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Evaluation of the collapsibility risk of loess based on oedometer test results

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ABSTRACT: 34 oedometer tests were performed on loess specimens to analyze the development of their collapse. The stress range that causes the collapse of soil's structure is determined, and its dependence on moisture content is discussed. 11 out of 34 tests were performed with water flooding. These tests were performed on soil specimens having different initial moisture content, and the effect of the stress level at which the specimen is flooded is analyzed.

Keywords: Loess, Collapsing soil, Unconfined compression test

1 INTRODUCTION

Loess is generally defined as a wind transported, cemented, highly porous material built up mostly by silt particles. The loess is generally homogeneous and exhibits advantageous strength and deformation properties when in dry state. Nevertheless if subjected to water and static or dynamic load the internal forces caused by cementation that provides its strength in the macro porous state gets weaker or disappears. In that case the highly porous soil skeleton collapses and causes significant volume change in the soil mass.

In order to estimate the risk of collapse, we must know the stress level that causes the collapse of the soil's porous structure. This stress rate can be influenced by the grain size distribution (sand and clay content) and the strength of cementation and the porosity, but probably the most important factor is the moisture content. A set of oedometer (unconfined compression) tests was performed to analyze the relation of these soil properties and the stress level that causes the collapse of loess.

2 LABORATORY TESTS

Loess samples were collected from three sites in Hungary. Two sites were located in the city of Dunaújváros and on in Kulcs. The typical grain size distribution curves of the samples are shown in Figure 1. and the characteristic soil properties are summarized in Table 1.

Table 1. Soil properties

	Sand	Silt	Clay	C_u	e	w	S_r
Dunaújváros South	12.93	76.95	10.12	17.08	0.83-0.94	9.89-14.20	0.31-0.41
Dunaújváros East	15.52	75.86	8.62	10.92	0.63-0.91	16.16-17.09	0.63-0.69
Kulcs	22.31	56.87	20.82	>32	0.56-0.72	16.36-19.03	0.78-0.80

The tested soils were of different void ratios; the samples collected from Kulcs and Dunaújváros had a lower void ratio than the "typical" value for loess, but all samples were classified as slightly collapsible according to Knight's criterion (1963).

Altogether 34 oedometer tests were performed on the collected samples, 23 specimens were tested without water flooding and 11 specimens were flooded at different stress levels during the compression test. The aim of the tests was to find the stress that causes the collapse of the soil skeleton.

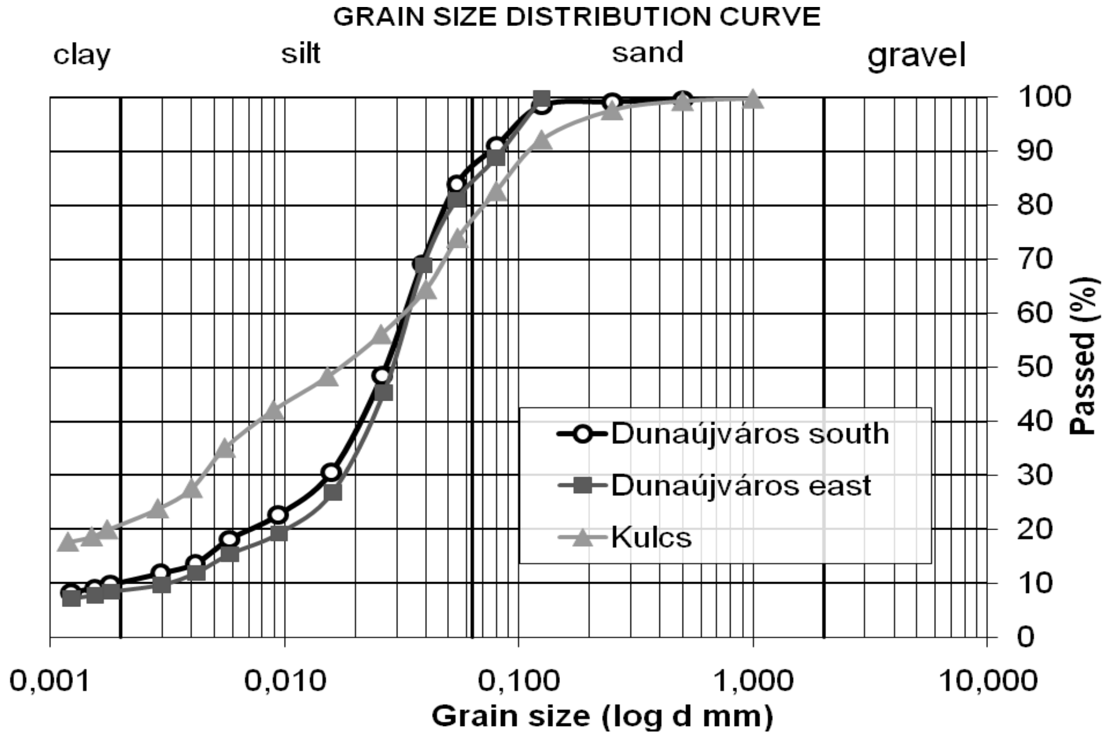

Figure 1. Grain size distribution curves of the tested samples

3 OEDOMETER TEST RESULTS

Figure 2. shows two typical oedometer test results. The compression curves can be divided to three parts: “pre-collapse” zone, “collapse” zone and “post collapse” zone.

