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EFFECT OF LIME FILLING ON THE COMPACTIBILITY OF CLAY SOILS

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Abstract

Insufficient resilience of the natural environment is one of the many problems with the foundation of linear structures, and one of the ways to solve the foundation of a linear structure is the stabilization of soils. Fine-grained soils are problematic for traffic construction. The properties of clay soils change due to climatic conditions. They swell and become plastic in the presence of water, shrink in dry conditions, increase in volume, and freeze due to frost. Improving the properties of fine-grained soils with lime is a suitable solution to the problem in traffic construction. The purpose of soil improvement is to modify soil properties such as creating soil without cavities and gaps, increasing shear strength, reduce compressibility and permeability, the soil must be able to transfer the load without further settling (or unnatural compression). Soil improvement can be defined as an intervention in the natural geological environment or artificially built earth structures (embankments, notches), the purpose of which is to increase the resistance of the subsoil, achieve even settlement of the structure or object, accelerate consolidation, optimally build earth structures, etc. We can encounter the stabilization of the subsoil in all types of constructions, but most often in line constructions and water management construction. In our article, we focus on the effects of soil treatment with lime. The treated soil was F8 (CH) clay with high plasticity.

Keywords:

Stabilization;
Soil treatment;
Lime;
Proctor standard;
Laboratory test.

1 Introduction

If the parameters of the natural rock environment, which do not guarantee sufficient resilience of the natural environment, necessary for designed objects, are verified in the engineering geological survey, it is possible to consider improving the parameters of the original rock environment. The interest is mainly focused on improving the properties of foundation soils, which modify the foundation soil, increase the compressive strength and shear strength, and improve workability and resistance to climatic effects.

Many researchers have studied soil improvement, modification, or reinforcement. Materials that are readily available in the country are primarily used to improve soils. For example, in the Middle East, iron filings are used [1], in Algeria they use a straw to improve soils [2], and various types of fibers are used to reinforce soils, such as polyester fibers [3], coconut fibers [4], palm leaves [5], papyrus fibers [6] and PET bottles were also used [7]. In traffic constructions, in addition to soil stabilization, soil reinforcement with geomaterial is often used [8]. Cement and lime [9, 10] are mainly used in Slovakia. The stabilization of soils with cement can be further improved with various additives [11].

By using different types of binders, we also improve other mechanical and physical properties of the original soil. Stabilization by hydraulic binders significantly reduces the necessary construction costs and at the same time reduces the total thickness of the substructure layers by 15 % (in many cases by 20 %) depending on the type of subsoil and the type of building. The type of subsoil plays an important role in the selection of the hydraulic binder, therefore it is first necessary to classify and name the soil flawlessly first. From the above, it is clear that the type and content of the binder are

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chosen depending on the original soil, for example, when building roads, it is possible to change the content and type of binder during the route. This paper aims to determine the effect of lime on the behavior of fine-grained soil.

2 Compaction control

Compaction quality control is becoming a very serious issue. Because in nature we do not find incoherent soils without admixtures of fine-grained particles, as well as pure clays. We can use different compaction methods. Each one has its advantages and disadvantages. The purpose of soil compaction is to achieve:

- soil density according to the prescribed range of the Proctor test,
- equilibrium soil density,
- require relative density,
- the prescribed value of the deformation modulus,
- permissible value of transplanting after saturation with water.

The quality of the compaction of the soils is checked using the compaction degree, the characteristics of which we examine with the Proctor Standard laboratory test [12].

The compaction degree for cohesive soils is expressed using the Hilf method; the resulting values are compared with the required values, which can be found in Table 1 according to the following expression:

$$D = \frac{\rho_d}{\rho_{d,max\,PS}} * 100, \quad (1)$$

where:
D - compaction quality factor [%],
ρ_d - dry soil density according to STN 72 1010 [kg/m^3],
$\rho_{d,maxPS}$ - maximum dry soil density determined by the standard Proctor Standard test according to STN 72 1015 [kg/m^3].

