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Research Article

Study Of The Evolution Of The Fractal Dimension Of Soil Gains During Compaction

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Abstract **–** The study of the shape and texture of grains (angularity, sphericity and roughness) plays a very important role in better understanding the mechanical behavior of granular media. This affects their strength, their compactness, their particle size, etc. However, Euclidean geometry which does not study irregular real objects cannot completely satisfy this study. This is why we use the fractal dimension to properly describe a complex structure composed of irregular soil grains. SO; It is necessary to characterize the shape of the grain with methods of calculating the fractal dimension, such as the area-perimeter method used, which is a number that measures the degree of irregularity and fragmentation of a grain, before and after each test carried out. Our work is an experimental study carried out in the laboratory with the Proctor test for the grains of the limestone material. To understand its behavior, it is important to analyze the correlation between the fractal dimension and the characteristics obtained during the different Proctor tests. The results obtained show that the variation of the calculated fractal dimension, corresponding to the crushing effect of the grains, is strongly influenced by their shape, their size, their particle size distribution, the number of blows, the compaction energy and the number of layers made. This confirms that the fractal dimension is a very effective tool for measuring and understanding the physical and mechanical properties of granular materials.

Keywords – Grain Shape, Fractal Dimension, Proctor Test, Grain Crushing, Correlation.

I. INTRODUCTION

To study the behavior of granular media, it is necessary to characterize its aggregates which are a part of civil engineering's structures such as dams, foundations, roads, etc. However, these materials are continuously subjected to harsh environmental conditions and high compressive stresses. Then, these granular materials are fragmented into pieces of different sizes [1] and [2] which cause a change in the granulometry (size, shape) of the grains and the porosity of these materials, and consequently inducing a change in their mechanicals properties.

Euclidean geometry is not suitable to represent all the natural objects, because they are not always perfect. It becomes essential to study the form's irregularities for more understanding. He has shown that the "fractality" of an object is only the intuitive perception of its irregularity or roughness; more irregular is an object, the higher its fractal dimension is [3], [4], [5] and [6].

The goal of our research is to use the concept of fractal dimension for the grains of local materials (limestone) subjected to compaction tests.

II. CRUSHING AND FRACTAL DIMENSION OF GRAIN

Describe The grains of soil can undergo a phenomenon of rupture or collapse under the compaction's effects. This causes a fragmentation of the grains in various aspects. The rupture of the grains is generally limited to the contact points as it may be extended into the interior of the grain. When grains are solid, hard and rounded enough, they can return to high stress; on the other hand, the angular grain's shape of freshly extracted quarried materials undergo a fragmentation due to the breakage of asperities under smaller stresses. In fact, the mechanical strength can be related to the mineralogical nature of the grains, and their state of alteration. The various experimental studies on this subject have shown that this phenomenon is related to physical and mechanical properties of the grains and the applied stress paths [7], [8], [9], [10] and [11].

III. MATERIAL IDENTIFICATION OF THE STUDY

Limestone is sedimentary massive rocks which are very widespread. To define the limestone, three parameters are essential: mineralogy, structure and porosity.

The different physical and mechanical characteristics (γ, n, e, MDE wear resistance, LA abrasion resistance, γdopt and Wopt) of limestone are respectively grouped in the Table 1.

Table 1. Physical and mechanical characteristics of limestone.

Charact.	**MDE (%)**	**LA (%)**	**γd_{opt} (g/cm3)**	**W_{opt} (%)**
Limestone	20	24	1.62	5.58

Charact.	**γ_s (g/cm3)**	**n (%)**	**γd_{max} (g/cm3)**	**e_{min}**	**e_{max}**
Limestone	2.7	9.37	1.42	0.90	1.21

To check the quality and the effectiveness of the compaction, the measured characteristics (Wopt, γdmax) should be checked on the site. The Modified Proctor tests have been implemented in this study.

IV. PRESENTATION AND INTERPRETATION OF RESULTS

Samples of calcareous material are subject to different energies (25, 35, 55 and 75 blows) and curves Proctor (density as a function of water content) and grain size distribution curves before and after the Proctor tests are used to determine the influence of the energy of compaction on the variation of the grain's fractal dimension.

