ON FINDING A SUITABLE STATE INDEX FOR THE STUDY OF THE MECHANICAL BEHAVIOUR OF POST SUFFUSION SOILS

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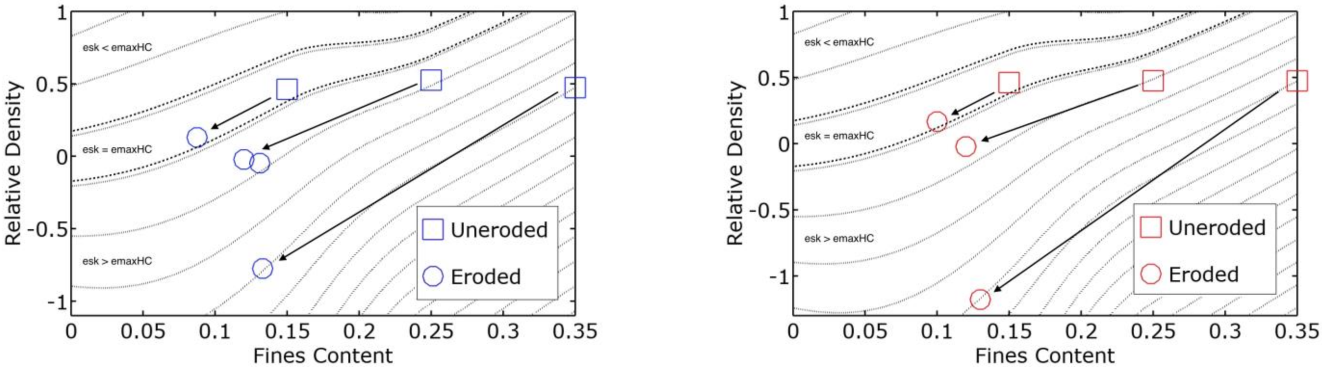
Introduction

There is a hypothetical relationship between suffusion and dam failure, for both internal and surface failure. So far, the effects of changing grading though suffusion has been numerically investigated using models have investigated using 2D DEM simulations. The results obtained from these numerical simulations need to be compared to experimental data. In order to conduct our own experimental investigation on post suffusion soils, a proper state index must be found can that relate the changes in fabric caused by erosion to the mechanical changes in the soil.

Granular Soils With Fines

The behaviour of soils containing fines has yet to be fully understood and depends on state parameters and the fabric of the sand as well as the drainage condition of the test (Ni et al, 2014). The state index most used for the study of such soils is the skeleton void ratio, defined as the void ratio of the coarse fraction where the fines are counted as voids, $e_{sk} = (e + fc)/(1 - fc)$ (Thevanayagam, 1998). Unlike the global void ratio, the shear strength is more or less independent of the fines content for a given type of fines (Salgado et al, 2009). However, there are still some concerns. For one, the skeleton void ratio does not take into account the plasticity of the fines (Salgado et al, 2009). Also the skeleton void ratio does not vary within well-defined boundaries like relative density (Salgado et al, 2009). Therefore, it may be advantageous to relate the skeleton void ratio to the relative density for the purpose of studying the mechanical behaviour of post suffusion soils, as shown in figures 1 (a) and (b).



(a) (b)

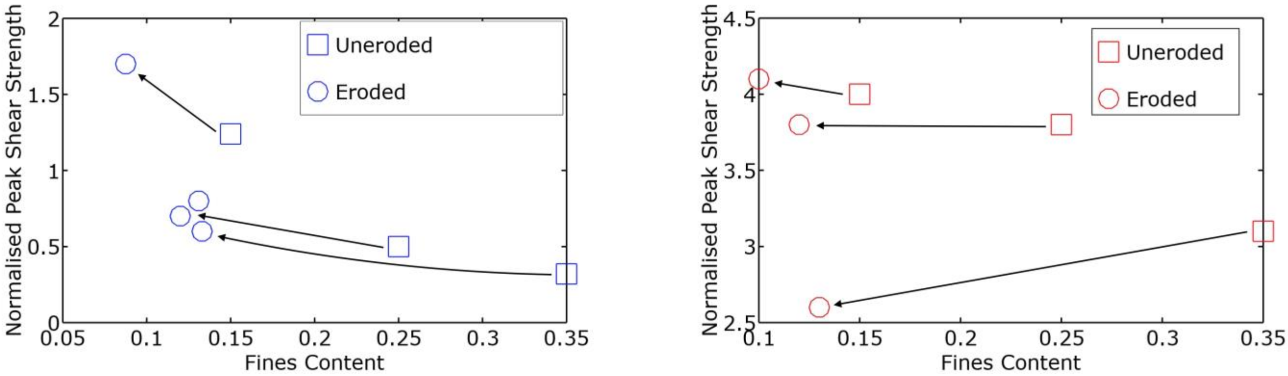
Figure 1: Erosion Paths for Undrained (a) and Drained (b) Triaxial Compression Tests

Skeleton Void Ratio

Ouyang and Takahashi (2016) investigated the undrained behaviour of silty sand subject to large degrees of erosion. Results of soil tests can be seen on figures 1 (a) and 2 (a). Similarly to studies performed by Thevanayagam (1998), uneroded soil strength decreases with the increase of fines content at constant void ratio. This is due to the fines separating the coarse grains, leading to a less stable supporting structure. Furthermore, we notice that eroded soils plot in the same band of skeleton void ratio as the uneroded soil except in the case of 35% fines, where the loss of fines is so great that the compressive volumetric strain is unable to compensate for the loss of fines. Also, we notice that whilst the eroded soils have similar fines content post erosion, they do not have the same peak strength (normalised with the confining stress). The soil having the lowest skeleton void ratio showed an increase in normalised peak strength of around 0.2, whereas the soil with the highest skeleton void ratio showed and increase of just under 0.1.