It is the ratio of soil taken directly in the field and laboratory determination of the maximum soil density according to the Proctor Standard.

Table 1: The lowest compaction rate of cohesive soils [12].

Soil with max. dry soil density according to STN 721015 by the Proctor Standard method	Parameter D [%]			
	Construction plain		In the body of the embankment 0.5 m and more below the plain	Embankment subsoil up to 0.5 m
	Depth below the plain			
	Embankment to 0.5 m	Notch to 0.5 m		
1.50 – 1.60 g/cm^3	-	-	95	92
1.60 – 1.75 g/cm^3	102	102		
> 1.75 g/cm^3	100	100		

The compaction degree for incoherent soils (sandy and gravelly soils) is expressed by the relationship relative density ID. The resulting data is determined by comparison with the required value of relative density ID according to Table 2 by the following expression [12]:

$$I_D = \frac{\rho_{d,max} * (\rho_d - \rho_{d,min})}{\rho_d * (\rho_{d,max} - \rho_{d,min})} * 100, \quad (2)$$

where:
I_D - index relative density [-],
ρ_d - dry soil density in its natural state, or compacted using Proctor Standard according to STN 721010 [kg/m^3],
$\rho_{d,max}$ - maximum dry soil density according to STN 72 1018 [kg/m^3],
$\rho_{d,min}$ - minimum dry soil density according to STN 72 1018 [kg/m^3].

Table 1: The lowest compaction rate of incoherent soils [12].

Name of the soil	Symbol	Other qualitative features	Relative density I_D	
			Plain to 0.3 m	Embankment to 0.5 m
Well grained sand	SW	$g < 25$ % ($f + s + g$)	0.90	0.80
Badly grained sand	SP			
Sand mixture	S-F			
Well grained sand	SW	25 % $< g <$ 50 % ($f + s + g$)	0.85	0.75
Badly grained sand	SP			
Sand mixture	S-F			
Well grained gravel	GW	25 % $< s <$ 50 % ($f + s + g$)		
Badly grained gravel	GP			
Gravel mixture	G-F			
Well grained gravel	GW	$(f + s) \leq 25$ % ($f + s + g$)	0.80	0.70
Badly grained gravel	GP			
Gravel mixture	G-F			

In field conditions, we can use a static or dynamic load plate for their qualitative control [13].

3 Laboratory tests

Soil compactibility is expressed by the maximum dry soil density $\rho_{d,max}$, which is achieved by certain compaction of the soil in a standard mortar using a standard compactor (Fig. 1) at optimum water content w_{opt}. The soil was excavated from the site of the University of Žilina by STN 73 1001, we classify the soil as F8 (CH) clay with high plasticity. The wet soil sample delivered to the laboratory is allowed to dry in an oven (max. 60 °C). After drying, the required amount of soil is sieved through a 0.5 mm sieve. A representative sample of the soil weighing 10 kg or more shall be taken. The excess surplus will not be used for further tests.



Fig.1: Proctor Standard test equipment.

The selected sample is thoroughly mixed with water so that the soil moisture is approximately four percent lower than the optimum moisture. The sample is then left to stand for at least 12 hours in an airtight container so that the moisture is evenly distributed throughout the sample. The soil is successively placed in three equally high layers in an assembled mortar with an internal diameter of 101.5 mm and compacted so that, after compaction, the total height of the sample in the mortar with the extension is about (12.5 ± 0.5 cm). If the height is not observed, compaction must be repeated. Each layer is compacted by 25 evenly distributed strokes of a standard beater weighing 2,500 g, falling freely from a height of 300 mm, at a frequency of 20 to 30 strokes per minute. The height from which the hammer strikes the soil is measured from the level of each layer after compaction. During

