We are IntechOpen,
the world's leading publisher of
Open Access books
Built by scientists, for scientists

6,900
Open access books available

186,000
International authors and editors

200M
Downloads

Our authors are among the

154
Countries delivered to

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities

CLARIVATE ANALYTICS
BOOK CITATION INDEX
INDEXED

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

Chapter

Application of a Granular Model to Identify the Particle Size of the Granular Mixtures of Concrete Based on Dune Sands

Mhammed Abdeldjalil

Abstract

The control of the determination of concrete depends on the basic properties of the desired concrete and thanks to the type of granular mixture of concrete. We arrive at the required concrete quality. And in this study, we can identify the granular distribution class of concrete using the fractal model. In particular, the granular distribution can be determined by the fractal dimension, either for each granular component separately, or for the dry granular mixture of the concrete. The fractional dimension is obtained by transforming the particle size curve to a fractal line. In this study, we used some experimental results obtained from projects already carried out in arid regions. Knowing that we have applied parameters such as granular extent and fractional dimension to the study of these existing projects, we can define a dry mix of concrete through the granular distribution. Therefore, we used the program that we proposed previously of transforming the grain size curves to a fractal line which was obtained for each grain mixture with a very acceptable correlation.

Keywords: Concrete, Aggregate, Fractal Dimension, Granularity, Identification

1. Introduction

Civil engineering practitioners such as researchers, engineers, technicians and those interested in it have always favored the best concrete formulas based on classical or modern methods. The methods used were either experimental (laboratory tests), or empirical or semi-empirical method or analytical methods. The current results of concrete production always indicate that they are oriented towards modern methods which are mainly based on numerical modeling [1–10].

Scientific research in the field of civil engineering, as in many other applied sciences and technologies, is a major use of its implementation according to modern tools, in particular calculation tools [1, 3]. The main objective of this study is to discover the best methods that help in the economic aspect, in particular the building materials when testing, in addition to saving time and effort lost in their realization without taking them into account. Thus, it was more interesting to use technology (electronics and computer) with analytical methods and concrete models to achieve experimental methods.

On the other hand, our main goal is to take advantage of recent studies [5–10] that rely on granular distribution to quantify aggregate dosages. According to the parameters of the fractal dimension FD [1–4] and the granular extent D/d [2].

On the other hand, we emphasize the importance of extending the determination of the granular distribution by using the fractal distribution as a new model to determine the granular mix class of concrete. Our experimental results, which we adopted in this study, allow us to determine a numerical value as one of the physical properties of the aggregate, which is the fractal dimension (FD). It facilitates the formulation of concrete by precisely specifying the components of the aggregate. Our objective in this study is to create a large database which helps us to save time and materials in experimental studies within the framework of concrete formulation methods to determine dosages of granular materials, which is certainly useful in the field of civil engineering. Initially, we rely on the study of a component to facilitate the process and start from the simplest operations. We took, for example, the study of the effect of the sand component [4]. It should be noted that this work is mainly based on the data, which takes the aggregate as the basic component in the production of concrete so that as it is known, 80% of the concrete is composed of aggregate, in order to obtain a good granular distribution (continuous granulometry). We emphasize that the appropriate selection of aggregates according to the desired concrete requirements allows us to achieve one of the most important characteristics that distinguish concrete, which is the compressive strength of concrete [3, 4]. In addition, the new definition of granularities by fractal dimension helps in choosing the classes of aggregate to be used in concrete. We confirm that one of the main objectives of this study is to highlight the optimal importance of the fractal dimension parameter and its results, which brings us to the possibility of knowing how to determine the reference particle size curve of granular mixtures at using the fractal model for granular concrete mixtures.

2. Conventional concrete methods

To obtain a concrete having the desired properties according to climatic and other requirements, and to use local materials for economic reasons and in order to know the proper method of concrete formulation, we have seen that it is necessary to mention some of the conventional methods widely used in the formulation of concrete.

Methods were adopted for the formulation of concrete whose first principles of physical relations emerged at the end of the 19th century, and these methods of formulation have varied depending on the materials available and our need for the required concrete quality.

2.1 Strength formulas

2.1.1 Formulas of Feret

René Féret [11] in 1892 was one of the first to research the law governing the prediction of the compressive strength of concrete f_c (1).

Its formula based on the strength of the cement (the true class), the nature of the aggregate, the cement/water dosage ratio and taking into account the volume of voids. But does not take into account neither the shape of the aggregate nor the granular distribution, nor the resistance to fragmentation of the aggregate. The latter is formulated using the following expression:

In 1892, Féret [11] to whom the first researches are attributed, worked on a principle of the mechanical resistance of concrete f_c (1). K_{feret} coefficient of the resistance of the cement and the type of the aggregate. c, e are dosages of cement and water. v is the volume of the area. But it does not directly take into account neither the shape nor the type of gravel used, as well as the granular distribution of the granular concrete mixture.

$$f_c = K_f f_{mc} \left(\frac{V_c}{V_c + V_w + V_a} \right)^2 \qquad (1)$$

- f_c: Strength of the concrete at the maturity considered

- K_f: Model constantly (index f for Féret)

- f_{cm}: Normal strength of cement

- V_c Absolute volume occupied by the cement

- V_w: Volume occupied by water

- V_c: Air volume

2.1.2 Methods of fuller

Fuller and Thomson [12] in 1907 established their method based on the maximum compactness of the continuous granular mixture, and it depends mainly on the porosity of the granular mixture (2) and the granular expansion. However, it does not directly take into account the shape of the grains, nor the resistance to friability of the aggregate used, and its relation is written as soot:

$$P_{F\,T} = 100 \sqrt[5]{\left(\frac{d}{D} \right)} \qquad (2)$$

- P_{FT}: Porosity of the granular mixture

- d/D: The granular extension.

2.1.3 Methods of Abrams

Abrams [13] in 1918, Regardless of the European school, he empirically proposed an exponential equation to predict the compressive strength of concrete, still used in North America, which has two adjustable parameters [Popovics, 1995].

The cement/water ratio, and involves through a coefficient (improved K_Féret) which indirectly presents nature and shape of the aggregates.

