A NEW METHOD FOR THE SUFFUSION AND SUBESEQUENT SHEARING OF ERODED SOIL

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1. INTRODUCTION

Suffusion is one of the four categories of erosion along with piping erosion, contact erosion, and backward erosion; and consists of the removal of the finer fraction of the soil by the flow of water (Koelewijn & Bridle, 2017). The consequences of suffusion thus far are understood to be excessive settlement, possible slope failure and sinkhole events (Zhang et al., 2017). However suffusion is typically just one of many factors leading up to potential failure. In order to gain a more subtle understanding into its effects on the mechanical properties of soil, and by extension how it may participate to the failure of water retaining structures as one of many possible factors leading to failure, a method of producing and shearing eroded soil has been developed.

2. APPARATUS

Up to now, the testing procedure in suffusion research seeks to saturate and consolidate before eroding (Ke and Takahashi, 2014; Chang & Zhang, 2011). However this method requires a closed system in order to achieve high level of saturation for undrained testing. What is proposed in this paper is the possibility of using an open system and saturating and consolidating after erosion. The idea is based on studies on the effects of fabric as a result of different preparation methods: Vaid et al. (1999) conducted experiments on different methods of sample preparation and, despite saturating/consolidating post specimen preparation, the effects of fabric are still clearly distinguishable.

a. Triaxial Cell
The pedestal and top cap are 75mm in diameter, and are connected to thick pipes at the top and bottom of the triaxial cell. The pipe at the top of the triaxial cell is twisted into a spiral to limit the stiffness and effect on the load cell measurements. The pedestal and top cap have been fitted with 5mm holes to allow for erosion and evacuation of eroded particles. The pedestal and top cap are also fitted with a 1mm aperture mesh so that the coarse fabric is not eroded with the fines. Finally, a HCDPT is attached to the top and bottom pipes and repurposed to measure the hydraulic gradient of the flow.

b. Hydraulics
The triaxial cell is connected to two large tanks which each have a capacity of 13 litters. Each tank is connected to both the collection tank and the top of the triaxial cell. Therefore, the water can flow from one tank to the other and the flow of water can be reversed once the receiving tank is full, thereby allowing continuous erosion and a large degree of suffusion.

b. Fines Collection
The collection of fines is done as follows: pure water carries fines from the bottom of the specimen to the collection tank through a pipe connecting the top of the tank to the bottom of the specimen. The pipe extends to the middle of the tank to encourage the settlement of fines at the bottom of the tank, and is pierced along its length to progressively reduce the velocity of the flow and reduce mixing at the bottom. The amount of fines in the tank may be measured one of two ways: for fines larger than 0.075 the fines tend to settle at the bottom and their weight is measured using a load cell. The volume of the tank remains constant so the load cell is calibrated to account for the volume of water that is replaced by soil. Fines smaller than 0.075mm can be measured using a turbidity meter. The flow of water is intermittently stopped and a sample of the water from the settlement tank is taken from the bottom valve and tested.

3. TEST

a. Soil
Soil tested is manufactured using silica sand n1 as the coarse fraction and silica sand n6 as the fines fraction. Geometric information on these two sands are summarised in Table 1. When mixed these sands form an erodible gap graded soil, according to the internal instability criteria used.

Internal Stability Criterion	Internal Stability Formula	Soil Tested (25% fines)
Kenney & Lau (1985)	$(H/F)_{min} \geq 0.9$	Unstable
Kedzi (1979)	${D_{15}}/{d_{85}} \leq 4$	Unstable
Burenkova (1993)	$0.76 * log(h'') \leq h' \leq 1.86 * log(h'')$ $h' = {D_{90}}/{D_{60}} \quad h'' = {D_{90}}/{D_{15}}$	Unstable

