SOIL EROSION ON THE MIX OF SAND-KAOLIN: THE INFLUENCE OF SOIL PARAMETERS AND HYDRAULIC PARAMETERS

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Abtract: *This work presents the influence of soil parameters on erosion parameters of sand-kaolin an the influence of hydraulic parameters on the result of erosion. The tests were carried out on the mix of sand-kaolin by using the Jet Erosion Test. It found that the erosion resistance increases with an increase of dry density, and the influence of compaction water content on erosion is negligible. For influence of hydraulic parameters, it found that the erosion parameters (erosion coefficient k_D and critical shear stress τ_c) deduced from theoretical head hydraulic and real head hydraulic are not similar, and the head hydraulic influence only the erosion coefficient but not critical shear stress.*

Keywords: Erosion parameter, erosion coefficient, critical shear stress, hydraulic parameter, soil parameters.

1. INTRODUCTION

The erosion phenomenon of the earthen construction such as dams, dykes, etc… present a major risk for these works, so it is necessary to understand, quantify and prevent. Erosion occurs when the effective shear stress (τ_e) depending the hydraulic parameters exceeds the critical shear stress (τ_c) of soil depending the soil parameters at the boundary of the soil. We can assess the erosion rate of cohesive soils with an assumption that the erosion rate is proportional to the effective shear stress and was expressed by the following equation (Hanson, 1990a, 1990b; Hanson and Cook, 1997):

$$\dot{\varepsilon} = k_D.(\tau_e - \tau_c)^a \qquad (1)$$

where $\dot{\varepsilon}$ is the erosion rate (cm/s), k_D is the erosion coefficient (cm^3/N-s), τ_e is the effective shear stress (Pa), τ_c is the critical shear stress (Pa), and, a is an empirical exponent commonly assumed to be unity (Ariathurai and Arulanandan, 1978; Hanson, 1990a, 1990b; Hanson and Cook, 2004; Al-Madhhachi et al., 2013; ; Nguyen, 2014; Nguyen et al, 2014).

In the past, a numerous works study the influence of soil parameters on erosion of soil, but there was not work studying the influence of hydraulic parameters on erosion of soil. The aim of this work is to study the influence of soil parameters like case study, and to study influence of hydraulic parameters on the mix of sand-kaolin.

2. SOIL CHARACTERIZATION AND EXPERIMENTAL APPARATUS

2.1. Soil characterization

Kaolin P300 is an industrial clay containing about 95% of pure kaolin also known under the name of yellow clay, some identification parameters are given in Table 1 and, the Hostun RF sand is a quartz sand whose characteristics are shown in Table 1 as follows:

Table 1: Characterisation of Kaolin P300 and Hostun RF sand

Index / Material	Dmax (µm)	D60 (µm)	D10 (µm)	< 80 (µm %)	wL (%)	wP (%)	γs/γw	wOPN (%)	γdOPN (kN/m^3)
Kaolin	20	2	0.05	100	40	20	2.65	24	15,7
Hostun RF Sand	800	350	10	10	-	-		4-16	≈16

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2.2. Experimental apparatus

In this work, we used the Jet Erosion Test, which was described in the work of Nguyen (Nguyen, 2014; Nguyen et al., 2014).

The Proctor mold with the sample is placed in a reservoir under the jet, The sample is submerged in the downstream reservoir (h_2 = 10 ÷ 15 cm), and the jet is centrally located above the sample. The distance between the jet orifice (nozzle) and the initial surface of the sample is h_3 = 5 ÷ 10 cm. Then the jet is centerd with respect to the sample and supply water to the system from the upstream reservoir with a real hydraulic head h_1 = 106 ÷ 190 cm corresponding theoretical hydraulic head h_1^* = 130 ÷ 250 cm which was suitable to this tested soil. Schema representing h_1, h_2 and h_3 is presented on Figure .

