Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 53(10) (2022) 977-980
DOI: 10.22060/ceej.2021.18360.6848

Application of Lime and Nano Lime in Control of Failure in Side Slope of Earth Channel

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ABSTRACT: The instability of earth slopes in open channels has always been considered by hydraulic engineering. In the present study, the application of lime and nano lime in control of failure in the side slope of the earth channel has been investigated experimentally. Results showed lining of 20% lime and 5% nano lime increased the angle of internal friction 31.8% and 35.5%, respectively and cohesion reached a value of 3.3 kPa. In feeding, for slopes of 26.5, 33, 45 and 53-degree failure occurred in water levels of 560 mm, 460 mm, 460 mm and 410 mm, respectively. For the seepage situation, the slope of 26.5 degree was stable and slopes of 33 and 45 became instable in a water level of 510 mm. Slopes of 45 degree with 10% lime and 53 degree with 20% lime were stable in the maximum level of 660 mm. Potential variation behind the slope showed curve procedure with lime percent. The lining of the side slop with lime and nano lime decreased seepage discharge in the same water level. Also, the application of lime and nano lime changed the shape of the failure zone and using nano lime decreased cracks in size. In feeding, without and with lime lining, curved failure surface and crack were observed on the slope.

Review History:

Received: May, 04, 2020
Revised: Jan. 09, 2021
Accepted: Jan. 18, 2021
Available Online: Jan. 29, 2021

Keywords:

Failure
Lime and nano lime
Feeding and drainage
Seepage discharge
Side slope earthen channel

1. INTRODUCTION

One of the factors affecting the instability of inclined embankments is shear force, which is controlled by effective stress. Effective stress is defined as the difference between total stress and pore water pressure. Rising water levels increase pore water pressure and reduce effective stress, thus leading to decreased stability of embankment slopes. Therefore, pore water pressure plays a vital role in the stability of soil slopes. There are various methods for stabilizing soil slopes, which are based on reducing pore water pressure and increasing resistance. One of the methods for increasing resistance on slopes is to cover them with hydrated lime or nano-lime which play an important role in the stability of soil slopes as they will improve cohesion.

Daryaee and Kashefipour [1] investigated the effect of increasing blown sand and lime content on the resistance of clay soils. In another study, Shen et al. [2] used hydrated nano-lime with an average particle size of 660 nm, which increased the indirect tensile strength of the asphalt mixture and tensile strength ratio of the samples by 15 and 8 percent, respectively. Abedi Koupai et al. [3] evaluated the possibility of enhancing the resistance of clay soils stabilized with hydrated lime in the vicinity of hydraulic structures by adding various percentages of hydrated lime under optimal or saturated moisture conditions.

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As can be seen, previous studies have mostly concentrated on clay soils and their stabilization with lime or the use of nano-clay, and there is no published study concerning pure sandy soils and the application of lime and nano-lime for investigating the shear strength parameters and failure control in such soils. Accordingly, this study aimed at evaluating the role of hydrated lime and nano-lime in controlling the stability of the slide slope of soil channels under both recharge and discharge conditions. Also, the impacts of hydrated lime and nano-lime on seepage discharge and potential were evaluated.

2. METHODOLOGY

The experiments were performed on a seepage and drainage tank in the Hydraulics Laboratory at the Department of Water Engineering of the Shahrood University of Technology. The tank was built using a 185 × 55 × 100 cm^3 Plexiglas container (length × width × height).

In order to perform the main experiments, determination of various soil parameters such as specific gravity, mean particle diameter, hydraulic conductivity, cohesion and internal friction angle of the soil was necessary. These parameters were determined by specific gravity (direct method), grading (US standard), constant head and direct shear tests. Type 1 Shahvar hydrated lime was used in the experiments. A planetary ball mill was used for preparing nano-lime. For this purpose, lime was mixed with different percentages of alcohol and milled with a ball to powder ratio of 1:10 and

Table 1. Properties of the prepared nano-lime

Properties of the nano-lime	Values
Particle size (nm)	470
Density ($gr.cm^{-3}$)	2.93
Melting point (°C)	825

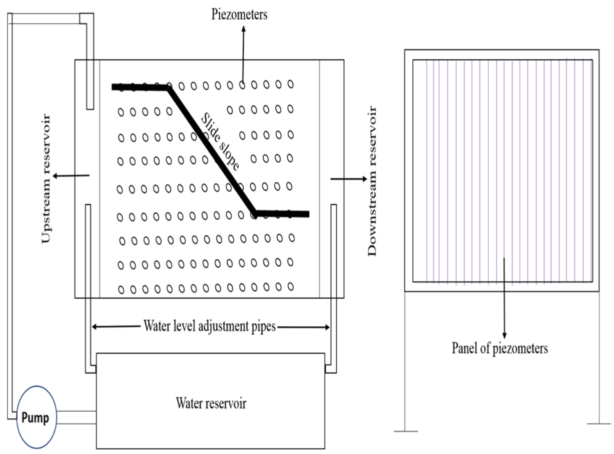

Fig. 1. Schematic drawing of the model

a rotation speed of 400 rpm. After approximately one hour, nano hydrated lime was harvested (Table 1). Processing times were equal for all samples (24 hours, according to the soil type, i.e., pure sand).