Table 1. Characteristics of soil tested

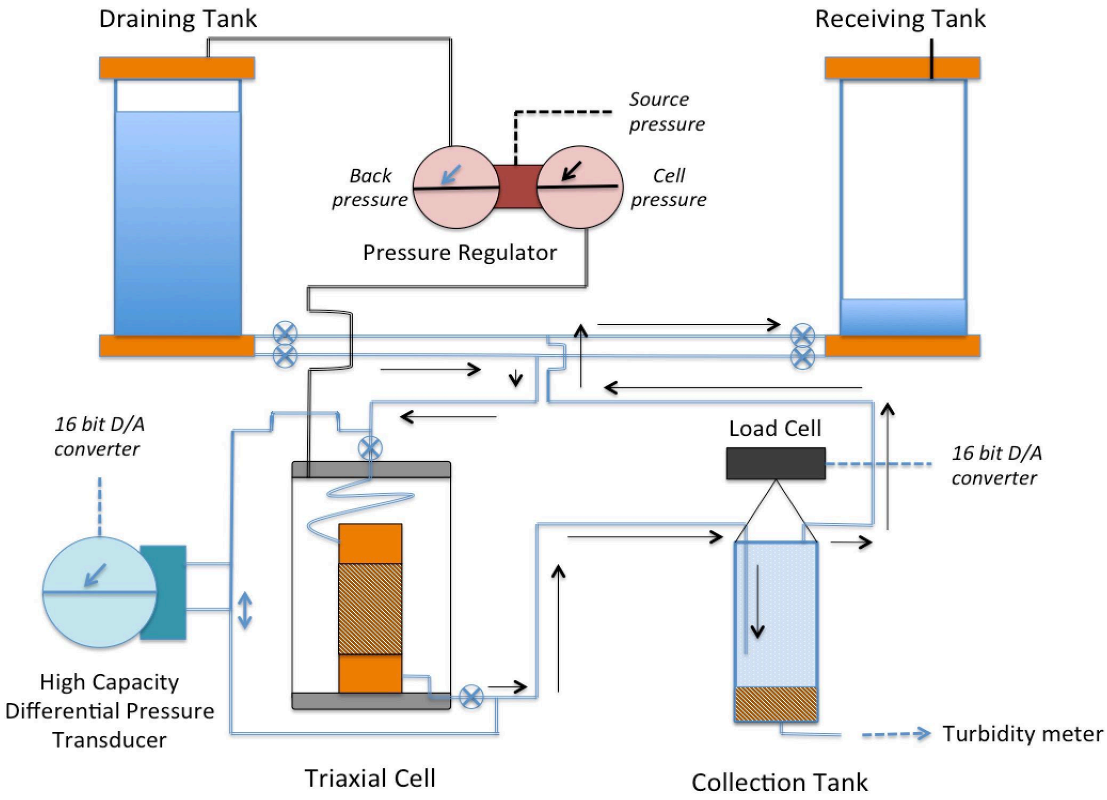

Figure 1. Schematic of testing apparatus

b. Procedure and result of erosion test

The specimen is prepared using the moist tamping method so as to avoid segregation of finer particles. The silica n1 is mixed with 25% silica n6 and compacted at e=0.76 and 10% water content. The specimen is held by 15kPa cell pressure. The specimen is then eroded using pure water. The maximum pressure applied to wither tank is 80kpa and the pressure is increased slowly so as to avoid hydraulic shocks to the system. As the pressure in the water tank is increased, the pressure in the triaxial cell is also increased to avoid liquefaction of the soil or ballooning of the membrane. Results of water usage and fines removed are compared with other suffusion research in Table 2.

Author	**Soil tested**	**System type**	**Volume of water used /time to end erosion**	**Degree of erosion**
Chang & Zhang	Leightin Buzzard Sand & CDG	Closed	Unknown/ 6.6 hours	50g
Ke & Takahashi	Silica n3 & Silica n8	Closed	62 litters/ 3.3 hours	200g
Bedja*	Silica n1 & silica n6	Open	39 litters/ 1 hour	90g

Table 2. Results of suffusion test

4. CONCLUSION

In this paper, a new system to conduct suffusion erosion test is discussed. The system is open to the atmosphere, and erosion is meant to occur before saturation and consolidation. Based on preliminary erosion test on gap-graded silica sand the system developed seems to be as efficient as other systems implemented previously, producing roughly similar rates of erosion.

REFERENCES

Chang, D.S., Zhang, L.M. (2011), A Stress-Controlled Erosion Apparatus for studying Internal Erosion in Soils, Geotechnical Testing Journal, 34(6), 579-589

Ke, L., Takahashi, A. (2014): Triaxial Erosion Test for Evaluation of Mechanical Consequences of Internal Erosion, *Geotechnical Testing Journal*, 37(2), 1-18

Koelewijn, A.R., Bridle, R. (2017): Internal erosion in dams and dykes: a comparison, *Proceedings of the 25th Meeting of the Working Group on Internal Erosion of Embankments and Dams and Their Foundations*, 1-11.

Vaid, Y. P., Sivathayalan, S., and Stedman, D. (1999), Influence of Specimen-Reconstituting Method on the Undrained Response of Sand, *Geotechnical Testing Journal*, GTJODJ, 22(3), 187-195

Zhang, L., Xu, Y., Chang, D. and Peng, M. (2017). *Dam failure mechanisms and risk assessment*. Hoboken, N.J.: Wiley.