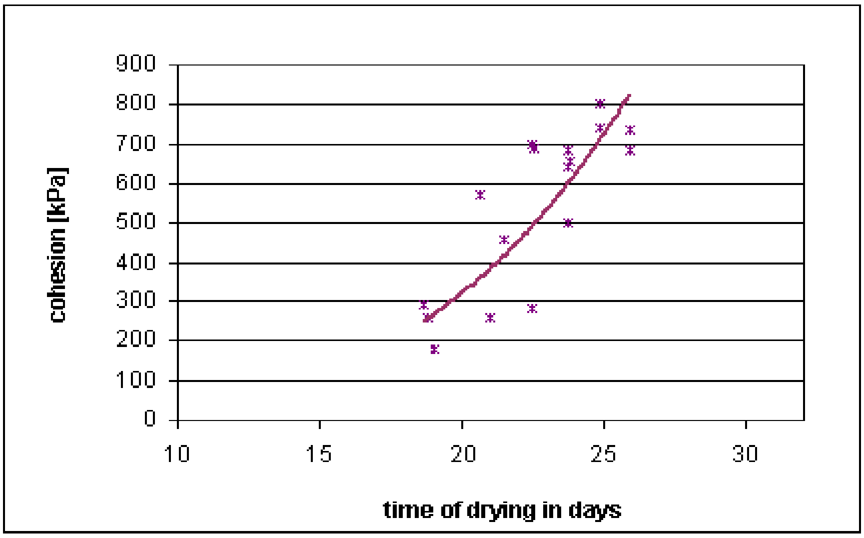

Figure 6. The graph of dependence of cohesion on time of drying for samples of loess sheared by means of AB -2a direct shear apparatus

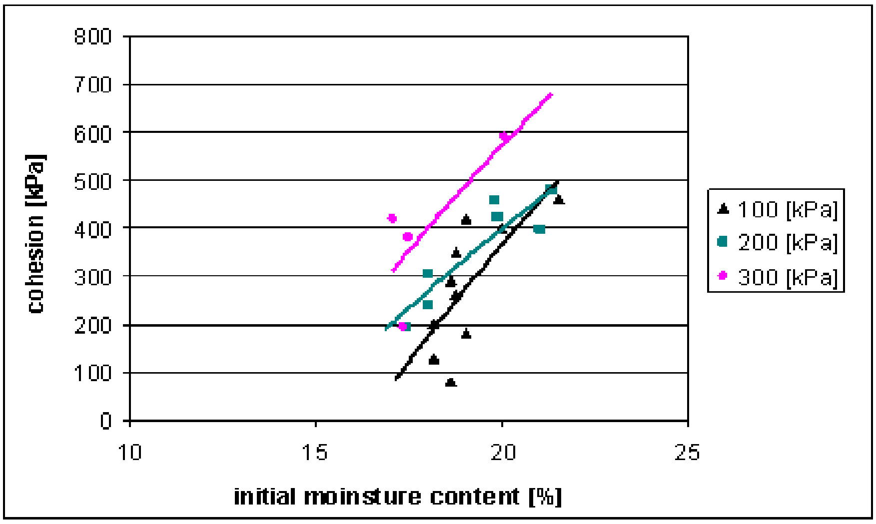

Figure 7. The graph of dependence of cohesion on initial moisture of loess samples subjected to the various loads

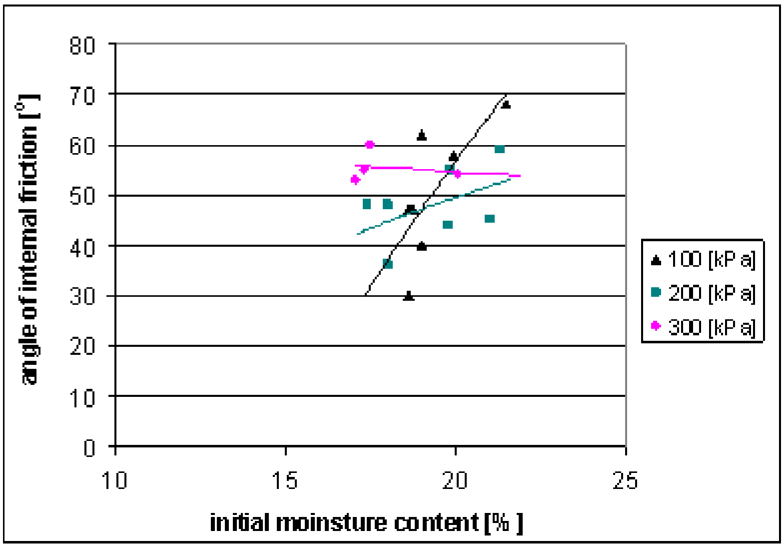

Figure 8. The graph of dependence of internal friction angle on initial moisture of loess samples subjected to the various loads