We note the absence of a direct representation of the resistance to fragmentation of the aggregate and of the granular distribution, as is the case in the rest of the previous methods, its formula (3) is written:

$$f_c = K_{Abrams} \left(\frac{1}{7.5^{(1.5(W/C))}} \right) \qquad (3)$$

- W/C: Ratio of cement and water,

- K_{Abrams}: Nature and the form of the aggregates,

- f_c: Mechanical strength of concrete

2.1.4 Methods of Bolomey

Bolomey [14] in 1925 is based on a formula (4), (improved iron) to determine the dosages of cement and water. This formula for predicting the mechanical compressive strength of concrete, which depends on the shape of the aggregates as well as the consistency of the concrete, and the dosages of cement and water, and the volume of voids. But does not take the representation of resistance to aggregate fragmentation.

This formula, like that of Féret, is the product of three terms which share, in order of factors, the influence of aggregates, cement and concrete formulation. The difference, compared to the relation of Féret, relates exclusively to the third term, parabolic in Féret, linear in Bolomey. It has been shown that the Bolomey relation is a good approximation of that of Féret for the values of the E/C ratio between 0.40 and 0.70; within this range, the error is less than or equal to 3%.

$$f_c = K_{Bolomey} \left(\frac{C}{W+V} - 0.5 \right) \tag{4}$$

- f_c: The mechanical resistance of concrete,

- K_B: Depends on the shape of the aggregates and the consistency of the concrete

- C, W: The dosages of cement and water,

- V: The volume of the area.

2.1.5 Methods of Caquot

The scientist Caquot [15] circulated his research during the year 1937, through which he sought to find the optimal aggregate distribution in which the porosity of the aggregate mixture is minimal, according to the basic hypothesis of compatibility between two aggregates classes without influence due to the presence of another aggregates class.

This basic idea was taken up by F. de Larrard [3], who had previously embarked on a vast process of developing other concrete formulation programs.

The relation is determined empirically by assuming that the volume of the voids depends on the dimensions of the small grains, then on the addition of grains, then on a constant determined empirically according to the relation of Caquot (5).

$$V = V_0 \sqrt[5]{\left(\frac{d}{D} \right)} \tag{5}$$

- V: The volume of voids,

- d, D: The dimensions of small grain, more grain.

- V_0: Constant defined experimentally

2.1.6 Methods of Faury

We find in the work of Faury [16] and Joisel [17] that they made modifications to the work of Caquot in 1942 and 1952, and Faury extends to the granular range up to 6.5 μm, incorporating the cement as a granular material and taking into account the effect of the wall. And Joisel gave a reference straight line (at a complex scale) taking into account the cement, water, voids, granulometry and the compactness of the granular classes. Here, we note an indirect representation of the granular distribution with the mechanical resistance of the aggregates [18].

The optimum grain size of a concrete is a mixture (in a certain proportion) of two kinds of grains of the aggregate.

The reference curve to be followed consists of two straight sections.

The first AB gives the granulometry of fine grains. The second straight line is that of coarse grains. The y coordinate of, called the break point, indicates the percentage by volume of the grains. Its value is given by the experimental formula (6).

$$Y = A + 17.\sqrt[5]{\left(\frac{d}{D}\right)} + \frac{B}{\frac{R}{D} - 0.75} \tag{6}$$

- D: maximum aggregate size in mm

- **R**: average radius of the formwork in mm

- A: coefficient taking into account the shape of the aggregates and the consistency of the concrete.

- B: depends on the tightening. It varies from 1 for a powerful vibration to 1.5 for an average tightening.

2.1.7 Methods of Dreux-Gorisse

He method of Dreux and Gorisse [19] is based on the optimal granularity which is still current for the design of the concrete formulation. This is an empirical approach according to an OAB granular reference curve (segments of two lines in a semi-logarithmic plot). Contrary to the moment, the cement is not part of the reference curve of the mixture, since its mass is determined separately. It is a method which takes into account a large number of parameters [18]. But it does not take into consideration the direct representation of the granular distribution of the aggregate, and indicates what the true class of cement represents, and the dosage of cement and water, type, shape, quality and dimensions. of aggregates, the smoothness, consistency and strength of concrete.

This method is fundamentally empirical in nature, unlike the Faury method which predates it [Faury, 1942] and which is based on Caquot's theory of the granular optimum [Caquot, 1937]. Dreux carried out a large survey to collect data on satisfactory concretes [de Larrard, 2000]. On the basis of a statistical analysis of this large number of concretes and by combining the granular curves obtained, they were able to base an empirical approach to determine a reference granular curve.

It is also very easy to use since it only requires knowing the grain size curves of the aggregates used.

A test batch is necessary to be carried out in the laboratory in order to make any usage corrections.

"B" (on the ordinate 100%) corresponds to the dimension D of the largest aggregate.

"O" (at ordinate 0%) corresponds to the dimension d of the smallest aggregate.

The break "A" has the following coordinates:

- on the abscissa (from the dimension D of the sieve) on the ordinate.

Si: D ≤ 20 mm; the abscissa is D / 2.

If: D ≥ 20 mm; the abscissa is located in the middle of the "gravel segment" limited by the modulus 38 (5 mm) and the modulus corresponding to D.

in ordinates (7)

$$Y = 50 - \sqrt{D} + K + K_s + K_p \tag{7}$$

- **K**: corrector which depends on the cement dosage, clamping efficiency, the shape of the rolled or crushed aggregates

- K_s additional correction according to the fineness modulus of the sand (case of coarse sands) by adding the value $K_s = 6.M_F - 15$

- K_p: the coefficient depends on pumped concrete or not.

2.1.8 Baron and Lesage

The method of Baron and Lesage [20] is based on a technique proposed in 1976 to improve the granular skeleton according to the principle of relating the minimum flow time specified by the LCL Maniabilimeter according to Standard 18–452 [21] with the quantity optimal granularity for constant cement and water ratios.

The principle is to measure the time taken for a concrete sample to flow under vibration to a certain mark. The optimum proportions of aggregate are assumed to give the minimum flow time, for a given amount of cement and water. Once the granular proportions have been identified, the water and cement dosages are adjusted experimentally, so that the mixture has the desired workability and resistance. It is assumed, in this method, that the optimum proportions of aggregates do not depend on the quantity of cement.