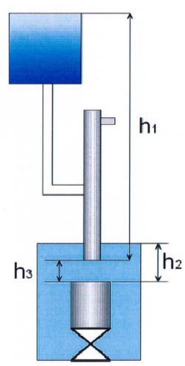
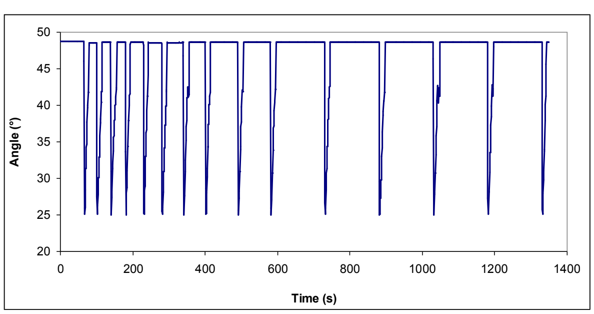


Figure 1: Schematic representation of h_1, h_2, h_3

Whenever operate the system we measure the scour depths at given times and the acquisition center automatically records the measured data (Figure). The chosen times were: 5 s, 10 s, 20 s, 30 s, 50 s, 70 s, 100 s, 130 s, 190 s, 250 s, 370 s, 490 s, 610s , 730 s, 850 s.



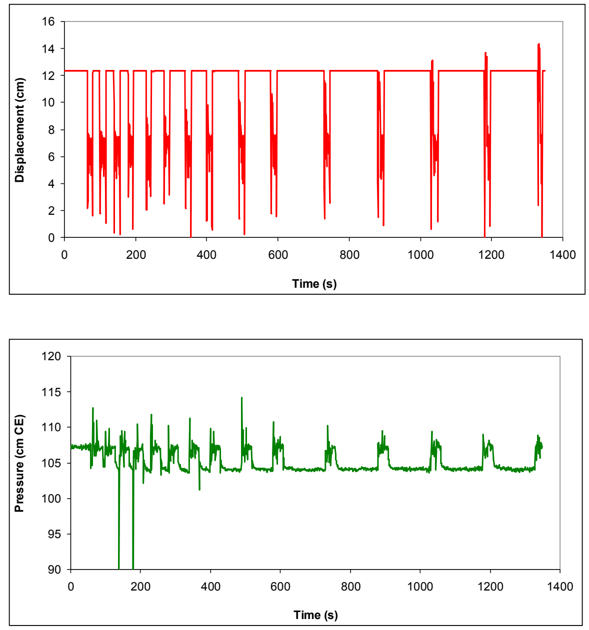


Figure 2: Example of recorded raw data

Base on the recorded raw data we treated the data, and found an evolution of scour depth with time of jet (Figure 3) and calculate the mean pressure of jet on the sample.

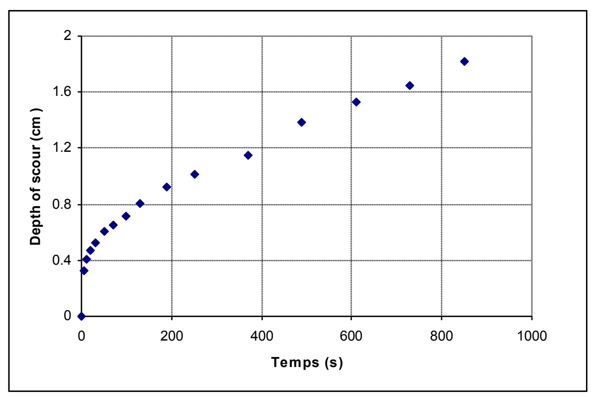


Figure 3: Example of evolution of scour depth with time of jet

3. RESULTS AND DISCUSSION

Base on the evolution of scour depth (Figure), we used a method proposed by Nguyen (Nguyen, 2014; Nguyen et al., 2014) to estimate the erosion parameters.

