INFLUENCE OF THE GEOMETRICAL SHAPE OF AGRICULTURAL FURROW (GROOVES) ON THE SEDIMENT TRANSPORT

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SUMMARY

In this experimental work, it is shown that the geometric shape of the farming grooves could play an important role in sediment dynamics. From these results, it appears that, for slopes less than 40%, the grooves with a sinus shape export the least sediment mass. For steeper slopes, agricultural furrows in a circle lead to the minimum of sediment transport. The rheological behaviour of the solid discharge depends also strongly on the geometry of the grooves.

KEY WORDS: Furrow, geometrical shape, erosion, sediment transport, experimental.

INTRODUCTION

The erosion of agricultural soils, following surface irrigation, is a serious problem because it leads to a decrease in soil fertility, loss of productivity and, consequently, to lower revenues ([1], [2], [4], [5] and [21]). The Algerian mountains form a vast region of over 8,719,000 hectares, 3,450,000 hectares of agricultural area. In Algeria, the areas threatened by the harmful effects of runoff cover nearly 12 million hectares, of which over half is on the slopes most susceptible to erosion [1]. Each year, more than 120 million tons of soil is pulled by the erosion of mountain slopes. This large amount of soil lost is essentially the result of excessive and inefficient use of agricultural land and poor farming practices ([1], [12] and [24]). Surface irrigation furrow is a technique widely used in Algeria in view of its simplicity and economy. This technique is suitable for many crops: vineyards, orchards and trees ([4], [5] and [32]). According to the Algerian Ministry of Agriculture, the use of furrows on slopes greater than 12% is quite common. The theory of irrigation furrows advocates the use of land on which the maximum slope is 0.5% to 1% ([4] and [32]). The agricultural furrows and can have various geometrical forms: triangular, trapezoidal, rectangular or parabolic with varying widths 15cm and 75cm and between the depths of going 10cm with 20cm ([4] and [32]). With the opposition to their simplicity and effectiveness, the furrows can easily become the seat of serious problems of erosion as soon as the slope Exceeds 1% ([4], [5] and [32]). The literature gives six factors responsible for this erosion: slope, size, and flow, time of watering, vegetation and length [2], [30], and [31]. It is necessary to add the probable effects of the explosion of the air stored in the layers of the soil and the effect of the electric double layer [13]. In the forties and fifties of last century, work of E. W. Lane was centered on the research of the best geometrical profile being able to be stable ([8] and [22]). Let us note that work of E. W. Lane was directed towards the large irrigation canals, but V. T. Chow [11], in "Open Channel Hydraulics" that points out the boundary shear stress distribution is independent of the size of the cross section of the channel. So, it is logical to think that there can be influence of the form of the cross section of the furrows on solid transport.

1. GENERAL CHARACTERISTICS

The soil which was used for our experimental investigation was taken on the first 30 centimeters of an Algerian agricultural soil of the plain of Abadla (Figure 1)

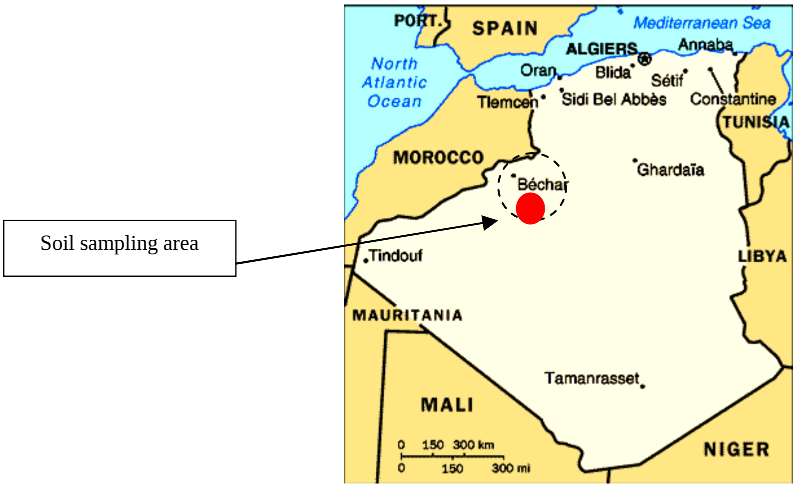


Figure 1: Location of the sampling zone of the soil

After soil sampling, testing granulometric, physical-chemical and mechanical properties were performed in the laboratory. The results are given in the table below (Table 1).