compaction, the grinder must stand on a solid and level surface, which forms e.g. a concrete block weighing at least 100 kg. The compaction of the individual layers and the whole test must be carried out at a uniform speed and without interruption. After compaction, the total height of the sample in the mortar is checked, the extension is removed and the soil surface is thoroughly leveled with a leveling ruler according to the upper edge of the mortar. Optionally, cavities on the surface of the aligned sample, created by plucking coarser grains, are supplemented with finer-grained cut soil. Weigh, to the nearest 5 g, a soil sample with a mortar [14]:

$$\rho = \frac{(m_1 - m_m) * 100}{V_m}, \tag{3}$$

where:
m_1 - the weight of moist soil after compaction, including the weight of the mortar [g],
m_m - the weight of empty mortar [g],
V_m - mortar volume [cm^3].

The soil is removed from the mortar and the sample is cut with a vertical cut into two symmetrical halves. A representative sample of a minimum weight of 200 g is taken from the section to determine the moisture content. For further compaction, pre-dried soil is used, prepared so that its moisture increases by 1.5 to 2 percent. The whole procedure is repeated with a gradual increase in water content until the weight of the moist soil in the mortar begins to decrease or until water begins to be expelled from the sample. Moisture w is calculated from the soil sample taken after each test after weighing and drying. The dry weight ρ_d is calculated (4):

$$\rho_d = \frac{\rho}{w + 100} * 100, \tag{4}$$

where:
ρ - soil density of moist soil [kg/m^3],
w - soil moisture during compaction [%].

Dolomite quicklime chemically calcium oxide (CaO) was used to stabilize the soil. The soil preparation is the same, except that the initial test soil moisture is the same as the optimum soil moisture without a binder. After the time required for the moisture to decompose in the soil has elapsed, the calculated amount of lime is added to the dry matter and the mixture is homogenized. It is then stored in an airtight container for 60 minutes. After this time, compaction is then performed. The determination of the bearing capacity ratio IBI is performed according to STN EN 13286-47 on soil with optimal moisture and the proposed dose of the binder. If the instantaneous load-bearing capacity index IBI at the maximum amount of binder is < 12, the soil is not suitable for improvement or stabilization with lime [15].

4 Results of untreated and treated soil

The results of laboratory experimental tests are given in the evaluation. In laboratory experimental tests, the effect of lime on fine-grained soil was observed. Soil F8 = CH - clay with high plasticity, and powdered quicklime were used for the tests. A comparison of the results is in Table 3, which shows the results from all three measured experiments. Graphs were made from the results obtained after laboratory tests, into which trend lines were subsequently inserted. Then, the optimal water content and the associated maximum dry soil density were read from the graph, Fig. 2. A total of six measurements were taken from each sample.

Table 3: The resulting maximum dry soil densities at optimum water content.

Test	Optimal water content [%]	Max. dry soil density [g/cm^3]
Untreated soil	15.2	1.648
Treated soil, 2 % lime	14.2	1.555
Treated soil, 3 % lime	13.4	1.542

