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COMPRESSION OF UNSATURATED CLAY UNDER HIGH STRESSES

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The isotropic compression response of compacted, low-plasticity clay specimens having various initial degrees of saturation $S_{r,0}$ to high stresses under drained and undrained conditions was investigated using the approach of Mun and McCartney (2015). The compression curves in terms of void ratio e versus mean effective stress p′ or mean total stress p are shown in Figure 1.

DRAINED COMPRESSION RESPONSE

After an initial elastic response, the drained specimens reach an apparent mean effective preconsolidation stress that increases with decreasing $S_{r,0}$. As p′ increases further, the compression curves for the unsaturated specimens converge with the curve for the saturated specimen as air is expulsed. The value of p′ required to reach the point of pressurized saturation increases with decreasing $S_{r,0}$. At higher p′, the initial soil structure induced by compaction has an effect on the shape of the compression curves, which are also distorted by the use of the logarithmic scale.

UNDRAINED COMPRESSION RESPONSE

The compression curves for undrained specimens with a lower $S_{r,0}$ have a softer response due to the compression of the air-filled voids. With increasing mean total stress, the pore air dissolves into the pore water until reaching the point of pressurized saturation, which depends on $S_{r,0}$. After this point, the specimens are water-saturated and the shapes of the compression curves are dominated by the pore water compressibility. The point of pressurized saturation can be assessed by revisiting the model of Hilf (1948), who combined Boyle's law and a simplified version of Henry's law to estimate changes in pore air pressure during undrained compression. Specifically,

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by considering a pressure-dependent solubility of air in water ($h=u_a/k_h$, where u_a is the pore air pressure and k_h is Henry's constant), the value of Δu_a for a change in mean total stress Δp can be calculated, as follows:

$$\left(\frac{S_{r,0}n_0}{k_h}\right)\Delta u_a^2+\left((1-S_{r,0})n_0+\frac{2u_{a0}S_{r,0}n_0}{k_h}-m_{v,u}\Delta p\right)\Delta u_a-m_{v,u}u_{a0}\Delta p=0 \qquad (1)$$

where n_0 is the initial porosity, u_{a0} equals 101.3 kPa, and $m_{v,u}$ is the coefficient of volume compressibility of the soil in undrained conditions. The change in mean total stress required to reach pressurized saturation (Δp_{ps}) can then be estimated as follows:

$$\Delta p_{ps}=\frac{(1-S_{r,0})n_0\Delta u_{a,ps}+\frac{S_{r,0}n_0}{k_h}\left(\Delta u_{a,ps}^2+2\Delta u_{a,ps}u_{a0}\right)}{m_{v,u}\left(\Delta u_{a,ps}+u_{a0}\right)} \qquad (2)$$

The predicted values of Δp_{ps} for specimens having different values of $S_{r,0}$ is shown in Figure 2 along with the experimental points of pressurized saturation from the undrained compression curves in Figure 1. A good match is observed, with differences due to the choice of $m_{v,u}$ for specimens with different $S_{r,0}$ values.

IMPLICATIONS

Although the trends in preconsolidation stress for the drained curves are well-captured by available suction-hardening models, the process of pressurized saturation and the slope of the compression curve for unsaturated soils need to be better characterized. The shapes of the drained curves at high p′ indicate that a bi-log-linear compression curve should not be used for values of p′ greater than 10 MPa. Instead, an exponential decay model may better capture the transition to void closure. The transition point at which the undrained compression curve is dominated by the air-filled voids or the water-filled voids can be better captured using the modified analysis of Hilf (1948).

ACKNOWLEDGEMENTS

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Hilf, J.W. (1948). “Estimating construction pore pressures in rolled earth dams.” Proc. 2nd Int. Conf. on Soil Mechanics and Foundation Engineering. Rotterdam, Vol. 3, 230-240.

