APPLICATION OF DRIP TEST FOR STUDY THE EROSION OF EARTHEN WALL BY RAINFALL – CASE OF LE HAVRE AREA, FRANCE

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Abstract: *This paper presents the influence of the properties of soil of earthen wall of constructions on its durability to erosion by rainfall. An improvement Drip Test was used to simulate the affects of rainfall on the erosion resistance of earthen wall. For the soil without binder, it found that, soil erosion decreases in power with an increase of dry density and an increasing linear relation between soil erosion with compaction water content was established. A correlation between soil erosion with liquid limit and percentage of clay was found, it showed that erosion depth achieves a minimal value at certain value of liquid limit as well as percentage of clay, it mean soil erosion was a quadratic function of liquid limit and percentage of clay*

Keywords: Drip Test, erosion resistance, soil erosion, dry density, compaction water content, liquid limit, percentage of clay

1. INTRODUCTION

In its life the earth constructions and the soil in the field are always subjected by natural condition, so are influenced by rainfall over time. The durability of earthen constructions is depended not only on its properties but also on weather. The durability of earth building materials was defined as resistance to weathering over time (Heathcote, 2002). During its life numerous factors that affect sustainability, such as: the loss of strength due to a significant increase of moisture in the wall (rising damp, infiltration of water during the rainy season and floods). The surface erosion is due to rain or rain splashes, it occurs on the surface of walls and on the foot of the walls. Rain and raindrop play an important role if the intensity of the rain is over 25mm/min (Ogunye and Boussabaine, 2002).

When a drop of water caused by rainfall or leak of water coming and touching the wall surface by the wind or the soil on the foot of the walls, it beats the wall surface with its kinetic energy.

Among the factors affecting the erosion resistance of earth wall, the properties of materials play a role very important such as soil composition, dry density, compaction water content, cement content, percentage of clay, etc. It found that the durability of earth wall increase with an increase of clay percentage (Reddy and Jagadish, 1987), with dry density of material (Cytryn, 1956); Jagadish and Reddy, 1984; Tannous, 1995), with cement percentage (Abrams, 1959; Ngowi, 1997; Walker, 1995). For earthen constructions as, dam, dyke, etc the influence of liquid limit and percentage of clay were well study but this study did not performed on earthen wall, that why in this work we studied complementarily influence of these parameters on erosion of earthen wall.

To study the influence of some properties of soil on erosion, we used an improvement Drip Test (Nguyen and Taibi, 2015), which is adequate to study the durability of earthen construction in Le Havre area in France where the rainfall is about 760mm because of its simple.

2. MATERIALS

In this work, we used six different materials to characterize surface erosion such as CémaTerre, Toprak, Silt, Marl, Limon GO and Kaolin P300. Their properties and their behavior are exposed following:

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CémaTerre and Toprak are materials consisting of a soil Limon GO with binder (cement and lime), the samples were dried in a natural environment. The composition of CémaTerre and Toprak are 7.5% of cement, 2.5% of lime and the initiation water content is 22%.

Silt: $w_L = 30\%$; $w_o = 16\%$; $\rho_{dmax} = 1.84$ g/cm^3

Marl: $w_L = 80\%$; $w_o = 27.5\%$; $\rho_{dmax} = 1.5$g/cm^3

The granulometry of Silt and Marl are presented in Figure 1

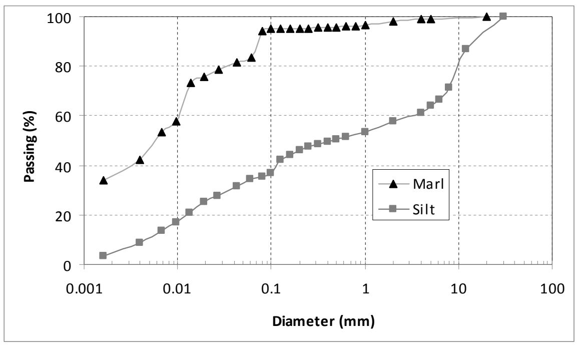

Figure 1. The particle size distribution of the Marl and the Silt

Limon G.O: $w_L = 22\%$; $w_o = 11.5\%$; $\rho_{dmax} = 1.8$ g/cm^3. The granulometry of this material gives: 0% of clay (<2 μm), 25% of silt (2 μm to 60 μm), 67% of sand (0.06mm to 2mm), 8% of gravel (>2mm).