Table 1: Characteristics of soil

A	L F	L G	S F	S M	S G	D50	WL	WP	IP	Ac	pH (soil)	K
19%	10%	6%	47%	7%	11%	0,090 mm	39,12%	16,54%	22,58%	1,2	8,20	27 mm/h
Po	n	D_r	D_{Ap}	$[Co3^-]$	$[Cl^-]$	$[So4^{2-}]$	CC	[SiO2+CaO+MgO+Al2O3+Fe2O3]				
0,47	0,88	2,969	1,410	17,8%	1,34%	Traces	22%	80,86%				

Reading the table includes information on soil which is a fine sandy loam [14]. From a mechanical standpoint, the soil is clay-like inorganic low to medium plasticity. Of the value of the activity index (Ac), one can conclude that the clay in the soil type is kaolinite with low swelling capacity.

2. EXPERIMENTAL MODEL

All tests were performed on an experimental model (Figure 2) made entirely of galvanized steel sheet 3 mm thick. The model has the form of a rectangular channel length, width and depth respectively of 2000 mm x 150 mm x 120 mm. Holes, 3mm in diameter, were provided on both sides and the bottom of the model to ensure a free flow underground. The downstream portion is provided with a system for the rotation of the model. The upstream part, provided with a manual hydraulic cylinder, allows lifting of the model. Inside it, a system, honeycomb, is arranged to calm the flow of water and make them uniform before entering inside the model. For the collection of volumes of clean water and mixture, containers were placed on the floor.

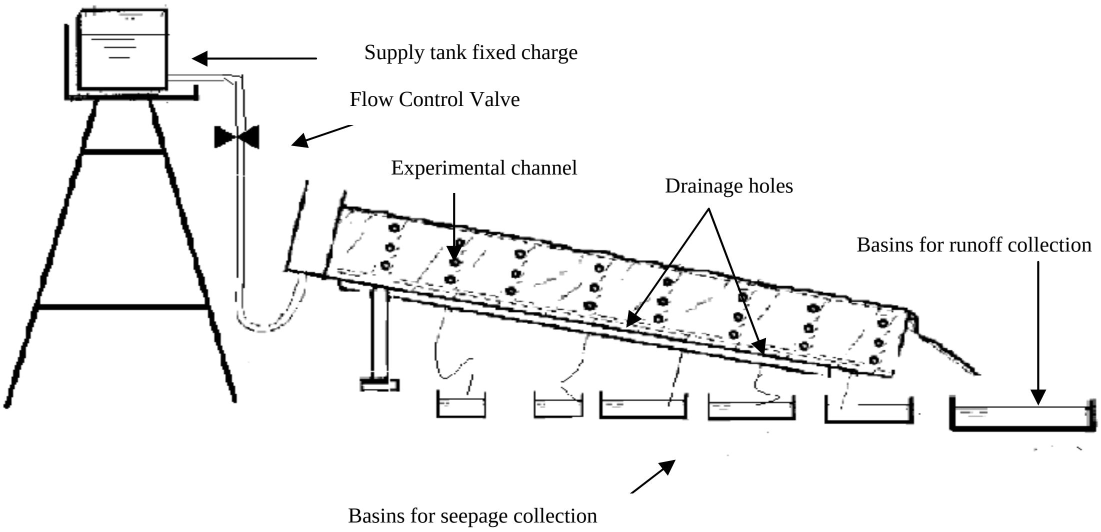


Figure 2: General diagram of the experimental model

3. SOIL PREPARATION

Before placing the soil, naturally ventilated, dry in style, sieved through meshes of 3mm x 4mm. Is then added amount of water that achieves the desired percentage of moisture and the whole is mixed to ensure a good homogenization. Following this, we passed a second time the wet mixture through the same sieve. The interior of the experimental model is then covered with a sponge sheet 5 mm thick to act as a drain filter. Seepage from the sides or bottom of the model is collected in bins spaced 30cm, which will make the measurement and monitoring of the infiltration rate. Before starting the phase of the development of soil, it is useful that the model is horizontal. The soil is deposited inside the model in layers of 5 cm thick. After gently leveled with a wooden spatula, soil compaction is subjected to free fall from a height of 30 cm, weighing 15 kg on a flat sheet steel of 65 cm x 14 cm placed above the ground ([15] and [28]). The same procedure is repeated until a total thickness of soil equal to 10cm.
The ground being prepared, the shape of each groove agricultural carried out using a suitable metal tool. There are many tools as forms of furrows. These small tools are reduced forms of real hoes used by farmers (Figure 3).