From the above figures it appears that the angle of internal friction is 30-70 degrees, and cohesion of the same samples is 200-900 kPa. These data are valid for the samples subjected to loading 100 kPa under room conditions by more than 50 days. After that time, moisture of the samples after shearing was from 1 to 1.7%. It was found that the samples of water content 17-26 % reached the maximum angles of internal friction and coherence.

In Jaremski (2000, 2004) one can find the results of tests of strength parameters, performed in the apparatus for triaxial shearing. In this case, the samples could be prepared for a limited range of moisture. Introduction of additional tests in the apparatus for direct shearing enables preparation of samples of much higher water content and better drying conditions, so registration of coherence reconstruction is possible.

At last, the tests of loess were started from very low increments of moisture. The assumed test procedure includes also stresses occurring at particular depths of loess deposits and uses preliminary loading of samples with use of the oedometer. The former Proctor apparatus for triaxial compression Jaremski (2000) has been eliminated. The prepared samples of different water contents are subjected to shearing at various time intervals and changes in reconstruction of coherence are registered. Water permeability is strictly connected with changes of coherence. Thus, the prepared samples and samples subjected to shearing are tested with use of the apparatus for direct shearing. The tests are performed in order to determine moisture of samples for which the tested geotechnical parameters would be compatible with geotechnical parameters occurring under in situ conditions. The performed tests allow toshow threshold moisture and time in which coherence increase occurs and leads to loess petrification.

The migrating stiff layer changes calculations of ground settlement under direct foundations, because in calculations multilayer foundation is assumed, for which settlements are calculated. Formation of the migrating stiff layer at the top part of the active zone of the foundation changes working conditions of the foundation – the traditional Winkler foundation forms, where deformations generate above that layer. It seems to be right to understand such foundation as a stiff layer, because brittle damage is observed while tests. It can be proved by a small longitudinal strain, large and rapid decrease of stress after reaching the strength limit, and analysis of the shearing surface. Moreover, let us note that while shearing the sample damage moment is accompanied by an acoustic effect (an inherent attribute of brittle damage).

In some samples, the shearing planes are analysed with a laser profile measurement gauge and a fractal dimension is determined at this stage (see Figures 9 and 10). The shearing planes of the considered samples are tested with a laser profilograph (TALYSKAN 150 made by TALOR-HOPSON) and for the separated elements of these planes the fractal dimensions are determined by a French program MAUNTAIN-MAP. In the author's opinion, application of a profilograph for tests of the loess formations gives new and promising possibilities.

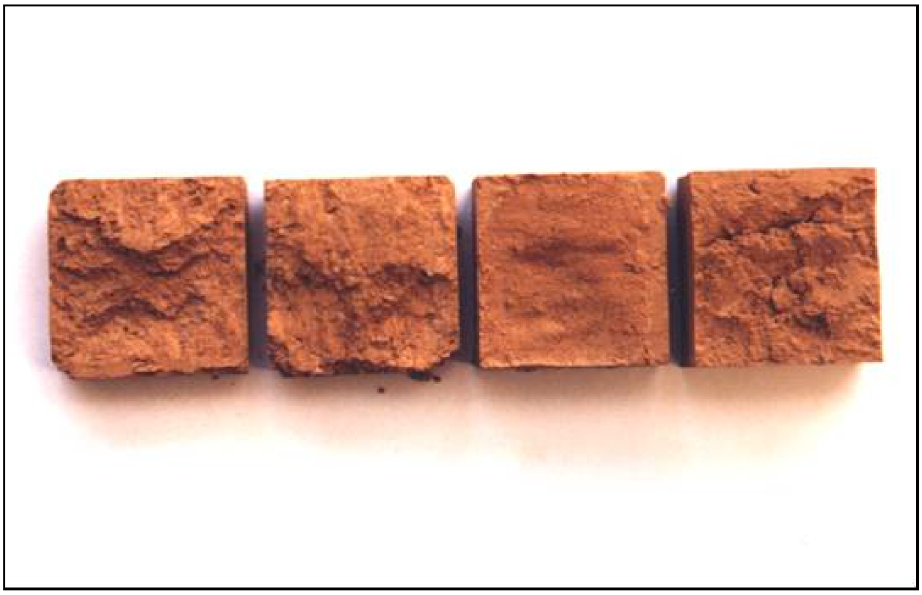

Figure 9. Shearing planes of four samples of 7.02%, 10.12%, 12.20%, 18.35% moisture contents