2.2 Other models

Baron and Olivier have developed a formulation method derived from the Dreux-Gorisse method with modifications to adapt to existing concrete in 1996. This method makes it possible to integrate a large number of the parameters listed, taking into account the additives and incorporating mineral additives.

Baron and Olivier have developed a concrete formulation method derived from the Dreux-Gorisse method with modifications to adapt to existing concrete in 1996. This method makes it possible to integrate a large number of listed parameters, taking into account the additives and incorporating mineral additions.

The method is due to Mr. BARON, from the experimental studies he carried out in the years 1970–1980 and which were subsequently optimized by using the directives of the NF P 18–305 standard, replaced by the European Standard. EN 206–1. This method is developed in a book co-written by Messrs. BARON and OLLIVIER "BETONS, Bases and data for their formulations" published by Eyrolles.

The experiments confirmed the work carried out by BOLOMEY and FAURY, certain formulas of which were adopted with regard to the binder and water dosages.

For the dosage in aggregates, it is, in part, the work of DREUX that was retained. The whole is completed by experimental results which make the method as affordable as the DREUX method without having the drawbacks of its limitation to the only common concretes.

The problem of the optimal dosage of concrete is not unique: there are actually two problems that can be addressed independently of each other:

• Binding paste

We start the formulation from 2 main assumptions which are the target resistance and the optimal effective water quantity.

The target resistance R_c is obtained from the calculation of the concrete or R_{c28} required by the work to be constructed. Taking into account the true resistance class of the cement and the nature of the aggregates, the BOLOMEY formula is used to define the W/C ratio. The optimum effective water is defined in a simple and provisional way according to the target consistency of the concrete by a table created by BARON taking into account a certain number of corrections relating to the dimension D of the gravel used (dimension of the smallest sieve which leaves pass all the components of the concrete) and at the temperature of the concrete pour.

From these values, we can therefore determine the cement dosage. Corrections are made from a trial mess.

• The granular skeleton

The granular skeleton retained by BARON is very close to that obtained by DREUX, however with a simpler approach and definition. This method was chosen not for its scientific basis, but because its results have been satisfactory over the past 25 years.

There are other innovative methods of concrete formulation, which can use numerical models such as René LCPC or BétonLab and BétonLab Pro2 [3], and other methods are analytical.

The first theories dealing with the maximum pressure of granular mixtures [Féret 1892, Caquot 1937] do not explicitly take into account the interactions and grain sizes between them. Through the compact stacking model, De Larrard [3] incorporates new concepts such as clamping, wall effect and thinning effect.

3. New models (mathematical analysis)

3.1 Fractal analysis

The fractal model for determining the granular distribution is a conclusion drawn from fractal analysis and is a new model for the mathematical description of everything used and found in nature, in which its truncated shapes reveal patterns similar to increasingly precise scales. And irregular and recurring shapes can be described using mathematical models. The term "fractal" is a mathematical term coined by Benoit Mandelbrot [22] from the Latin root fraction. It was originally used as an adjective (fractal line) and today is a noun meaning broken or irregular.

Sebsadji and Chouicha in 2012 [5–10, 23] showed that Fractals can be defined as disordered systems that are self-similar independent of scale of observation. Their fundamental property is a non-integer dimension called fractal dimension, which can measure.

Its result builds on the findings of previous researches (Lecomte and Thomas, 1992; Chouicha, 2006), according to which ideal grading curves of concrete can be transformed into straight-lines power-law of the form given in Eq. (11).

3.2 Fractal dimension (FD)

Marmi [24], in 2019 he expressed the fractal dimension as a parameter exists in classical geometry, and is a line is a one-dimensional object a surface a two-dimensional object, a volume a dimensional object. We are therefore used to objects whose dimension (D) is an integer 1,2 or 3. But it is not specified, what would be the dimension of a series of points on a line, an irregular and plane curve, a surface full of convolutions. For this purpose, the term fractal dimension was introduced by B. Mandelbrot in 1975 the fractal dimension is therefore a number which measures the degree of irregularity or fragmentation of an object or which measures the roughness of a surface.

The fractal dimension is the fraction or an irrational number (; 1.23; etc.) or an integer.

This notion of fractal dimension applies to scale-invariant objects: there are parts which are similar to the object itself up to an expansion (enlargement).

When we change the observation scale of a scale invariant object, we keep the shapes.

The particle size distribution curves of the cumulative sieve percentages as a function of the grain dimensions can be transformed to a straight line representing cumulative numbers as a function of the grain dimensions.

We can do this by assuming that the shapes of the grains have the same oval shape, and this, if we adopt the same hypothesis proposed by Lecomte and Thomas [25] in his work, which first touched on the analysis fractal and through which he approached the application of the fractal dimension in the determination of three types of granular mixtures for high-performance concrete. And in 1992, he achieved his study results by applying fractal analysis to a granular mixture of concrete related to the definition of granular analysis of granular mixture of concrete, which consists of several granular types. These results indicate at the time that he adopted the hypothesis of the dimension of a spherical grain of aggregate of main and standard dimension G, and the relation (8) below summarizes the determination of the volume of the spherical grain.

We can estimate the mass of the grains, called **M** mass, as well as their true density ρ and the average size of the grains **V** for each initial class of grains, n being the partial number of grains refused on the opening screen **G** [25] as a relationship (9) below.

$$v = \frac{\pi}{6} G^3 \tag{8}$$

$$N = \frac{M}{\rho \left(\frac{\pi}{6}\right) G^3} \tag{9}$$

It is also possible to express the cumulative number Nc of aggregate grains whose dimension is greater than or equal to the size of the opening of the sieve G, and Relation No. (10) shows the determination of the cumulative number of grains of aggregate. Thus, Relation (11) allows us to express the number of grains of aggregate rejected in a sieve, in terms of the cumulative numbers of all the granular components.

$$N_c = \sum_{i=1}^{n} \frac{Mi}{\rho \left(\frac{\pi}{6}\right) Gi^3} \tag{10}$$

$$\text{N}_{\text{c}} = \sum_{i=1}^{n} \frac{MiP}{\rho \frac{\pi}{6} Gi^3} \quad \text{N}_{\text{cumule}} = \sum_{i=1}^{n} \frac{MiP}{\rho \frac{\pi}{6} Gi^3} \tag{11}$$

The granulometric analysis of cement is done by laser, "Laser granulometry" this technique is based on the diffraction of light and was proposed by Fraunhofer under the application of their theory of Fraunhofer ". We have **Table 1** below which shows by a sub-detail of the fractal analysis which will identify the particle size of an example of CPA cement by the fractal dimension (FD).

