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# Settlement of Loaded Loess during its Silication

## Tassement de Loess Chargé pendant sa Silicatisation

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**SYNOPSIS** Considerable settlement results when the collapsible soil under existing buildings is strengthened by injecting water glass (silication). This can cause fissuring and reduces the structural safety of the buildings. In order to avoid this, a simple calculation method is proposed, based on the relation between settlement and vertical stress, between settlement and quantity of injected water glass, between settlement and time elapsed, on the increase of the cube strength with time, as well as on the stiffness of the bearing structure of the building. The method is applied successfully in the strengthening of collapsible loess under a number of cultural monuments in Bulgaria.

### INTRODUCTION

The application of silication for the strengthening of collapsible loess under existing buildings dates as back as 1944 (Askalonov). The injection of water glass in the loess however causes its partial collapse, whereby buildings with older structures (except reinforced concrete) may settle unevenly and become cracked. This settlement can be avoided if the injection is conducted in a certain order, namely in sections of a given length, at a given spacing and after a given time.

### STUDIES REQUIRED

In order to determine the sequence of injection, it is necessary to conduct the following laboratory tests on undisturbed loess samples with the standard oedometer.

- (i) Evaluation of the coefficient of collapse  $\sigma_c$  under different vertical stresses and different quantities of injected water glass (with  $\gamma = 11.3 \text{ kN/m}^3$ ) as part of the porosity  $n$  (Fig. 1)
- (ii) Evaluation of the relation between settlement after collapse and time (Fig. 2)
- (iii) Evaluation of the settlement curve of the natural loess (Fig. 3)
- (iv) Evaluation of the cube strength of samples silicated with different quantities of water glass with relation to the time after silication (Fig. 4).

### CALCULATION MODEL FOR STRIP FOUNDATIONS

The vertical stresses in the loess due to actual loading  $p_0$  are calculated (Fig. 5). The active zone of collapse due to injection with water glass is adopted to the depth of  $\sigma_z = 50 \text{ kPa}$ , since further deeper  $\sigma_0$  is very small

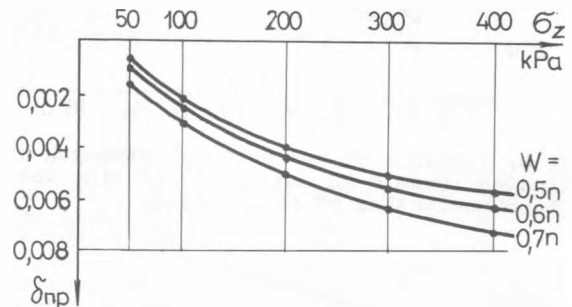


Fig. 1. Coefficient of relative collapse for various quantities of water glass.

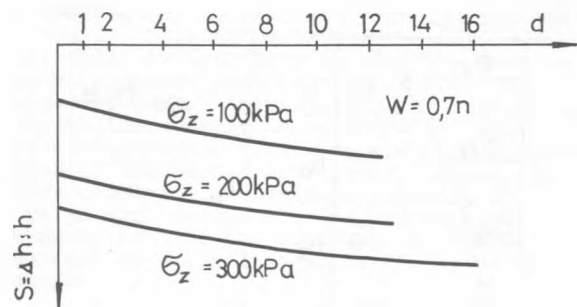


Fig. 2. Time-settlement relation for various vertical stresses  $\sigma_z$

and may be neglected. The active zone is divided in three or four intervals. The total collapse

$$\Delta h_0 = \sum h_1 \sigma_0 \quad (1)$$

is calculated for different quantities of water glass (0.5 n, 0.6 n and 0.7 n), whereby  $\sigma_0$  is evaluated after Fig. 1. If the settlement  $\Delta h_0$  is admissible for the building, no further