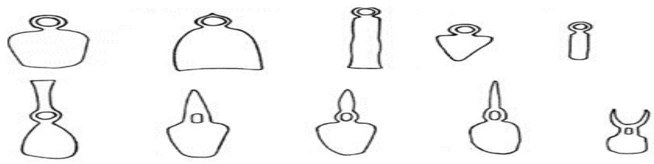


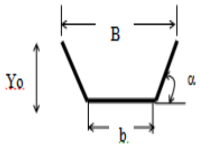
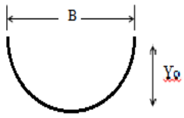
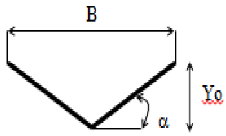
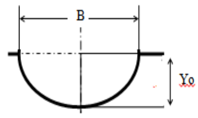
Figure 3: Some types of hoes used in agriculture

Once the dug trench and to obtain the desired slope, the model is moved by means of a jack. It then feeds the first flow of water for a relatively short duration of 2 minutes. This time of runoff was chosen in accordance with the work of T. J. Trout and J. A. Gomez concluded that, in the first few minutes, sediment transport and runoff follow linear laws ([15], [30] and [31]). Power is then stopped and took photographs. The mixture is then allowed to stand for 6 hours to facilitate settling and separating the solid phase to liquid phase. After settling, is carried out a first weighing of the liquid phase extracted. The solid phase, sip of water, is placed in an oven for 24 hours. After that, it performs a second weighing will give the actual mass of sediment exported from the furrow.

4. EXPERIMENTAL STUDY

Its purpose is the study of the influence of the geometric shape of the grooves on the sediment transport in agricultural soils. It is worth mentioning that in all series of experiments, we maintain constant soil type, moisture content (5%), soil compaction, runoff duration (2 minutes), the channel length (1,6m) and the flow rate (6,0 l/min). Only the geometrical shape of the grooves and the channel slope vary. Four forms of furrows and three slopes were tested. For forms, we considered the circle, trapezoid, triangle and sine. In terms of slopes, we have considered, and an almost flat slope, Class 03 (1%), a moderately steep, Class 08 (20%) and a steep grade 09 (52%) ([14]) The geometric characteristics of the grooves were obtained after studying the laws of similarity flows with movable bed ([9] and [16]). The final dimensions of the grooves are different forms of data in the table below (Table 2)

Table 2: Geometrical characteristics of furrows

	Trapezoid	Circle	Triangle	Sine
Furrow shape				
Mathematical function		$x^2 + y^2 = (3,2)^2$		3,2 sin[π x / 8,8]
Geometric parameters	Yo = 3,2 cm B = 7,2 cm b = 3,2 cm α = 58°	Yo = 3,2 cm B = 6,4 cm	Yo = 3,2 cm B = 12,6 cm α = 27°	Yo = 3,2 cm B = 8,8 cm

This study has highlighted the dimensional numbers $\left[\frac{P}{\sqrt[3]{B}}\right]^3$ where P is the wetted perimeter and B the width of the mirror. This number allows the transition from one form to another groove on the assumption of a constant depth of 3.2 cm.

5. RESULTS

The results of experimental measurements for each form of groove are summarized in Table 3 below.

Table 3: Sedimentary masses exported

	Sedimentary masses exported (g)		
Furrow shape	Slope = 1%	Slope = 20%	Slope = 52%
Sine	41.19	2178.90	9149.06
Triangle	93.15	3462.30	6464.39
Trapeze	870.48	5547.48	7606.91
Circle	192.28	4233.29	4967.55

In reading this table, it can be made the following remarks:

- The mass sediment exported varies strongly with the slope.
- The mass sediment exported varies considerably with the shape of the groove (furrow)

6. DISCUSSION

6.1 The effect of the geometry of the sedimentary mass exported

The parameter on the shape of the grooves has never been considered factor in the sediment dynamics in agricultural furrows. The table above (Table 3), Figure 4 and photographs of figures 5 and 6 clearly show that the shape of the groove has a strong influence on sediment dynamics. In fact, for slopes below 32%, the sine shape which gives rise to less sediment transport, followed by circular, triangular and finally trapezoidal. For slopes between 32% and 36%, the lowest shape of sediment export is the circle, followed by the sine, then the triangle and finally the trapeze. For slopes between 36% and 45%, we find the following classification: circle, triangle, sine and finally trapeze.