FD fractal dimension is, therefore, an approximation of the granular distribution curve. If this approximation is good over almost the entire grain size measurement field, the granular distribution line is said to be the fractal or quasi-fractal dimension. If the curve obviously tends towards a limit when the dimension of the seeds tends towards zero, then this curve is said to be semi-fractal.

We show without difficulty that any physical measurement on a granular structure, even purely fractal, results in a granular curve on a logarithmic scale (quasi-fractal) due to the smaller dimension of d mm, an empirically necessary procedure. It turns out that only successive zooms, and logarithmic scale transformations

| Sieve size (mm) | Particle size analysis | | | | | Fractal analysis | | |
| | Refusal mass (g) | | % Cumulated | | Density (g/cm³) | Grain volume (cm³) | Number of grains | |
	Partial	Cumulated	Refusal	Passing			Partial	Cumulated
0.125	0.00	0.00	0	100	3,00	1.02E-06	0.00E+00	0.00E+00
0.1	2.40	2.40	1	99		5.23E-07	1.53E+06	1.53E+06
0.08	9.60	12.00	5	95		2.68E-07	1.19E+07	1.35E+07
0.063	12.00	24.00	10	90		1.31E-07	3.06E+07	4.40E+07
0.05	12.00	36.00	15	85		6.54E-08	6.11E+07	1.05E+08
0.04	12.00	48.00	20	80		3.35E-08	1.19E+08	2.25E+08
0.0315	24.00	72.00	30	70		1.64E-08	4.89E+08	7.14E+08
0.025	21.60	93.60	39	61		8.18E-09	8.81E+08	1.59E+09
0.02	14.40	108.00	45	55		4.19E-09	1.15E+09	2.74E+09
0.016	12.00	120.00	50	50		2.14E-09	1.87E+09	4.61E+09
0.0125	24.00	144.00	60	40		1.02E-09	7.83E+09	1.24E+10
0.01	12.00	156.00	65	35		5.23E-10	7.64E+09	2.01E+10
0.008	7.20	163.20	68	32		2.68E-10	8.96E+09	2.90E+10
0.0063	4.80	168.00	70	30		1.31E-10	1.22E+10	4.13E+10
0.005	4.80	172.80	72	28		6.54E-11	2.45E+10	6.57E+10
0.004	19.20	192.00	80	20		3.35E-11	1.91E+11	2.57E+11
0.00315	9.60	201.60	84	16		1.65E-11	1.96E+11	4.52E+11
0.0025	2.40	204.00	85	15		8.18E-12	9.78E+10	5.50E+11
0.002	2.40	206.40	86	14		4.19E-12	1.91E+11	7.41E+11
0.0016	9.60	216.00	90	10		2.14E-12	1.49E+12	2.23E+12
0.00125	2.40	218.40	91	9		1.02E-12	7.83E+11	3.02E+12
0.001	2.40	220.80	92	8		5.23E-13	1.53E+12	4.55E+12

Table 1.
Particle size analysis and fractal analysis of CPA.

(d, D), probably reveal (on the slope of the lower higher convergence line) the effective quasi-fractal drift of the studied process.

If this drift has several changes in the slope, then in some cases it will be referred to as "multi-fractal."

Figure 1 Presented the granular distributions of four types of cement identified by the fractal line, the cements are:

Portland cement compound class 42.5 MPa CPJ 42.5.

Cement sulphate resistant class 42.5 MPa CRS 42.5.

Artificial Portland cement class 52.5 MPa CPA 52.5.

Portland cement compound class 42.5 MPa type P6 CPJ P 42.5.

We present in **Figure 1** - the different fractal distribution with correlation coefficients of the fractal lines of the granular distributions, and the minimum correlation coefficient value is R^2 = 0.96. Appears in the granular distribution between three closely related types of cement, and another is different.