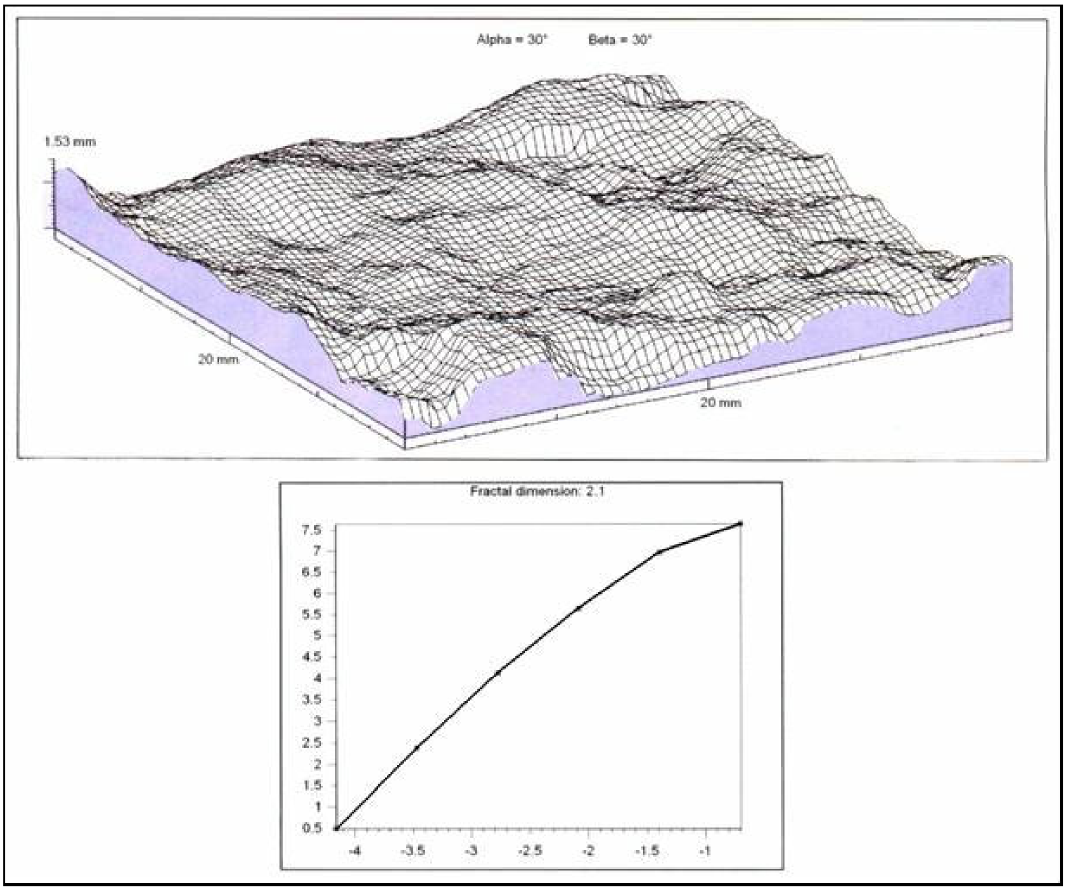

Figure 10. The printout of shearing plane mapping and received fractal dimension of that plane part made with laser profilograph for the sample of crushing strength

Next tests of the prepared samples were performed in order to simulate changes of water content and drying of soil, similar to those occurring in situ. Moisture tests were done for the samples coming from the same series as used for the tests of geotechnical parameters after drying. The prepared samples were made of the material coming from the same loess outcrop. The tests of moisture were performed for the petrified samples subjected to various drying times (from a year to some days). The samples were subjected to moisture from the bottom (see Figure11).