Kaolin P300: $w_L = 40\%$; $w_o = 24\%$; $\rho_{dmax} = 1.6$ g/cm^3. Kaolin P300 is an industrial clay containing about 95% of pure kaolin also known under the name of yellow clay, it consist of 100% grain less than 80 μm.

Where: w_L presents the liquid limit (%), w_o and ρ_{dmax} present the compaction water content and dry density at optimal condition corresponding 25 stroke per layer by a standard Proctor rammer.

3. EXPERIMENT DESCRIPTION

This device consists of one steel support, one bottle, one small tap connecting with the cap of a big bottle as an upstream reservoir (Figure 2a), one flexible plastic tube for under-pressure control (Figure 2a, b), one adjustable support (Figure 2c) and one plastic funnel (Figure 2a). The number of drop is about 14 drops/min, the diameter of a water drop is 6mm approximately, 100ml of water is allowed to flow the end and the test time is 60min. The water drops fall from a distance of 40cm, the surface of the sample was inclined 30^o relative to the horizontal surface. The detail of this device was presented in the work of Nguyen (Nguyen and Taibi, 2015).


(a)


(b)

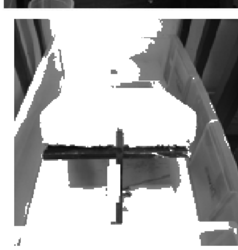
(c)

Figure 2. Set up the device "Drip Test"

4. RESULTS AND DISCUSSION

For the test on the Marl (M1 test), the sample was prepared at 1.5g/cm^3 of bulk density and 25.7% of compaction water content (in the optimal state of compaction), then this sample was tested after be dried in natural environment for at least a month. In this test, the evolution of the erosion depth was measured manually by a specific meter, every 10 minutes we derived drops by a funnel to measure the erosion depth.

For the other tests on the Marl (M2 and M3), and silt (S1, S2, S3), and the GO Limon (L1 to L10), and Kaolin (K), the samples were tested after compaction at optimum condition and the results and the erosion classification are presented in the Table 1.

Table 1. Results of improvement Drip Test (time of test about 60min)

Soil	Sample	w (%)	ρ_d (g/cm^3)	Erosion depth (mm)	e	S_r (%)	Erodibility index (1*)	Classification
Marl	M1	27.5	1.5	9.5	0.77	95.05	3	Erodable
	M2	29.48	1.46	6.54	0.82	95.85	3	Erodable
	M3	26.91	1.49	4.23	0.78	91.60	2	Slightly Erodable
Silt	S1	16.96	1.82	6.9	0.46	98.55	3	Erodable
	S2	16.04	1.83	8.94	0.45	94.86	3	Erodable
Limon G.O	L1	11.85	1.68	14.71	0.58	54.27	4	Very Erodable
	L2	11.93	1.68	21.05	0.58	54.86	5	Extremely Erodable
	L3	11.96	1.79	14.08	0.48	66.09	4	Very Erodable
	L4	11.54	1.77	11.58	0.50	61.80	4	Very Erodable
	L5	11.11	1.60	16.51	0.66	44.56	5	Extremely Erodable
	L6	10.30	1.70	18.70	0.56	48.73	5	Extremely Erodable
	L7	12.71	1.69	20.39	0.57	59.57	5	Extremely Erodable
	L8	11.63	1.59	19.85	0.66	46.55	5	Extremely Erodable
	L9	9.11	1.67	14.21	0.59	41.17	4	Very Erodable
	L10	14.15	1.69	21.68	0.57	66.09	5	Extremely Erodable
Kaolin P300	K1	24.19	1.56	4.36	0.70	91.76	2	Slightly Erodible

Note: w (%) – compaction water content, ρ_d (g/cm^3) – dry density, e – void ratio, S_r (%) – degree of saturation. 1* - classified according to standard NZS 4298 (1998) and SAZS 724 (2012).

4.1. Influence of dry density

In attempting to compare the influence of dry density (1.56, 1.68 and 1.77 g/cm^3), we conducted tests on the same material, Limon GO. The results in Figure 3 to Figure 4 shows a decrease in power of the erosion rate with an increase in the dry density if the soil has constant compaction water content ($w_o \approx$ 12.5%), the erosion depth at 60 min of test decreases with an increase of dry density. This decrease of erosion rate was caused by increase of bond forces between the particles and by increase of critical shear stress (Nguyen et al., 2014).