We followed the same method according to the results **Figure 2** of Lecomt [25] presented in the **Figure 2** which has ideally defined an example of the granular mixture containing a spread granular for a high-performance concrete, as well as all the granular classes of this concrete including the active mineral additions were used.
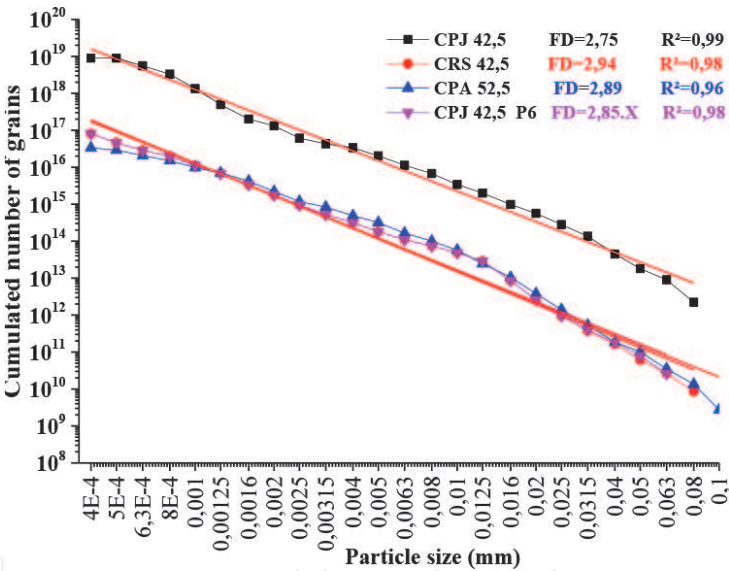
Figure 1.
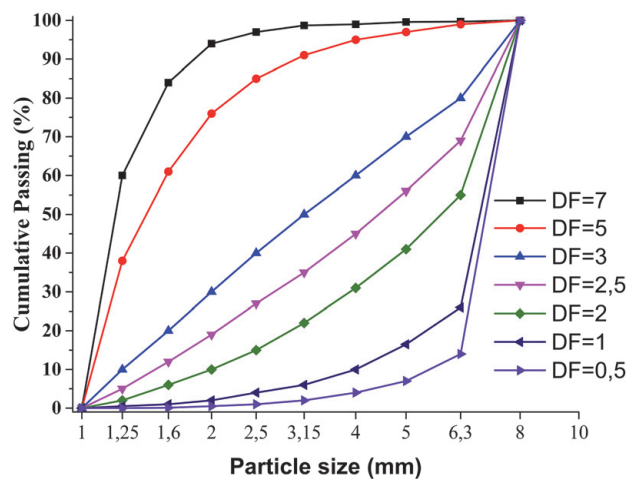*Fractal lines of granular distributions of four types of cements alone.*
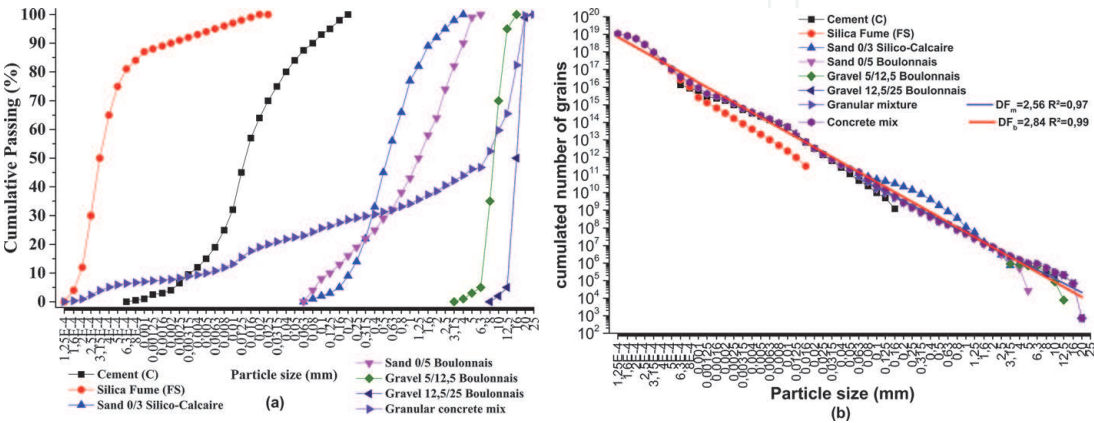
Figure 2.
Transformation from a particle size distribution to a fractal distribution for a concrete mixture and its components from the Lecompt [25]. a) Particle size curves, b) fractal line.

All concrete formulation methods, old or new, are based on particle size for determining the different dosages of the granular constituents. The results obtained by Lecompte [25] and Chouicha [2], show that these methods which use a granular distribution, indirectly use a fractal distribution.

In **Figure 3** of Chouicha [2], the particle size curves for different granular mixtures that he identified with a uniform particle size range, we can determine the particle distribution of the granular mixtures with a fractal dimension from FD = 0.5 to FD = 7, knowing that this field is for the granular mixtures in general, which is much larger than the field of the granular concrete mix, so it is outside the concrete field, because the fractal dimension FD does not exceed the value of 3 .

We applied one of the three high quality BHP concrete mixes that he adopted by Lecomt in his research (**Figure 2**), we clearly show through **Figure 4** the curves of the granular distribution of the component classes of the concrete, as well as its curve of the granular mixture, and this gives some similarities between Lecomt's work and what we got despite using different components in terms of density and type of aggregate ect, and what we got despite using different components in terms of density and origin of gravels, and this is due to our relying on the granule size assumption of the spherical-shaped relation (8) to obtain the fractal distribution of this granular mixture with its components as shown in **Figure 4 (a), (b)** which gives us the results of converting granular curves to fractal lines. Lines.
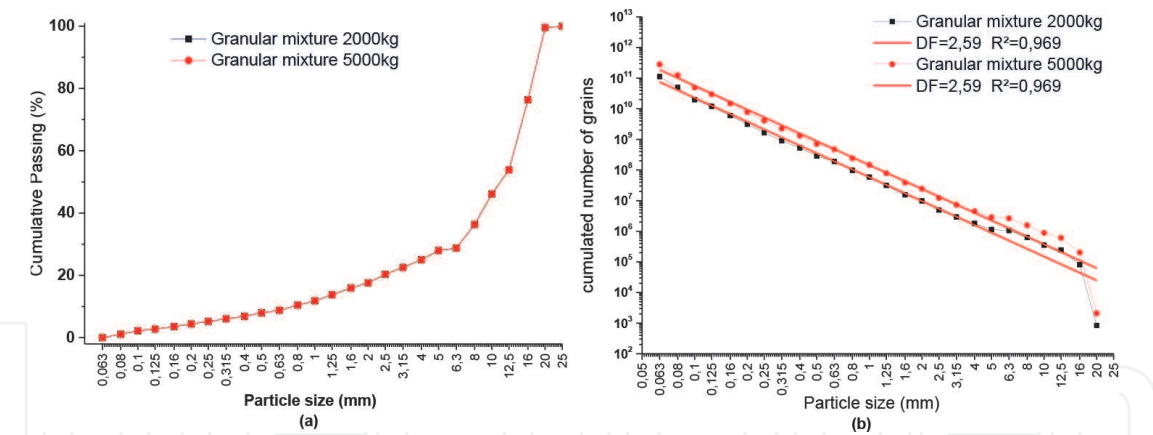