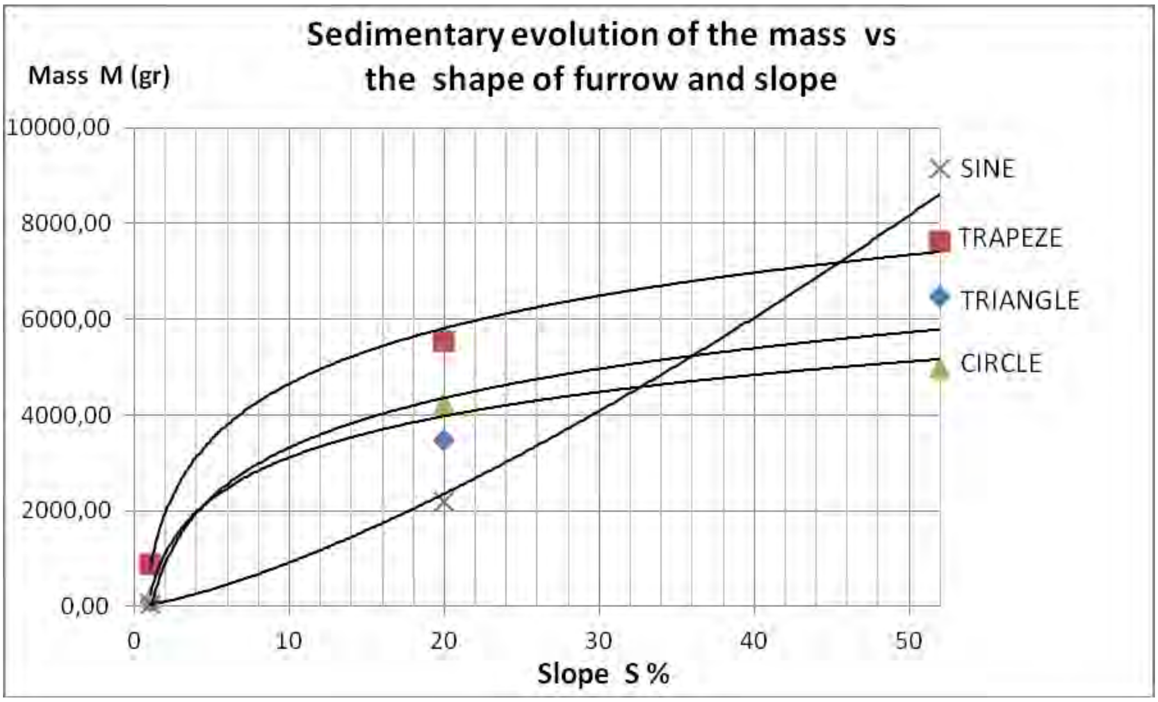
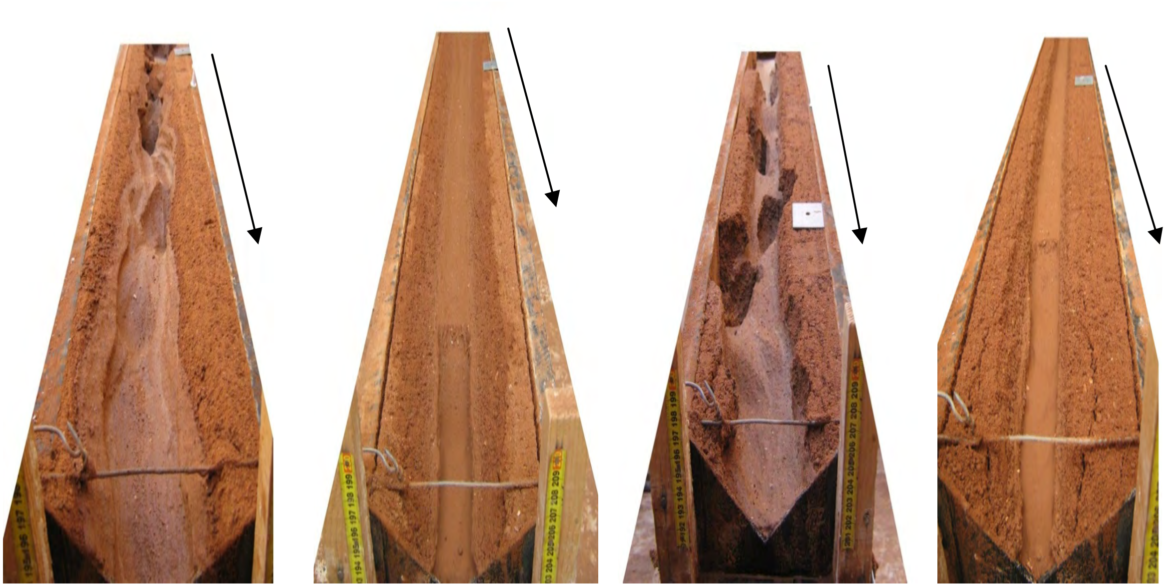