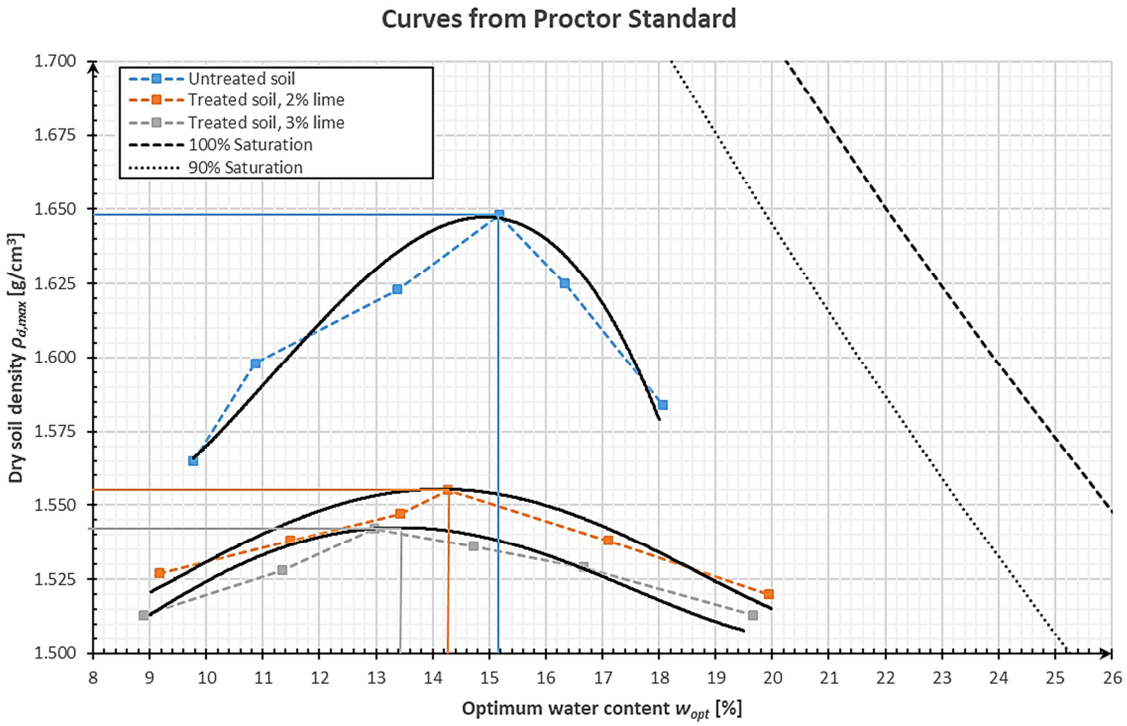


Fig. 2: Results and comparison curves from Proctor Standard.

Fine-grained soils contain clay minerals, which affect the deformation resistance and bearing capacity of countries with their properties. The modification of such fine-grained soils aims to improve the geotechnical properties. Where lime acts as a binder between the individual contact surfaces of fine-grained earth particles [16].

In the soil we treat after the later (powdered) lime, the following occurs:

- to reduce humidity (water content) in the soil, where the soil acts due to the mixing of the binder with the soil and the exothermic reaction: where heat is supplied. At soil F8 = CH humidity is decreased by 0.15 to 0.45 % after almost 1 % of lime. According [13], for the soil F6 = CI it decreased by 0.6 to 0.8 %,
- for flocculation, is the agglomeration of fine-grained particles into larger forms, which reduces the clay particles. For soils with a large number of fine particles and high plasticity, these are more significant changes. Fine-grain flocculation is an ongoing process that continues over time,
- to crystallize the lime hydrate, whereby the soil hardens,
- with an immediate response to reduce the liquid limit w_L,
- with an immediate reaction to increasing the plasticity limit w_P,
- with immediate reaction to decrease of plasticity index $I_p = w_L - w_P$,
- to increase the cohesion c and the angle of internal friction φ (shear parameters),
- to reduce soil icing,
- with immediate response to a decrease in optimal water content w_{opt} according to the Proctor Standard test,
- with immediate reaction to decrease dry soil density $\rho_{d,max}$ according to Proctor Standard,
- to flatten the compaction curves according to the Proctor Standard, thus extending the range of optimum water content.

5 Conclusion

The work was focused on ways to stabilize the subsoil. The paper aimed to clearly contribute to the consequences of the soil binder after the addition of powder lime. The soil was stabilized with 2 % and 3 % lime. After the addition of lime, there was a decrease in humidity, an expansion of the range of optimal humidity, a decrease in dry soil density and agglomeration of fine particles. In traffic construction, lime is often used to modify and improve the properties of the soil. The use aims to build better roads or construction layers. After the addition of lime, the curves are straightened and the range of optimal humidity is expanded, which improves the construction conditions of the earth

structure in linear constructions. The required amount of binder is determined by experimental laboratory tests, as demonstrated in the article.

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