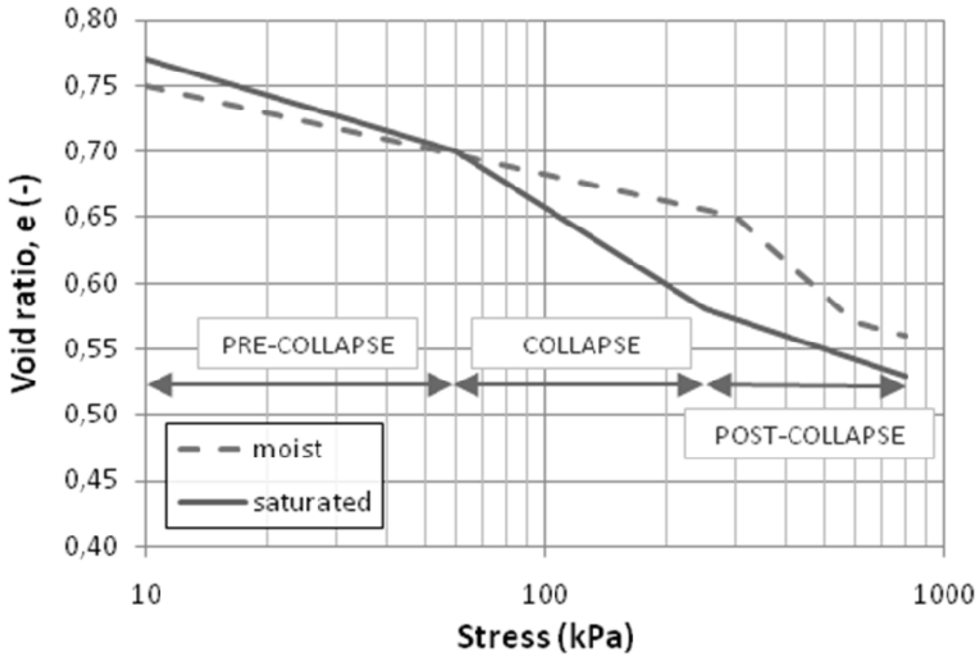

Figure 2. Typical oedometer test results

In the pre-collapse zone the soil behaves as a usual, cemented material, the deformation characteristics are governed mostly by the cemented bonds between the grains.

In the second zone gradual breakage of the bonds can be experienced, so the collapse of the porous structure doesn’t occur suddenly at a certain stress rate, but more partial collapse can be observed in a certain stress range (i.e. at more stress level). Because it is irreversible, the collapse is generally considered as plastic deformation. Alonso et al. (1990) proposed to describe this soil behavior using elasto-plastic soil model. The stress at which the collapse zone starts is therefore called yield stress.

The third zone describes the post collapse behavior of the soil, at this stress range, the cemented bonds are already broken and the soil particles are re-arranged in a more dense state, so the soil behaves as a non-cemented material.

The limits between the three zones are influenced by the different soil properties (as mentioned earlier), but are mostly defined by the moisture content of the loess. Figure 2. illustrates this fact well: in the case of soil with higher moisture content the collapse zone begins and ends at lower stresses than that of soil with lower moisture content. So to estimate the risk of collapse it is essential to analyze the relationship between moisture content and collapse forcing stress level.

4 CORRELATION OF YIELD STRESS AND SOIL PROPERTIES

4.1 *Yield stress against moisture content*

As mentioned previously the collapse does not develop in one step at a certain stress level, but in more steps in a larger stress range. In figure 3. the yield stress is plotted against the moisture content of the soil.