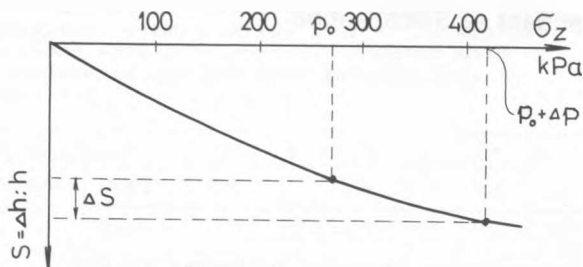


Fig. 3. Settlement curve of natural loess

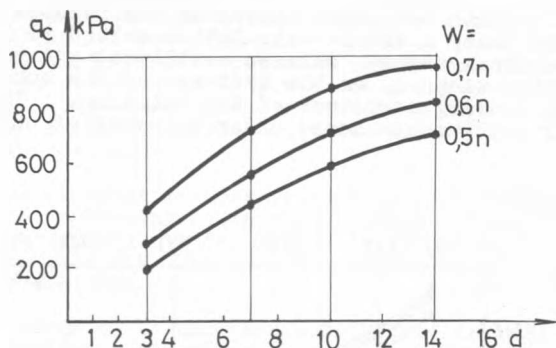


Fig. 4. Increase of the uniaxial strength of silted loess  $q$  in the course of time for various quantities of water glass.

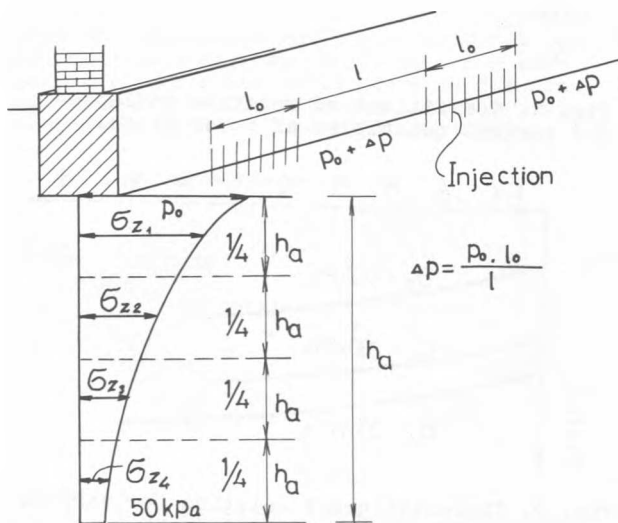


Fig. 5. Simplified calculation model for strip foundations.

technical measures are required. If however the collapse is inadmissible we have to evaluate:

- (1) The possibility of the strip foundation and possibly of the structure above it to transfer the loads acting on the injected section, of a length  $l_0$ , sideways

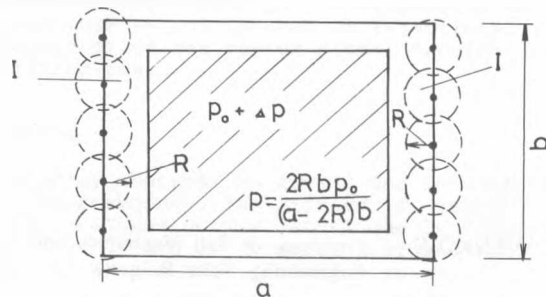


Fig. 6. Silication under a singly foundation.

to a section of the natural loess, of a length  $l$  (Fig. 5),  $p_0 + \Delta p$  being smaller than  $p_{adm}$  for loess.

- (11) The settlement of the natural loess within the interval  $l$ , due to the additional loading  $\Delta p$  (Fig. 3)

$$\Delta h = \int h_1 \Delta S_1, \quad (2)$$

which, after varying  $l_0$ ,  $l$  and  $\Delta p$  can be fit into the limits of the settlement admissible for the structure.

- (111) The time necessary to obtain the strength required in the section of silted loess  $l_0$  to make it able to carry again its load (Fig. 4) and the time after which no considerable additional settlement (Fig. 2) of the silted loess may occur.

#### CALCULATION MODEL FOR PAD FOUNDATIONS

The total collapse  $\Delta h_0$  is also calculated after formula (1). If the collapse is inadmissible we have to calculate:

- (1) The capacity of the foundation base to resist the increased soil reaction  $p_0 + \Delta p$ , resulting from the partial injection  $I$  of the subgrade (Fig. 6).
- (11) The settlement of the natural loess due to its additional loading  $\Delta p$  after the formula (2) and Fig. 3, which has to be smaller than the admissible for the structure. This is achieved again by reducing the number of injections in zone I or by relieving the column by side propping.
- (111) The time necessary to obtain the strength required in the section of silted loess  $I$  (after Fig. 4) and the additional settlement (after Fig. 2).

#### EVALUATION OF THE WATER GLASS QUANTITY

It is established (Askalonov) that the optimum density of the injection solution is  $11.3 \text{ kN/m}^3$ . The water glass quantity required to strengthen  $1 \text{ m}^3$  of collapsible loess is evaluated after Fig. 1, 2 and 4, depending on the final loess strength required and on the available time to operate.