3.1. Influence of the dry density

We performed a series of JETs on mix of

sand-kaolin using the Jet Erosion Test to study influence of dry density and compaction water content (w ≈ 11.5%) on soil erosion. In Figure and Figure show the influence of dry density on erosion parameters (k_D and τ_c), in this case the compaction water content was constant, it found that the erosion coefficient (k_D) decreases in power function and the critical shear stress (τ_c) increases in power function with an increase of dry density. It means that the erosion resistance of soil increases with an increase of dry density, this increase of erosion resistance is logical because density increases, the void ratio decreases which leads to the increase in suction (Fleureau et al., 2011; Taibi, 1994; Taibi et al., 2011) and soil strength. These results confirm those of previous researchers (Hénensal and Duchatel, 1990; Lim, 2006; Mostafa et al., 2008; Robinson and Hanson, 2001; Robinson et al., 2002; Benahmed and Bonelli, 2012).

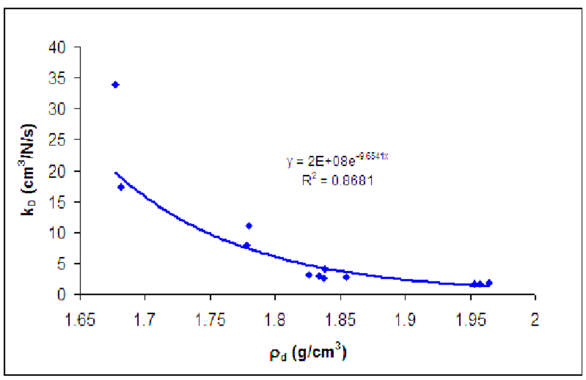


Figure 4: Relationship between erosion coefficient, k_D, and dry density, ρ_d

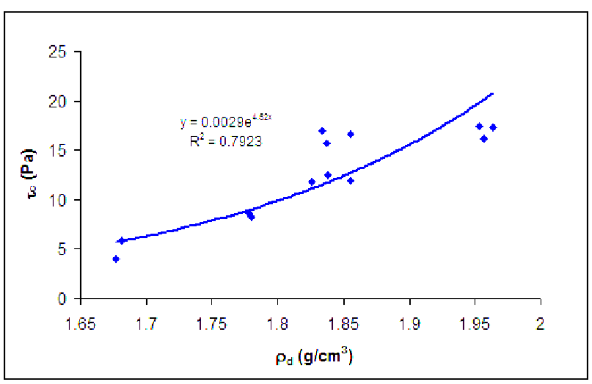


Figure 5: Relationship between critical shear stress τ_c and dry density ρ_d

3.2. Influence of gravimetric compaction water content

In order to study the influence of compaction water content, a series of JETs were carried out with constant of dry density the results were presented in Figure and Figure. For the mix of sand-kaolin, it found that at optimal condition of dry density of mix ($\rho_d \approx 1.85 g/cm^3$) the erosion coefficient and critical shear stress are quasi constant with an increase of compaction water content. In this case, we can conclude that the role of compaction water content is negligible.

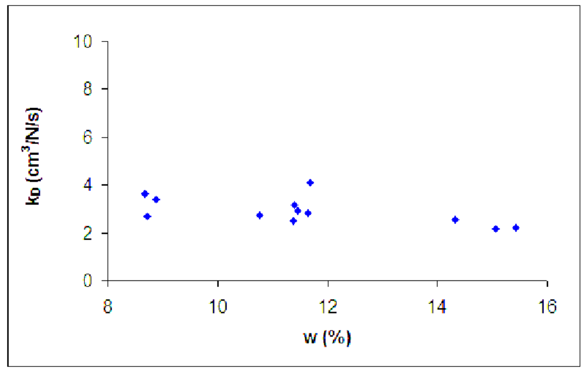


Figure 6: Relationship between erosion coefficient (k_D) and water content (w)