Figure 3.
Particle size curves of the different granular mixes identified by FD Chouicha [2].
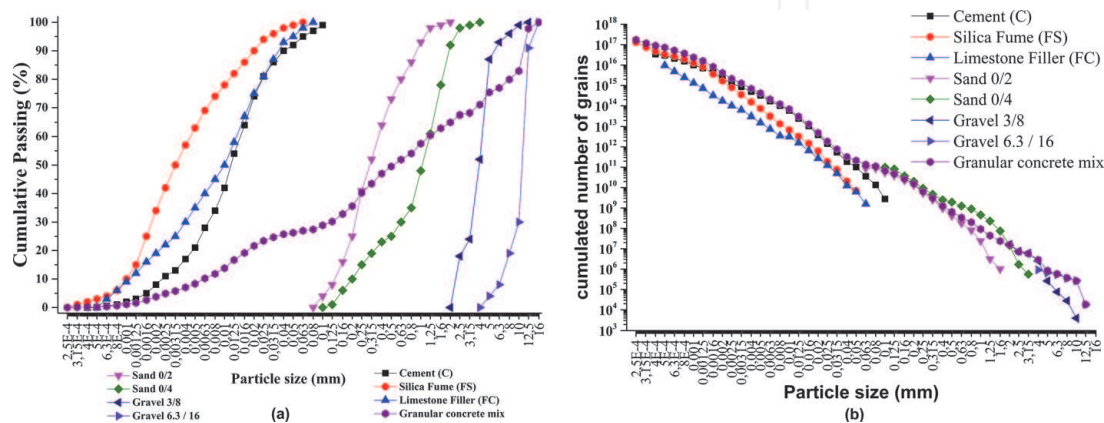
Figure 4.
Transformation from a particle size distribution to a fractal distribution for a concrete mixture and its components (example BHP) a) particle size curves, b) fractal line.

Figure 5.
Transformation of a particle size curve of a granular mixture 0,63/25 to a) fractal line particle size curves, b) fractal line.

The process of transforming the particle size curve into a fractal line has a direct relation to the granular variety of a granular class or of a granular mixture regardless of the mass taken for the granular variety. **Figure 5 (a)** shows that the grain size curve remains the same, regardless of the mass for the same grain class. **Figure 5 (b)** shows the transformation into a fractal line which gives us two lines of the fractal distribution, for each mass gives a fractal line for the same granular class, but with the same slope value, so it is the same value of the fractal dimension, and this is what he had confirmed by Chouicha [2] in his work in 2006.

4. The fractal line of sands/gravel and cement

First, on the one hand, we deal with the transformation of the granulometric curves of local materials concerning the granular classes of sand and then of gravel. On the other hand, we show the transformation of the particle curves for the cementitious materials of CPJ 42.5 and CRS 42.5.

The determination of the granular distribution is one of the important physical properties for the definition of aggregates and as is known in the context of concrete formulation methods, and it is important to control and determine the proportions of the appropriate aggregate components for concrete.

4.1 The fractal line of sands

Figure 6 (a) is an example showing the grain size curve of dune sand with a grain range of 0/5, **Figure 6 (b)** is its transformation into a fractal line, and this sand is one of the 10 sand classes of dunes shown in **Table 2** and its smallest, granular extent is 0.005/0.63 and it is a very fine dune sand. As for the granular extent of coarse dune sand is 0.005/5. Thus, a quarry sand with its granular extent is 0.063/63.

The identification results shown in **Table 2** were obtained by conducting laboratory experiments to determine the varieties of sand dunes at the Building Materials Laboratory of the University of Adrar in cooperation with the Regional Workshop Laboratory. On desert techniques (ARTS) [26]. The sand studied is sand from sites approved for the use of dune sands from different sites in the Saharan region in Adrar, Algeria.

The graphical fit of the fractal distribution is a linear fit by the equation y = b + ax. And constant "a ", it is the slope which represents the fractal dimension. **Figure 6** is
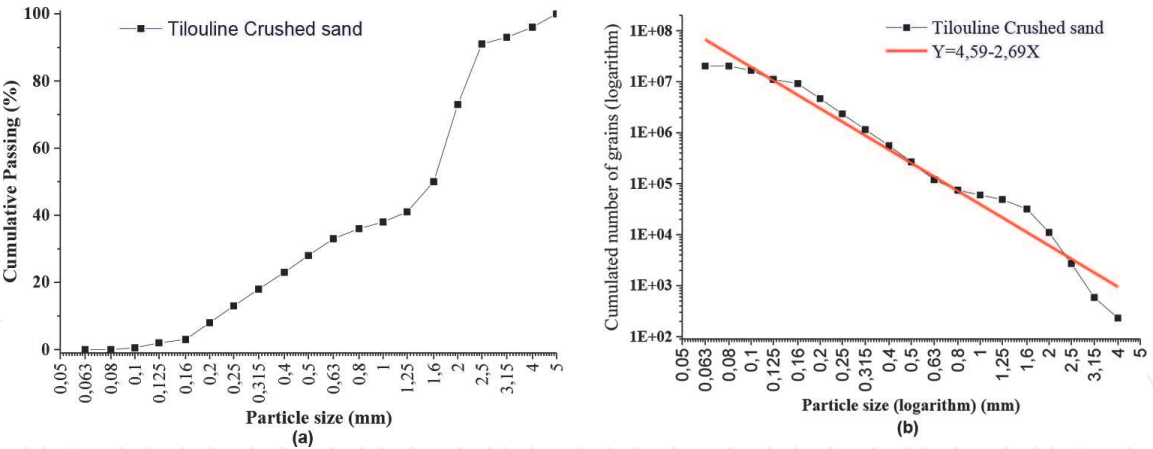
Figure 6.
Transformation of a grain size curve from a sand from Tilouline dune to a fractal line (example) [1].
a) Particle size curves, b) fractal line.

an example showing the methodology for determining fractal dimensions of all granular classes, including dune sand.

$$Y = 4,59 – 2,69 \, (x) \tag{12}$$

In this case, the slope is 2.69 and the correlation coefficient is $R^2 = 0.96$. The slope obtained by cumulative number of grains according to grain dimensions is the fractal dimension DF, which determines the class of the distribution of grains of a granular class or of the granular mixture.

4.2 Physical properties of dune sands

Table 2 summarizes the conventional physical properties of dune sands in the Adrar region, namely granular extent, fineness modulus and sand equivalent. And the unconventional properties are the fractal dimension of the granular distribution, whose value varies from 1.14 to 4.20 with a correlation coefficient whose value varies from 0.82 to 0.98, which is a value close to one therefore is accepted. In addition to the total area of the grains of sand calculated by the fractal dimension.