The main experiments were divided into three categories: no-cover models, hydrated lime-covered models and nano-lime-covered models. Initially, a 5-cm thick layer of clay was spread as an impermeable layer at the boundary between soil and the model's floor to prevent piping. since the water level is constant on both sides of the model, seepage from the canal is symmetrical relative to its central axis. Therefore, only half of the cross-section of the canal was modeled. Piezometers were numbered successively from left to right and from bottom to top (Figure 1).

3. DISCUSSION AND RESULTS

3.1. Soil shear strength parameters

As can be seen, an increased percentage of hydrated lime led to an approximately 31.8 percent increase of internal friction angle, and cohesion increased from zero to 3.3 kPa. Also, 5 percent (by weight) of nano-lime enhanced internal friction angle to 44.7 - about 35.5% increase compared to the uncovered state - and cohesion was equal to 3.3 kPa. After the addition of either normal or nano-sized calcium carbonate to the soil, Ca^{++} and $(OH)^{2-}$ ions are released and form hydrated silicate cement gels. These cement-like gels penetrate into soil pores and increase the cohesion between particles. "Figure 2" depicts failure envelopes plotted for different covers based on the Mohr-Coulomb criterion $(\tau = c + \sigma \tan\phi)$, showing that for a given normal stress, the 5% nano-lime cover has had the highest shear stress.

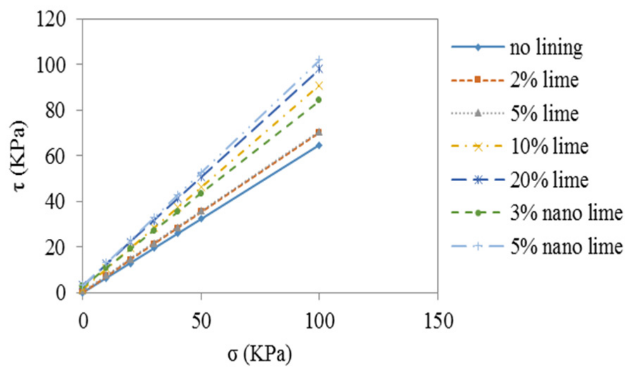

Fig. 2. Failure envelopes plotted for different covers

Fig. 3. Failure shape with 5% nano-lime covering

3.2. Potential variations

As the percentage of lime was increased, potential increased on the inclined part of the channel because cement gels were formed and penetrated into soil pores which improved the cohesion between particles, reduced infiltration on the surface, and increased the potential in the back part.

3.3. Seepage discharge

Adding various percentages of lime to the soil increases cementation properties on the inclined surface which acts as a barrier against the flow and lowers the passing discharge. In our experiments, increasing lime percentage improved the performance of seepage discharge control. Also, the use of nano-lime had a significant effect in terms of reducing the discharge, with both 3 and 5 percent nano-lime having the same performance and reducing seepage discharge by about 52%. In addition to cementation and obstructing the pores, nano-lime also increases the density and reduces infiltration, thus effectively lowering the seepage discharge.

In recharge conditions and without lime covering, the failure happened in rotational-circle form, whereas with lime covering, failure initially happened in the form of cracks on the surface, followed by slip-sliding of the inclined part of the channel. As the percentage of lime increased, the depth, size and number of cracks decreased, and nano-lime covering minimized the cracks (Figure 3).

4. CONCLUSIONS

According to the results, increasing the percentage of hydrated lime increased internal friction angle by approximately 31.8% and cohesion improved from zero to 3.3 kPa. With 5% (by weight) of nano-lime, the internal friction angle was about 44.7%, which was about 35.5% higher than the uncovered state. Under recharge conditions, application of 3 and 5 percent nano-lime led to a similar performance and reduced seepage discharge by about 52%. The use of lime and nano-lime changed the shape of failure. Therefore, according to extent and sensitivity, the application of 5% nano-lime or 20% lime is recommended for achieving the best performance.

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HOW TO CITE THIS ARTICLE

S. Najarzadeh, R. Moazenzadeh, S. Hossein Hosseini, Kh. Azhdary, Application of Lime and Nano Lime in Control of Failure in Side Slope of Earth Channel, Amirkabir J. Civil Eng., 53(10) (2022) 977-980.

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