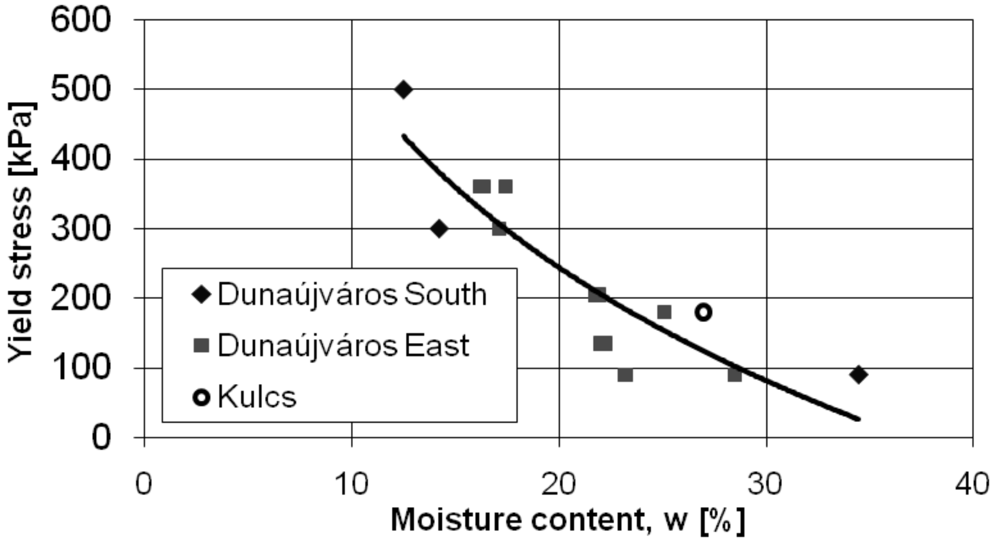

Figure 3. Yield stress against moisture content

In the case of dried soil samples the yield stress was not reached, because applying stress larger than 900 kPa was not possible. So the only fact that can be stated regarding the dried samples is that the yield stress is above 900 kPa.

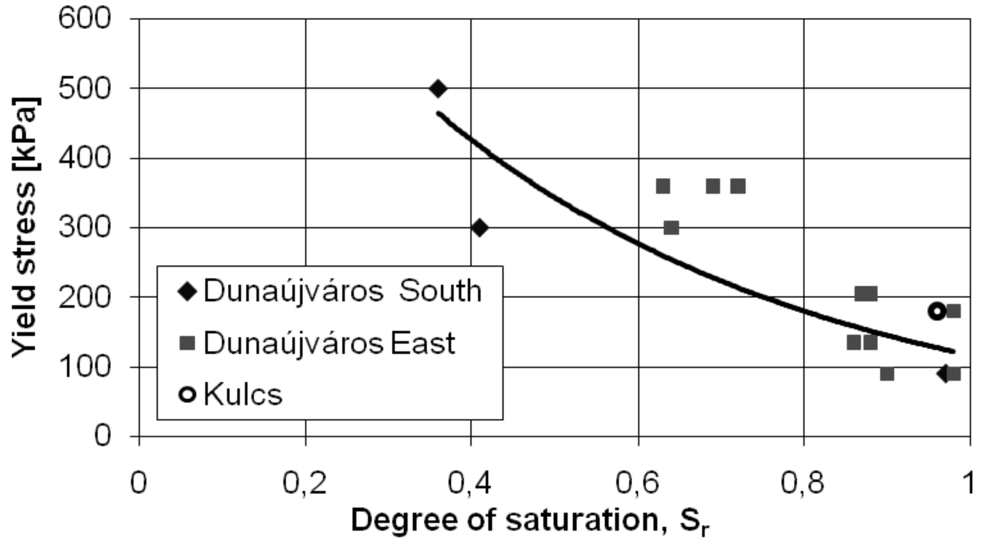

Figure 4. Yield stress against degree of saturation

4.2 *Yield stress against degree of saturation*

Although the correlation coefficient for the moisture content – yield stress relationship was quite good, the yield stress was plotted against the degree of saturation too. This is shown in Figure 4. This figure demonstrates clearly that the same trend can be observed, but the correlation coefficient is definitely worse. Therefore the use of moisture content – yield stress is recommended.

4.3 *Yield stress against void ratio*

The relationship of void ratio and yield stress was also analyzed in this work. These values were plotted against each other, and it is shown in figure 5. It can be observed that there is no significant correlation between void ratio and collapse forcing stress. Thus the importance of the soil's void ratio is marginal from this viewpoint.