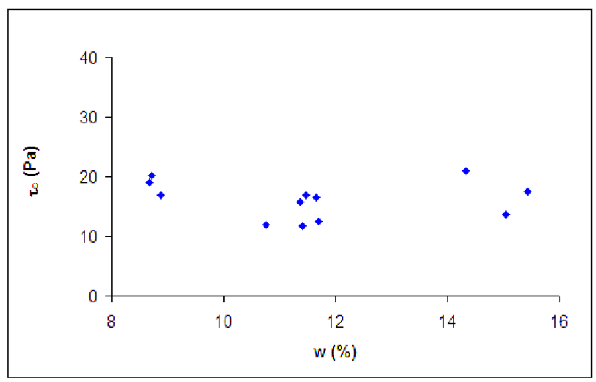


Figure 7: Relationship between critical shear stress (τ_c) and water content (w)

3.3. Influence of hydraulic parameters

The aim of this section is to study the influence of type of head hydraulic on the estimation of erosion parameters, also study the influence of head hydraulic. Figure and Figure show the erosion parameters deduced from theoretical head hydraulic and real head hydraulic. In this case, the theoretical head hydraulic was recored by pressure sensor, and the real head hydraulic was derived from equation (2):

$$h_{1\_real} = \frac{V_o^2}{2g} \qquad (2)$$

Where V_0 which was measured is the flow of water through the nozzle.

In Figure and Figure , it found that the erosion coefficient increases and the critical shear stress decrease if we use the real head hydraulic to derive these parameters. It mean that it is safe to predict soil erosion if we use the real head hydraulic.

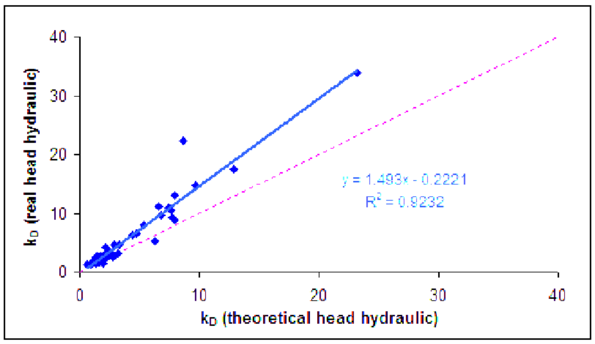


Figure 8: Erosion coefficient deduced from theoretical head hydraulic and real head hydraulic

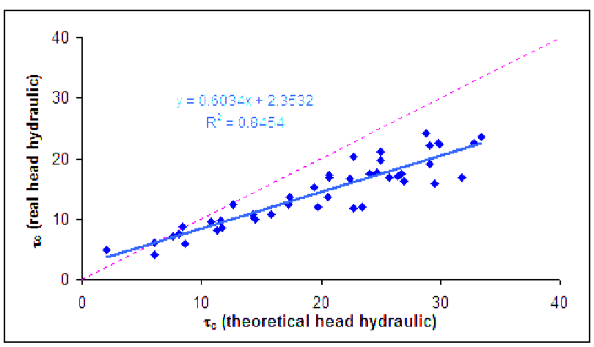


Figure 9: Critical shear stress deduced from theoretical head hydraulic and real head hydraulic

To study the influence of variation of head hydraulic, we have applied three levels of head hydraulic: 106cm, 130cm and 190cm, the figure from Figure to Figure present the influence of head hydraulic on erosion of soil. It found that the erosion coefficient and equilibrium scour depth increase with an increase of head hydraulic but the critical shear stress is quasi constant with the change of head hydraulic. It means that the erosion resistance of soil does not depend on head hydraulic, it depend on soil parameters. The variation of head hydraulic leads to change of erosion rate (erosion speed) because this variation leads to vary of the effective shear stress on boundary of soil surface (Briaud et al., 2001).