The evolution of erosion depth, and erosion rate are more clear after 500s of test whatever dry density (Figure 3). it found a bizarre result under 500s of test , the higher density soil (1.77 g/cm^3) is more eroded than the lower density soil (1.59 and 1.68 g/cm^3), the evolution of erosion depth is similar for two lower dry density (1.59 and 1.68 g/cm^3). It is difficult to explain this result, we suppose that in this case the state of surface which play a role.

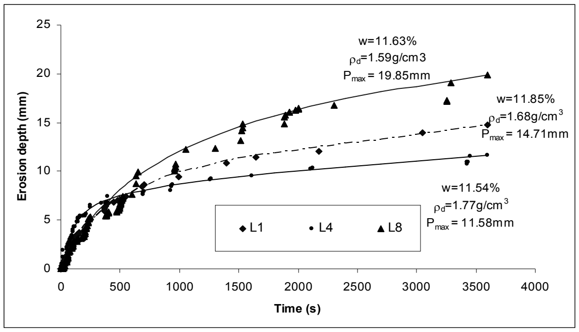

Figure 3. Evolution of erosion curve of tests on the Limon GO at different dry density

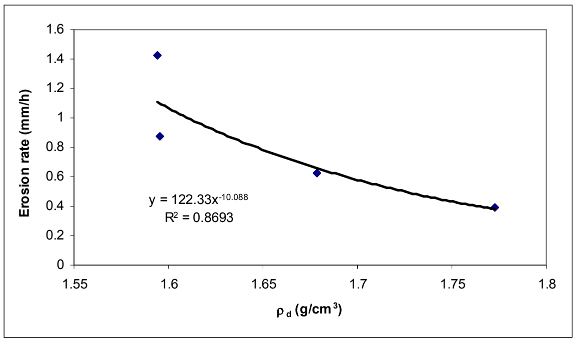

Figure 4. Relationship between erosion rate (mm/h) with dry density on the Limon GO (Erosion rate is the mean erosion depth after 60 hours of test)

4.2. Influence of initial water content

The dry density was controlled in constant ($\rho_d \approx 1.7$ g/cm^3) and the initial water content was varied meaning the compaction water content (10.3, 11.85 and 12.71%), the results in Figure 6 show that the depth erosion increases slightly with increasing initial water content. This result can be explained by the decrease of suction caused by increase of water content (Fleureau et al., 2011; Taibi, 1994; Taibi et al., 2011) and by the decrease of critical shear stress (Nguyen et al., 2014).

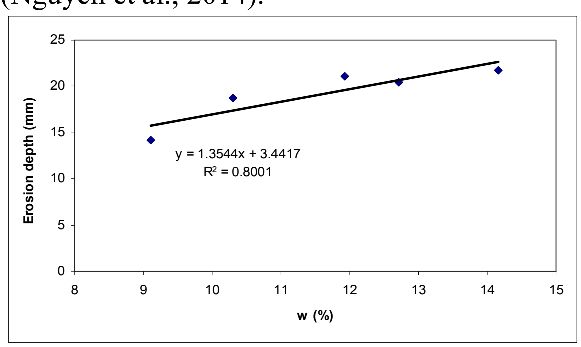

Figure 5. Influence of water content on the erosion depth of Limon GO (erosion depths were measured after 60min of test)

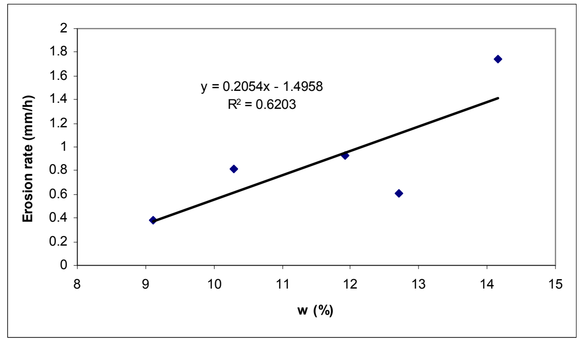

Figure 6. Relationship between erosion rate with water content on the Limon GO (Erosion rate is the mean erosion depth after 60 hours of test)

4.3. Influence of liquid limit

Base of tests conducted on four erodible materials: Marl, Silt, Limon GO and Kaolin P300, we were attempting to establish an empirical relationship between the erosion depth at the end of the tests and the liquid limit representing many properties soils (Figure 7). This shows a good correlation between two parameters in form of a quadratic equation, the correlation coefficient R^2 is about 0.96, and at a liquid limit of 60%, the erosion depth reaches a minimum value. But the restriction here is the limit of data (different soils), this correlation will be well confirmed if we use much more tested materials.