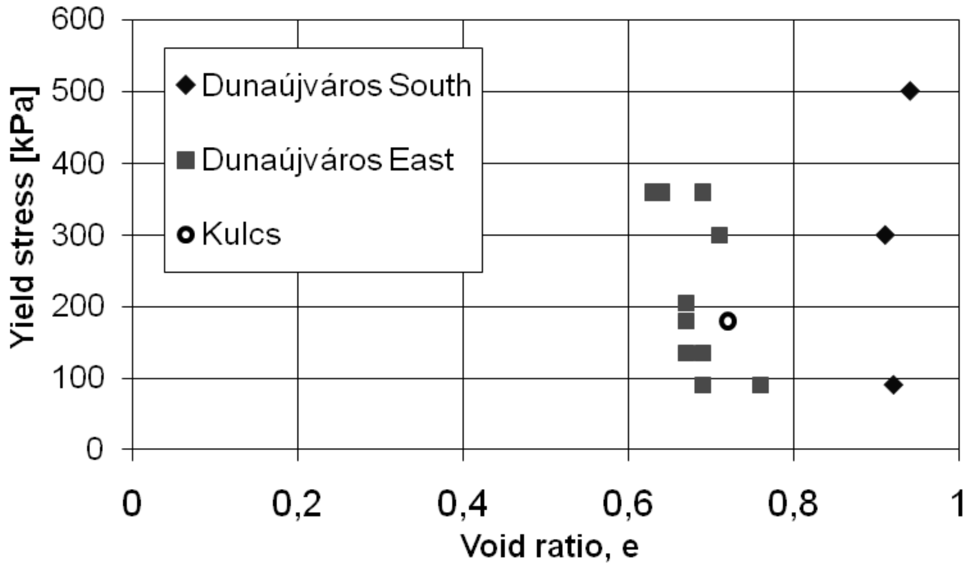

Figure 5. Yield stress against void ratio

5 COLLAPSE CAUSED BY FLOODING

It is well known that the collapse strain is influenced by the initial moisture content of the sample (Delage et al. 2005) and by the stress at which the specimen is flooded.

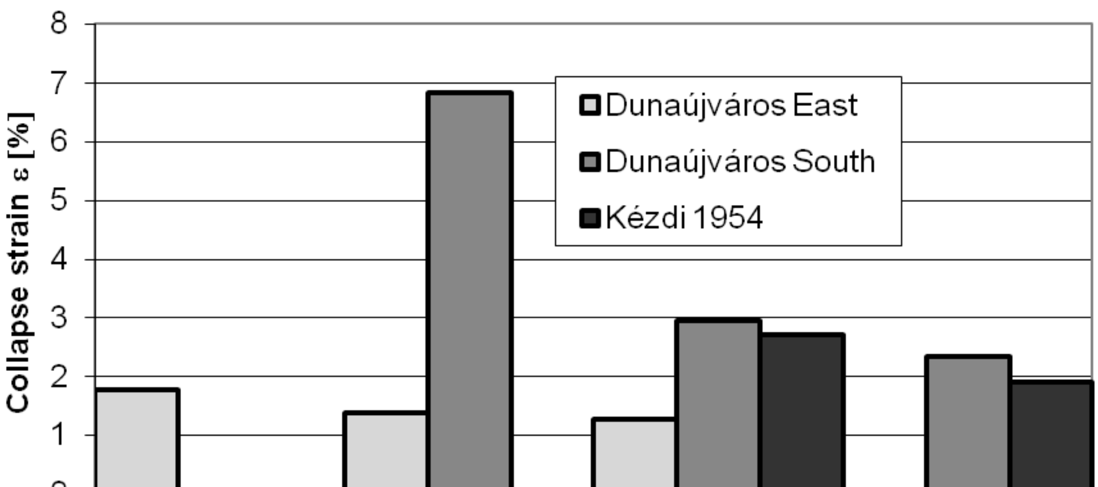

Figure 6. Collapse strain at different stress levels

In the case of the 11 oedometer test the soil specimens were water flooded at different stress levels. The aim of these tests was to analyze the effect of the stress at which the specimen is flooded on the measured collapse strain. Figure 6. shows the measured collapse strains of our tests and earlier tests on samples from Dunaújváros (Kézdi, 1954). A clear tendency can be observed: the higher the stress at which the sample is flooded the lower the collapse strain. Nevertheless it must be mentioned that the soil samples tested had relatively high moisture content, and therefore the yield stress was relatively low. It means that the collapse of the soils having the initial moisture content starts to develop at lower stress rate, so the collapse is already partially developed before the water flooding the samples. The larger the stress the larger part of the collapse is developed, therefore the less collapse occurs during the test (caused by water flooding the specimen).

Presumably in the case of dry soil samples the tendency is the opposite. The yield stress is high, definitely higher than the stress at which the specimen is flooded, so no partial collapse can be expected before the water flooding of the specimen. Therefore the larger the stress the larger the collapse strain.

6 SUMMARY, CONCLUSION

34 oedometer tests were made to analyze the collapse process of loessial soil samples. Based on the test results the following conclusion can be made:

- The compression curve can be divided to three parts: pre-collapse, collapse, and post collapse zone. In the second zone the collapse gradually develops in a specific stress range, which is mainly influenced by the moisture content of the soil.
- A reliable correlation can be found between the yield stress (at the beginning of the collapse zone) and the moisture content, but no such relationship was found for void ratio and yield stress.
- In the case of soil samples having high moisture content, larger stress level at which the specimen is flooded causes smaller collapse strain.

ACKNOWLEDGEMENT

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