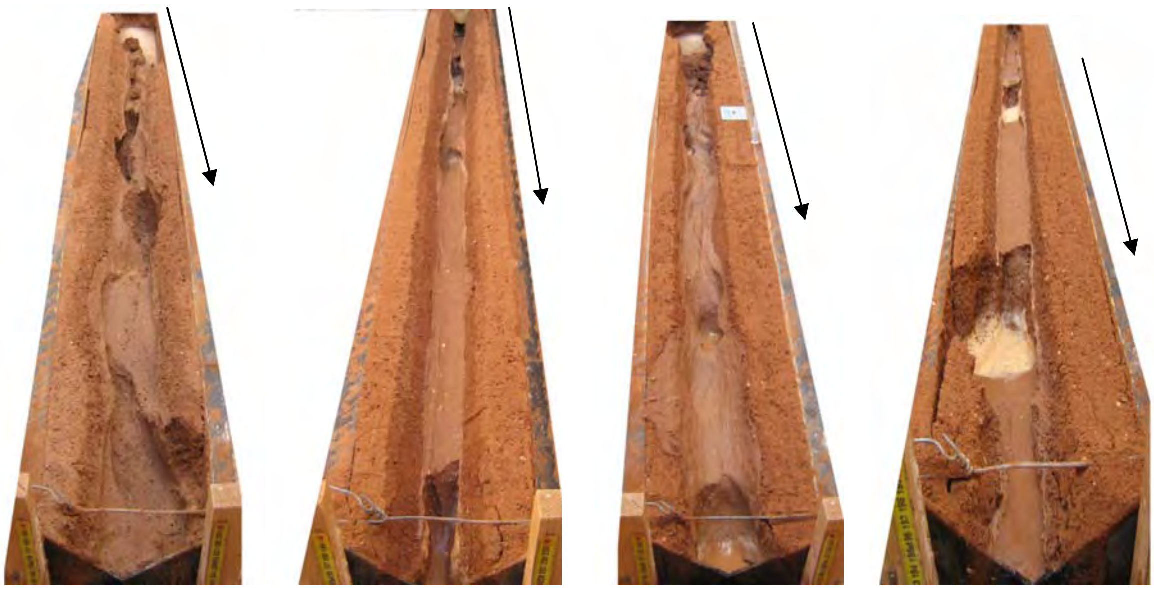
Figure 4: Evolution of the sedimentary mass exported

It should also be noted that the geometric shape of the grooves does not affect only the amount of sediment exported but also the forms of erosion that may occur. In our tests, the most spectacular forms were regressive erosion, stream bank erosion and scour erosion. For regressive erosion, it manifests itself very quickly. For the 1% slope, the whole mass collected sediment was the result of this form of erosion (Figures 5b and 5.d). For slopes approaching 20%, it is especially timely erosion dominates (Figures 6.b and 6.d.). For steep slopes of 52%, the three types of erosion occur simultaneously. Nevertheless, the bulk comes from , stream bank erosion (Figures 5.a, 5.c, 6.a and 6.c).



a) Triangle (52%) b) Triangle (1%) c) Trapeze (52%) d) Trapeze (1%)

Figure 5: Types of erosion furrows for triangular and trapezoidal



a) Sine (52%) b) Sine (20%) c) Circle (52%) d) Circle (20%)

Figure 6: Types of erosion for sinusoidal grooves and circular

6.2 Effect of geometry on the rheological behavior of the sediment exported

The experiments also led to the fact that the nature of the rheological sediment depends not only on the value of C_V [18] but also of the geometric shape of the groove. Figure 7 clearly shows that:

- For the trapezoidal shape, the fluid becomes non-Newtonian ($C_V > 5\%$ [18]) when the slope P is greater than 9%.
- For form of circle, this occurs for $P > 16\%$.
- For the triangular shape, the fluid becomes non-Newtonian when $P > 20\%$.
- For the sine form, the limit is even higher, since $P > 27\%$.