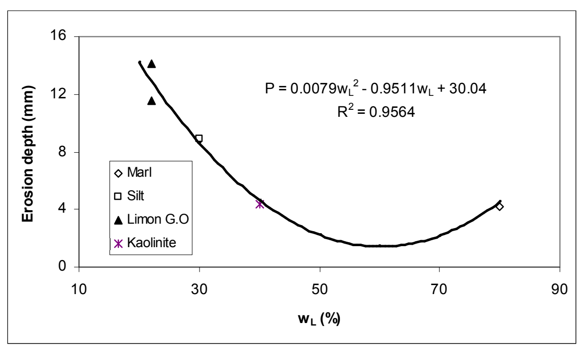

Figure 7. Correlation between the liquid limit (w_L, %) and the erosion depth erosion (P, mm).

4.4. Influence of clay percentage

Comparing the influence of the percentage of clay, we conducted tests on four different materials. The results in Figure 8 shows that the erosion depth is quadratic function of the percentage of clay. The minimum depth of erosion reaches at about 65÷70 % of clay.

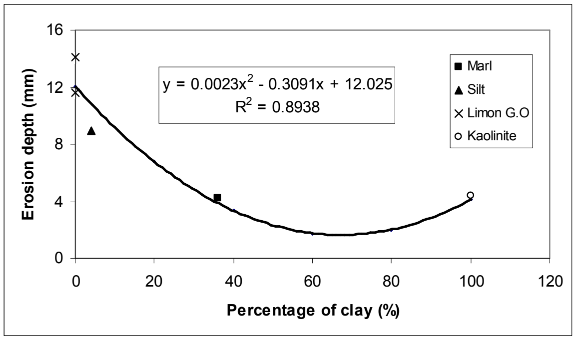

Figure 8. Correlation between the percentage of clay (%) and erosion depth (P, mm)

In the section 4.3 and 4.4 we found that the Kaolin P300 possess 100% of clay but its liquid limit (40) is less than liquid limit of Marl (80) that possess 40% of clay. So it exists a controversial question concerning the influence of liquid limit and clay percentage. We suppose that it miss some data of material which process the liquid limit from 40 to 80, and which process the percentage of clay from 35% to 100%. Or, between 35% and 100% of clay percentage, the percentage of clay does not play an important role on erosion of material, and durability resistance to erosion depend not only on percentage of clay but also on granulometry of material.

5. CONCLUSION

It found a significant influence of the dry density of mud soil, but not clearly influence of the initial water content on durability of soil: the erosion depth and erosion rate decrease with an increase of dry density and increase with an increase of initial water content.

The limit liquid and clay percentage influence significantly the erosion depth and erosion rate of soil. Two correlations were established between the liquid limit, percentage of clay and erosion depth. But these correlations need be verified by the soil possessing process the liquid limit from 40 to 80, and processing the percentage of clay from 35% to 100%.

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Tóm tắt

ỨNG DỤNG THIẾT BỊ DRIP TEST ĐỂ NGHIÊN CỨU XÓI CỦA TƯỜNG ĐẤT DO MƯA-TRƯỜNG HỢP VÙNG LE HAVRE, PHÁP

Bài báo giới thiệu ảnh hưởng của các đặc tính của đất làm tường đất của công trình đến độ bền chống xói do mưa. Thiết bị Drip Test (thiết bị Chảy nhỏ giọt) cải tiến được sử dụng để mô phỏng tác động của mưa đến độ bền chống xói của tường đất. Đối với đất không dung chất kết dính, kết quả cho thấy độ xói của đất giảm theo hàm số mũ với độ tăng của dung trọng khô và tăng tuyến tính với độ tăng của độ ẩm đầm nén. Một tương quan bậc hai giữa độ bền chống xói của đất với giới hạn chảy, phần trăm hàm lượng sét được tìm thấy

Từ khóa: Drip Test, độ bền chống xói, xói mòn đất, dung trọng khô, độ ẩm đầm nén, giới hạn chảy, hàm lượng sét.

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