Sand dune site	ES	MF	STg (mm²)	d/D	DF	R²
Ouinna site n°01 - Adrar (SD)	82,43	1,78	8,58E+14	0,05/1,6	**4,20**	0,91
Tinerkouk - Timimoun (SD)	78,08	1,06	3,45E+14	0,05/2,5	**3,72**	0,89
Tilouline - Z. Kounta (SD)	82,17	1,42	2,34E+12	0,063/5	**2,69**	0,96
Ouinna site n°02 - Adrar (SD)	74,20	1,78	6,39E+11	0,063/0,8	**2,21**	0,89
Bordj Badji Mokhtar (SD)	73,18	1,64	3,38E+12	0,05/0,63	**2,86**	0,82
Tsabit - Adrar site n°01 (SD)	74,32	2,22	6,63E+13	0,063/2,5	**3,36**	0,93
Tsabit - Adrar site n°02 (SD)	74,32	2,22	1,50E+13	0,063/1,25	**3,88**	0,93
Tsabit - Adrar site n°03 (SD)	74,32	2,22	1,69E+15	0,05/1	**3,82**	0,93
Mimoun Adrar (SD)	72,00	1,21	1,10E+14	0,063/1,25	**3,60**	0,88
Cherouine -Timimoun (SD)	75,00	1,82	5,27E+14	0,05/5,00	**3,24**	0,98
Ouinna -Adrar (SC)	77,90	1,67	4,84E+12	0,063/6.3	**1,14**	0,80

Table 2.
Conventional and unconventional parameters for certain sands of the Adrar-Algeria sites [1].
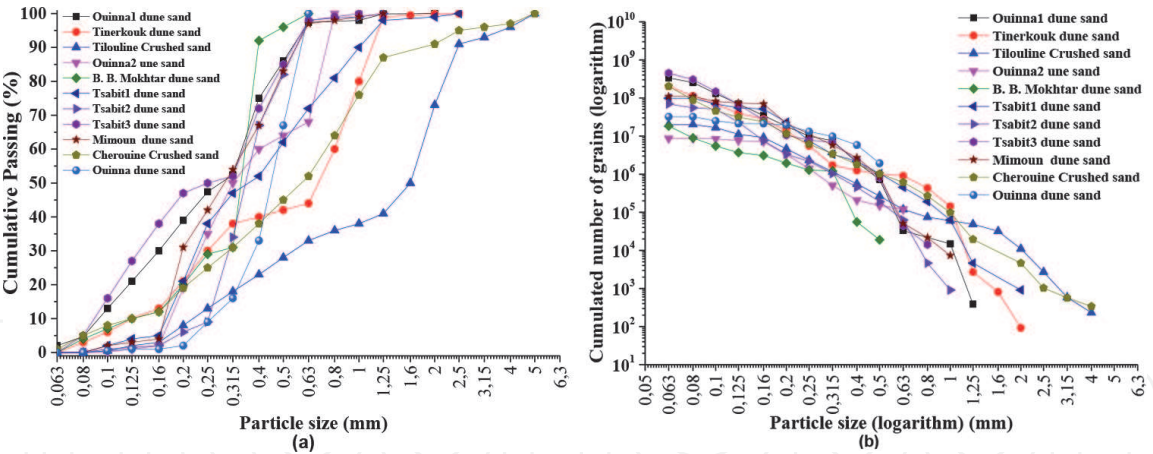
Figure 7.
Transformation of the particle size curves of Adrar Dune Sands to fractal lines a) particle size curves, b) fractal line.

Note: Physically, the value of the fractal dimension does not exceed the value of 3, because the study is within the framework of the three dimensions. But mathematically, that is to say according to the calculations of the hypothesis adopted, certain granular varieties can exceed the value of their fractal dimension the value 3.

But keep the optimal value that he adopted by chouicha [2], in his work, which does not exceed the value of 3 until the contrary is physically proven.

In **Figure 7 (a)** below, we show the grain size curves for all classes of dune sands as well as the quarry sand which we presented in **Table 2**, **Figure 7 (b)** we show the resulting fractal lines fractal distributions after transformation of their grain size curves for the different grain classes of dune sands. We note that the grain distribution of these sands is different and also gives us a different fractal distribution, which is proved by the obtained values of the fractal dimension.

Granular mixtures of concrete	Cement class		Concrete mix		RC28
	DFC	R^2	DFb	R^2	MPa
Mixture 01- [ARTS 22], CRS 42.5, Ouinna DS, Koussane Gr	2,85	0,98	2,66	0,99	22,80
Mixture 02- [ARTS 22], CPJ 42.5, Ouinna DS, Koussane Gr	2,75	0,99	2,83	0,99	20,60
Mixture 03- [LECT 24], CRS 42.5, Tinerkouk DS, Koussane Gr	2,94	0,98	2,61	0,98	17,90
Mixture 04- [LECT 24], CRS 42.5, Tillouline DS, Koussane Gr	2,94	0,98	2,76	0,99	18,90
Mixture 05- [LECT 24], CRS 42.5, Ouinna DS, Koussane Gr	2,94	0,98	2,85	0,99	18,40
Mixture 06- [LECT 24], CRS 42.5, DS Gr from B.B.M	2,94	0,98	2,87	0,99	19,10
Mixture 07- [LECT 24], CRS 42.5, Ouinna CS, Cherouine Gr	2,94	0,98	2,86	0,98	20,20
Mixture 08- [LECT 24], CRS 42.5, Brinkane DS, Cherouine Gr	2,94	0,98	2,83	0,99	29,50
Mixture 09- [LECT 24], CRS 42.5, Brinkane DS, Koussane Gr	2,94	0,98	2,76	0,99	20,50
Mixture 10- [LECT 24], CRS 42.5, Brinkane DS, Cherouine Gr	2,94	0,98	**2,79**	**0,99**	20,30
Mixture 11- [LECT 24], CRS 42.5, Brinkane DS, El Menia Gr	2,94	0,98	**2,79**	**0,99**	23,40
Mixture 12- [LAMCO 23], CPJ 42.5, Mimoun DS, Koussane Gr	2,75	0,99	**2,80**	**0,99**	18,80

B.B.M: *Badji Badji Mokhtar.* **El Menia**, *Ghardaia. DS: Dune Sand Gr: Gravel.*

Table 3.
Identification by DF for granular mixtures of concrete at Adrar [1].