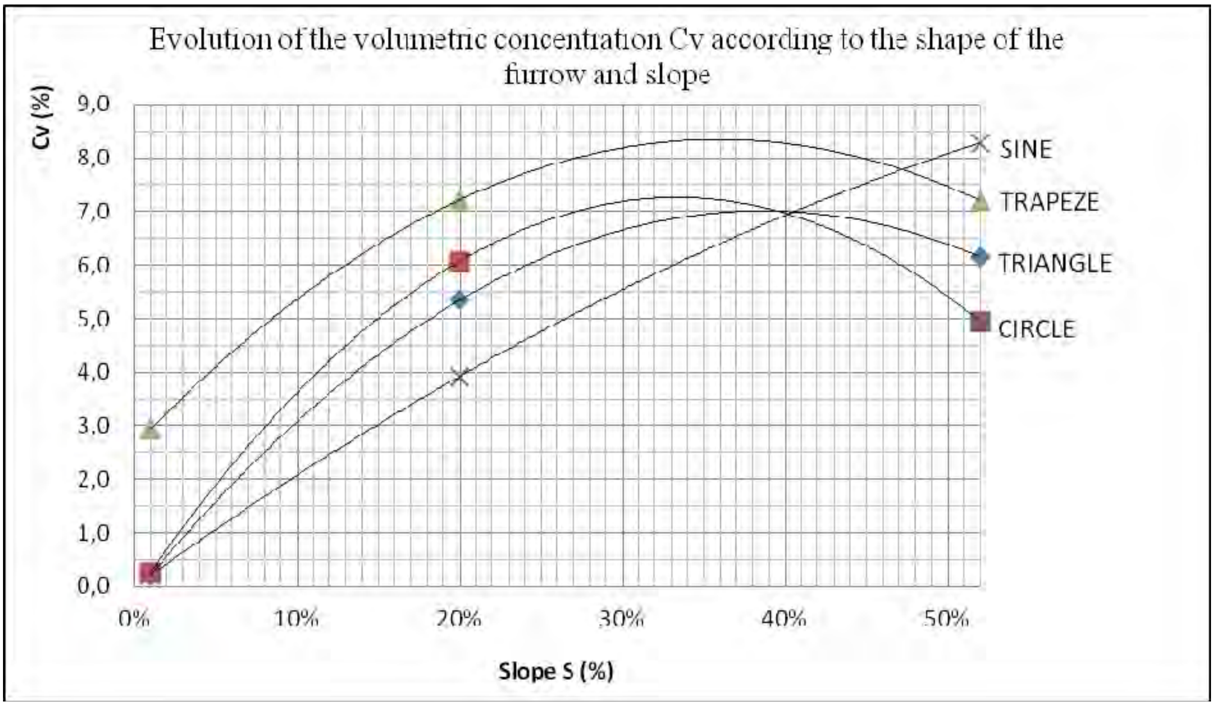


Figure 7: Evolution of the volumetric sediment concentration factor (Cv)

CONCLUSION

After these series of experiments, we conclude that the geometric shape of the grooves strongly influences agricultural sediment dynamics. For the predictive models of sediment transport in agricultural grooves, the introduction of a parameter that takes into account the geometric shape is required. Moreover, our experiments showed that the rheological behavior of sediment depends not only on the volumetric sediment concentration factor Cv but also on the geometric shape of the grooves (furrows)

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NOTATIONS

A	Clay %	WL	Liquid limit
L F	Fine silt %	WP	Plastic limit
L G	Coarse silt %	IP	Plasticity index
S F	Fine sand %	Ac	Clay activity
S M	Medium sand %	K	Soil perméability
S G	Coarse sand %	Po	Porosity
D50	Medium Diameter mm	n	Void ratio
D_r	Bulk specific gravity	$[So4^{2-}]$	Sulfate concentration
D_{Ap}	Apparente specific gravity	FC	Field capacity
$[Co3^-]$	Carbonate concentration	[SiO2+CaO+..]	Concentration of insolubles
$[Cl^-]$	Chloride Concentration		