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LIST OF FIGURE CAPTIONS

Fig. 1. Compression curves of compacted clay specimens having different $S_{r,0}$ measured under drained and undrained conditions

Fig. 2. Mean total stresses required to reach pressurized saturation for undrained, compacted clay specimens having different $S_{r,0}$

Figure 1

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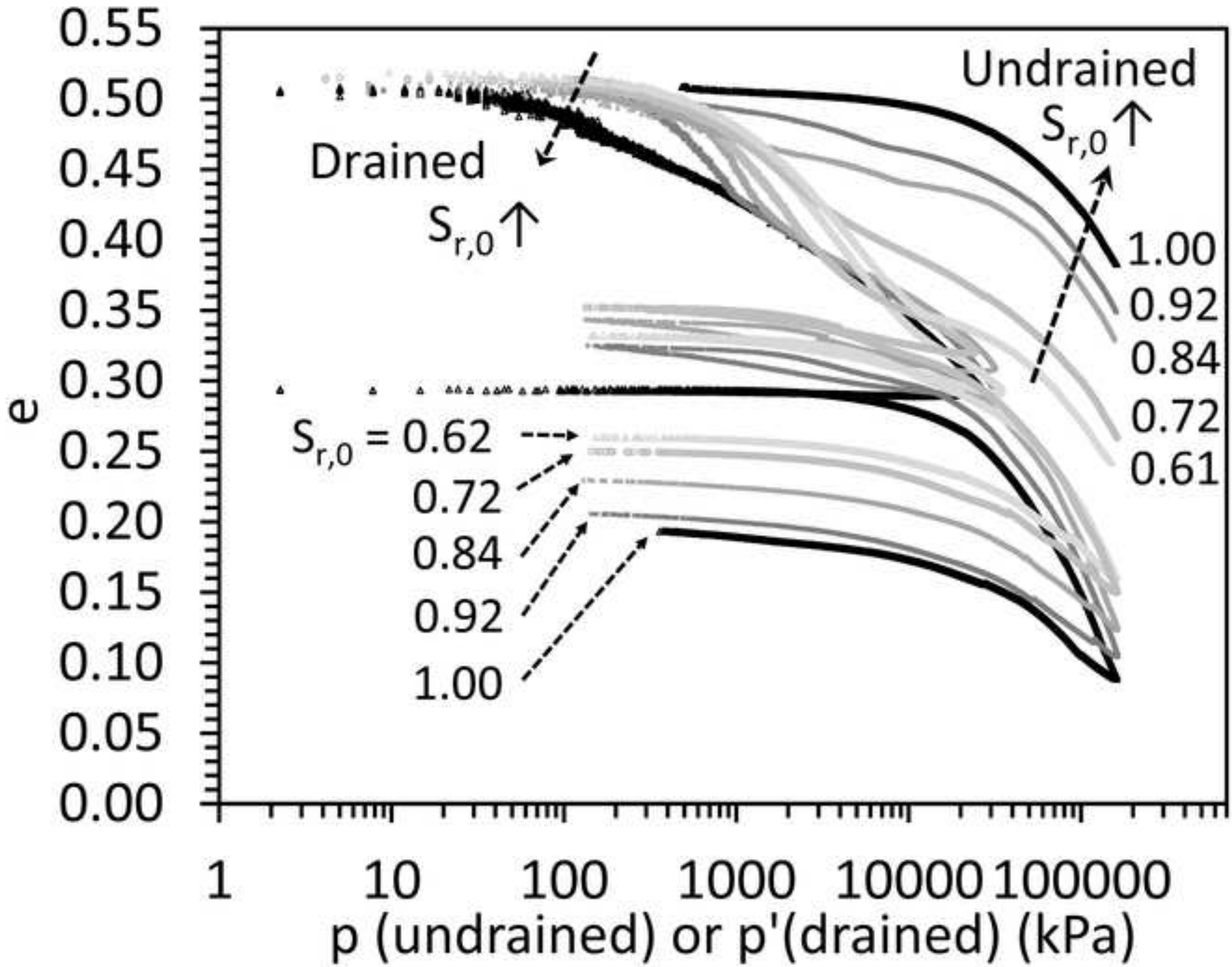

Figure 2

Click here to download Figure Figure 2.tif