To determinate the fractal dimension parameter, ten grains of each dimension were stained and the fractal dimension (Df) was calculated before and after each test. The "area-perimeter" method was used to determine the area and a perimeter of each grain with Auto-CAD software. Using the Excel, perimeters curves as a function of the surface (perimeter =f(surface) are plotted and the fractal dimension is deduced by $D_f = 2 / m$ (as m is the slope of the line of the best fit) Fig. 1 and Fig. 2.

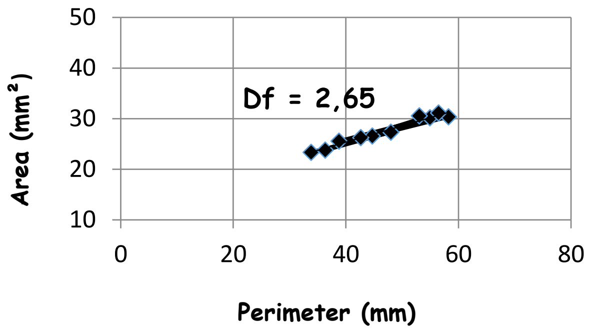

Fig. 1 Determination of fractal dimension to the types of grain size (4mm).

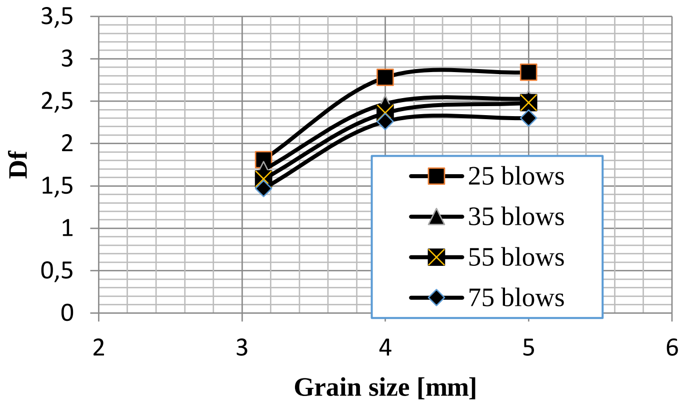

Fig. 2 Evolution of the fractal dimension as a function of grain size.

Table 2. Summary tables of fractal dimensions obtained before and after Proctor test

Blow's number	Df before -Df after Proctor test		
	5 mm grain	4 mm grain	3,15 grain
25	0.01	0	0.01
35	0.23	0.20	0.06
55	0.31	0.23	0.08
75	0.42	0.30	0.11

From the results shown in Tables 2, the fractal dimension obtained from these tests decreases practically too all the grain's different dimensions constituting the different samples. However, after 25 blows, the fractal dimension does mark almost no change compared to the initial state. Indeed, it's at 35 blows that the fractal dimension of the grains decreases in a remarkable way.

This decrease is explained by the fact that after the crushing some grain loses some of their material which induces a decrease in their sizes and surfaces. Usually, the rupture of the grains gives new grains with less rough surfaces. However, many parameters are influencing this phenomenon (the structure of the material, shape and grain size and the intensity of the applied loading). However, under the effect of successive moves, the material undergoes a densification, which indicates a decrease in the void ratio. Indeed, once the grains occupy the interstices, then they undergo a crash for abrasion and sometimes for chipping mode. Indeed, while increasing the number of blows (compaction energy), this creates more compression and therefore the fractal dimension of the grains decreases.

The fractal dimension decreases with the increasing of the dry density for the different grain sizes. The fig. 2 shows the evolution of the fractal dimension according to grain size. All these curves show a linear initial portion, followed by a progressive change in slope which tends to a bearing. For the grains of 3.14 (mm), the fractal dimension values is lower than those of 4 (mm) and those of 5 (mm).

V. CONCLUSION

The overall results were as follows:

- The variation of the grain's fractal dimension is caused by the grain crushing phenomenon. Indeed, the increase of Df usually results in the decrease the grain's dimension.
- The compaction energy increases the crushing grain and thus influences the variation of Df.
- The variation of the fractal dimension of the grains is affected by several parameters (the surface, size and shape of grain, etc.) which significantly affect the mode of failure of the grains and consequently leads to an increase or a decrease of the grain's irregularities. Indeed, the fractal dimension decreases in the case of a "splitting" and / or a "rupture of asperities" and is increasing in the case of a 'scaling' which causes the increase of surface irregularities.

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