

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

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ABSTRACT

Instability of earth slopes in open channels have been always considered by hydraulic engineering. In present study, application of lime and nano lime in control of failure in side slope of earth channel has been investigated experimentally. Results showed, lining of 20% lime and 5% nano lime, increased 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 seepage situation, slope of 26.5 degree was stable and slopes of 33 and 45 became instable in water level of 510 mm. Slopes of 45 degree with 10% lime and 53 degree with 20% lime were stable in maximum level of 660 mm. Potential variation behind the slope showed curve procedure with lime percent. Lining of side slop with lime and nano lime decreased seepage discharge in same water level. Also, application of lime and nano lime changed shape of failure zone and using nano lime decreased cracks in size. In feeding, without and with lime lining, curved failure surface and crack observed on slope.

KEYWORDS

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

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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.

Daryae 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 per cent, 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.

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 Department of Water Engineering of Shahrood University of Technology. The tank was built using a $185 \times 55 \times 100$ cm Plexiglas container (length \times width \times 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 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).

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 ($^{\circ}\text{C}$)	825

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 model's floor to prevent piping. since 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 modelled. Piezometers were numbered successively from left to right and from bottom to top (Figure 1).

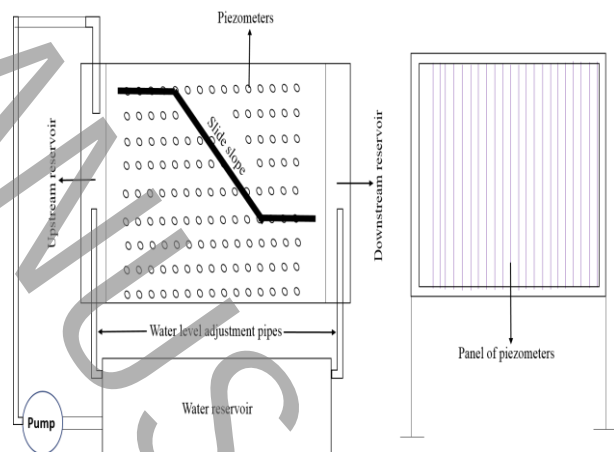


Fig. 1. Schematic drawing of the model

3. Discussion and Results

3.1. Soil shear strength parameters

As can be seen, Increased percentage of hydrated lime led to an approximately 31.8 per cent increase of internal friction angle, and cohesion increased from zero to 3.3 kPa. Also, 5 per cent (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 addition of either normal or nano-sized calcium carbonate to the soil, Ca^{++} and $(\text{OH})^{2-}$ 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.

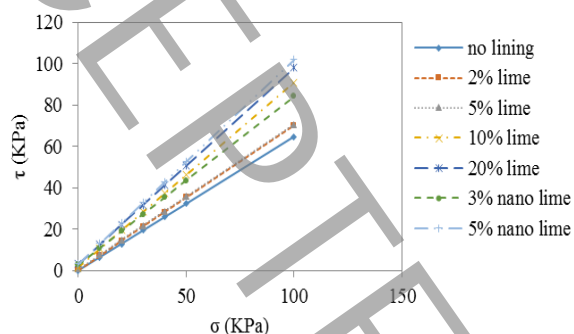


Fig. 2. Failure envelopes plotted for different covers

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 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 per cent 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, 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).



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

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 per cent 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, application of 5% nano-lime or 20% lime is recommended for achieving the best performance.

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