Ke & Takahashi (2014) investigated the drained behaviour of the same silty sand at similar values of relative density and fines content. Results of soil tests can be seen on figures 1 (b) and 2 (b). They found that for the uneroded soil the strength decreased with an increase in fines content, which contradicts other studies performed on drained silty sand (Carraro et al. 2009). Then, similarly to Ouyang and Takashi, the tested soils showed very little change in skeleton void ratio post erosion, except for the 35% case. Again, soils with similar fines content post erosion presented with different peak strengths. The soil with the lowest skeleton void ratio showed almost no change in normalised strength, and the soil with the largest skeleton void ratio showed the largest decrease (around 0.5).

It is possible that the post erosion behaviour of clast soils depends of the pre erosion stability of its coarse fabric. Soils with the most stable coarse structure (low skeleton void ratio) show the greatest potential for strength increase and are less likely to lose strength post erosion. Conversely, soils with a metastable structure (high skeleton void ratio) show the least potential for strength increase and the greatest potential for decrease in strength. This is because soil with a metastable structure may rely more heavily on fines as a source of lateral stability. This is shown by Ke et al. (2016), who found that at high confining stress the undrained peak strength of eroded soil with 35% initial fines content decreased compared with the uneroded soil. It is possible that the high confining pressure encumbered the rearrangement of the particles into a more stable structure and that the loss of fines removed the lateral support of the force chains. Thevanayagam (1998) found the same effect when investigating uneroded silty sands.

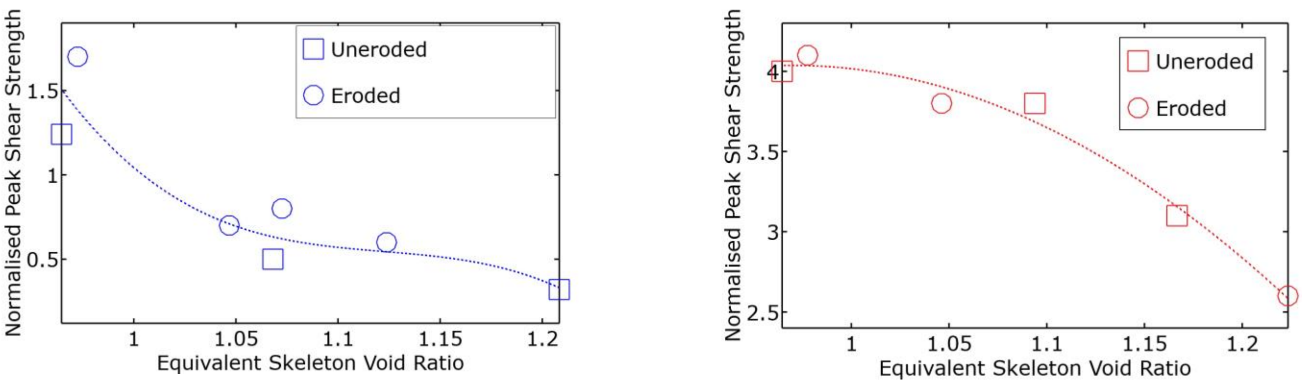


(a) (b)

Figure 2: Triaxial Compression Tests in Undrained (a) and Drained (b) condition

Equivalent Skeleton Void Ratio

When using the skeleton void ratio, we assume that all the fines are part of the voids. However, this condition is unrealistic. It is more likely that some of the fines are trapped as part of the force chains, between the coarser grains. In order to take into account the fines participating in the stress transfer through the soil, Thevanagayam (1998) used an equivalent skeleton void ratio $e_q = (e + (1-b)fc)/(1-(1-b)fc)$, where b represents the ratio of fines trapped in force chains over the total fines. Ni et al. (1994) has applied the equivalent skeleton void ratio on data from several investigations on clayey and silty sands and found that the behaviour of all soils collapsed unto one curve, and independently of fines content the strength of the soils correlated well. We have applied the equivalent void ratio to the data produced by Ke & Takahashi (2014) and Ouyang and Takahashi (2016) to see whether we could apply this to eroded soils. For the uneroded samples, we assumed that b would increase linearly from some fines content at which the skeleton void ratio is equal to the maximum void ratio of the coarse fraction, for some constant value of relative density. For the eroded soils, we have assumed that fines that are part of the force chains were not eroded. We searched over b values varying from 0 to 0.5 and found that the ideal b value for both undrained and drained was between 0.2 and 0.3, which is similar to the b value used by Thevanagayam for silty soils (1998). For this b value, the curves collapse and show a good correlation with the equivalent skeleton void ratio, for both eroded and uneroded soils.



(a) (b)

Figure 3: Normalised Peak Shear Strength vs Equivalent Void Ratio
for Undrained (a) and Drained (b) condition

Conclusion

Conflicting data exists regarding the behaviour of soils with fines and eroded soils with fines. However the skeleton void ratio remains the best index to work with. Combined with the relative density, it provides the best way to correlate fabric with changes in mechanical behaviour. We may distinguish three categories of stability based on the skeleton void ratio, which gives us some insight into the behaviour of eroded soil once sheared, given some hydro-mechanical state.

References

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