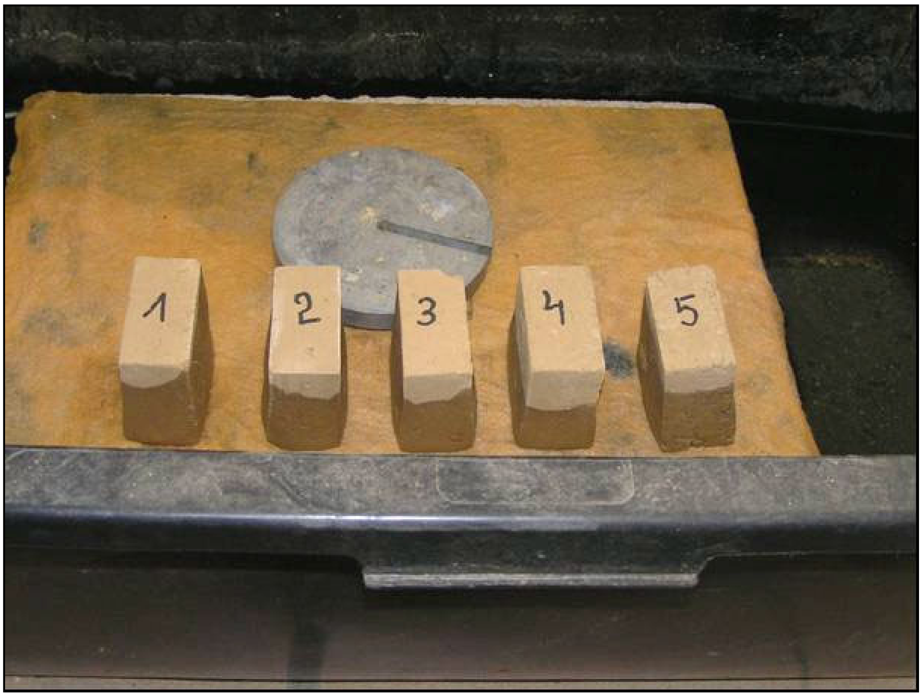

Figure 11. The example of moisture test of samples after different time of free drying

From the realized tests it appears that petrification time does not strongly influence loss of strength, after dripping the samples behave similarly. After reaching the threshold moisture content, the samples get scattered and lose their properties of a stiff layer.

AN ATTEMPT OF EXPLAINING SETTLEMENTS OF BUILDING OBJECTS, TAKING A STIFF LAYER INTO ACCOUNT

The presented and considered tests prove formation of a stiff layer in the loess massif, also in terraces of the Wislok River, formed of silty soils. From the tests it appears that formation of that layer is the main reason of generation of the foundation settlement, i.e. additional deformations. It is often difficult to find when these settlements formed (see scratches and cracks on the objects of the Old Town in Rzeszow. The author analysed the reasons of additional settlements in one building, where the scratches were very large. The settlements occurred after 20 years of the object operating. In the active zone, the stiff layer was identified as a package of silty half-compact soils. Above there were coherent soils, plastic and hard plastic.

CONCLUSIONS

New and better calculation methods for geotechnical problem solving are strictly connected with development of tests of geotechnical parameters. Silty soils have been tested for many years and they provide explanation for the occurring settlements after long periods of the object operation.

In loess and similar soils there is one more problem – determination of illite minerals fraction while their transition from silts to cohesive soil at the threshold water content. It can be proved by tests of loess microstructure by the scanning microscope, tests of endothermic maxima with the derivatograph, and tests of chemical composition with use of fluorescence, from which occurrence of illite and smectite groups results. The loess soils and similar soils behave in different ways. The described changes of moisture content cause additional settlements, which can occur late. The extreme behaviour of such soils need many tests and they are very important for application of the obtained values of geotechnical parameters. At present recognition of the maximum values of strength parameters of the considered soil seems very important. Loading occurring under foundations of old buildings was analysed – loading to 600 kPa was rarely registered there.

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Identification of the migrating stiff layer within the active zone under the foundation is very important for calculations and assumptions in computer simulations.

For loess, assuming the stiff layer at a given depth is important for the calculated deformations and should be taken into account in management of waters from precipitations and their draining away.

From the tests it appears that loess petrification cause increments of strength parameters comparable with parameters of solid rocks.

The tests can be applied for stabilization of silts occurring in Podkarpacie.

Contents of illite minerals in silty soils influence their mechanical properties and the medium water content, also physical and chemical processes in micro- and macrostructure. In his previous papers Jaremski (2003) the author postulated taking into account fraction of these minerals in determination of kind and state of the soils. He proposed to introduce tests of ability to swelling and the maximum swelling as auxiliary parameters, informing about contents of illite minerals Jaremski (1994b, 1995).

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