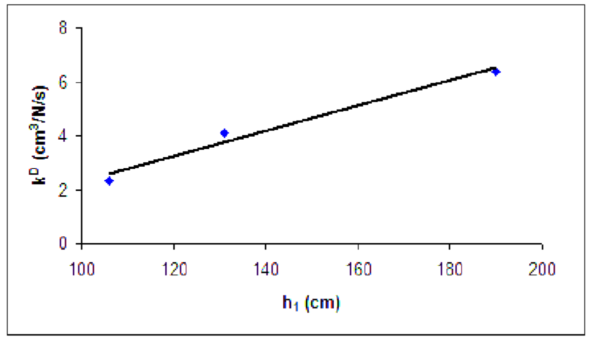


Figure 10: Relationship between the erosion coefficient, k_D, and real head hydraulic, h_1

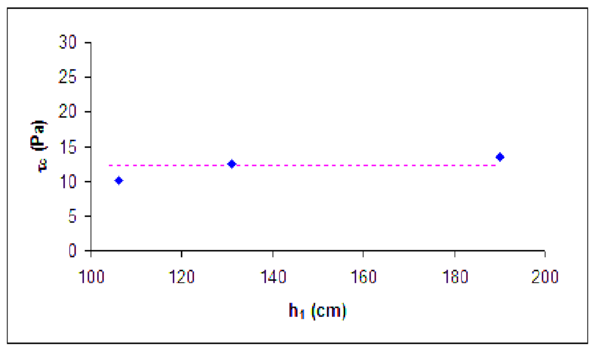


Figure 11: Relationship between the critical shear stress, τ_c, and real head hydraulic, h_1

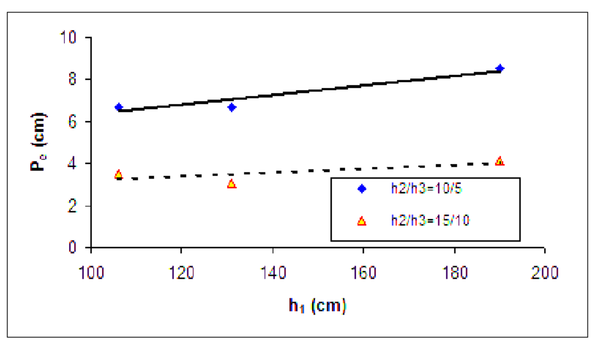


Figure 12: Relationship between the equilibrium scour depth, P_e, and real head hydraulic, h_1

4. CONCLUSION

This work presents the result of laboratory tests using a Jet Erosion Test device with an impinged jet. These tests highlight the influence of the dry density on the erosion coefficient, the critical shear stress. On the other hand, the influence of the water content on the erosion parameters appears negligible. The erosion resistance of soil does not depend on the head hydraulic but on soil parameters. It is better to use the real head hydraulic to predict the erosion parameters.

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Tóm tắt:

XÓI MÒN CỦA ĐẤT HỖN HỢP CÁT-ĐẤT SÉT KAOLIN: ẢNH HƯỞNG CỦA CÁC THÔNG SỐ CỦA ĐẤT VÀ THÔNG SỐ THỦY LỰC

Bài báo giới thiệu ảnh hưởng của các thông số của đất và thong số thủy lực đến các thông số xói mòn của đất hỗn hợp cát-đất sét Kaolin. Thiết bị Jet Erosion Test được sử dụng để tiến hành các thí nghiệm trên đất cat-sét. Kết quả chỉ ra rằng, độ bền chống xói của đất tăng khi dung trọng khô tăng nhưng gần như không thay đổi khi độ ẩm đầm nén thay đổi. Đối với các thông số thủy lực, kết quả cho thấy các thông số xói sẽ thay đổi nếu sử dụng cột nước ly thuyết và cột nước thực để dự đoán các thông số này. Cột nước tác dụng không ảnh hưởng đến độ bền kháng xói của đất mà chỉ ảnh hưởng đến tốc độ xói của đất.

Từ khóa: Thông số xói, hệ số xói, ứng suất giới hạn chống xói, thông số thủy lực, thông số của đất.

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