4.3 Particle size curves of mixtures

In this study, we adapted 12 concrete formulation tests for 12 projects carried out at the wilaya in the State of Adrar which are detailed in **Table 3**. Example of the particle sizes of the Granular Mixtures based on the particle sizes of different granular classes, **Figure 8** with cement and **Figure 8** without cement.

As for the concrete studies, we adopted the studies using dune sand that we have already studied, knowing that the concrete compositions included in this study are part of an executive study for projects scheduled to be implemented in arid regions.

Thus, the concrete compositions were studied in coordination between the building materials laboratory of the University of Adrar and the local technical laboratories, so that the study was carried out with the laboratory assigned to monitoring and control at the site. of the project. This within the framework of cooperation and the exchange of experiences between the university and the technical operator. These laboratories include the ARTS Soil Analysis Laboratory, Regional workshop of Saharan techniques, the LECT Technical Studies and Controls Laboratory and the LAMCO Building Materials analysis laboratory [26–28].

As for the aggregate materials used in these concrete structures, in addition to the sand dunes which were under study, the aggregates used locally come from quarries (Ouainna, Koussane, Cherouine, etc.), with two classes of CPJ cement. 42.5 and CRS 42.5.

In **Figure 8** we apply the hypothesis of fractal analysis and show through it an example of the granular mixture with its components, which is dedicated to the first concrete project, and through it we give a typical idea of granular mixtures applied in the field, giving us a clear picture of the conversion of the granular distribution into a fractal distribution from which we derive the fractal dimension of the concrete mixture, which is DF = 2.66 with a correlation coefficient of R^2 = 0.99. This granular mixture used, contains four granular classes, which are 03 classes of gravel and one of dune sand in addition to the cement class, which we have considered as a granular class in the dry concrete mix.

The variable component in our approved concretes is the variety of dune sands used, and we present in **Table 3** below a summary of the identification they concrete used through their dry granular mixtures used. The fractal dimension of concretes used in executive projects on site and not limited to laboratory research only. We draw attention to a necessary parameter, namely that we have taken into account the effect of cement as a granular material which participates in the
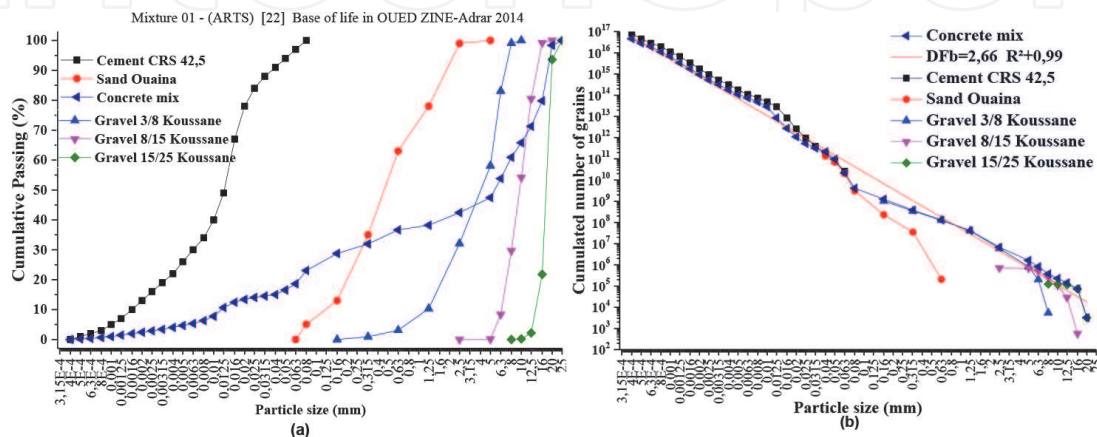
Figure 8.
Transformation of a grain size curve of the granular mixture of Oued zine to a fractal line (mixture 01) a) particle size curves, b) fractal line.

granular mixture by filling the pores with particles, while maintaining its main role in concrete, which is the main binder.

We have presented the values the fractal dimension of the cement used. Since we only used three classes of cement in the concrete compositions listed in **Table 2**, their values the fractal dimension of these classes, respectively, are as follows:

- CPj 42.5 DF = 2.75,

- CRS 42.5 DF = 2.85 Type 1,

- CRS 42.5 DF = 2.94 Type 1.

This is in accordance with what is indicated in the three cement classes mentioned in **Table 3**.

But it seems very clear that the difference in the values the fractal dimension of the granular concrete mixtures is due to all the different granular classes used in the concrete, which have shown their effect on the granular distribution in the granular mixture. The smallest value of the fractal dimension of concrete is DFb = 2.61 and the highest value obtained from the fractal dimension of concrete is DFb = 2.87. This confirms the previous results of researcher Chouicha [2], which indicates that the optimal value of the fractal dimension does not exceed the value 3.

5. Transformation of grain size curves using software

Table 1 shows details of how to transform a grain size curve into a fractal line for a single type of cement, and analytically we draw the fractal line of the cumulative grain sizes according to the grain dimensions with a scale logarithmic. But the granular mixture is made up of several different constituents, which makes it somewhat difficult to calculate the different arithmetic operations involved in fractal analysis.

The different required steps on which the proposed software is based can be addressed through two main sections.

First: enter the necessary data relating to each component of the mixture, namely the granular extent, the density and the standardized dimensions of the sieves, as well as the experimental data for the particle size analysis of each granular class.

Second: this software would draw the particle size curve of the granular mixture composed of several granular constituents, then display the transformed fractal line, and plot the linear fit and give its linear relationship followed by the correlation coefficient R2.

We proposed to name the program GranuFract in relation to the transformation of the particle size curve into a fractal line.

Figure 9 shows the image designed in the GranuFract software to capture basic information (density, cumulative sieve, and dimensions of sieve openings) to obtain the fractal distribution.
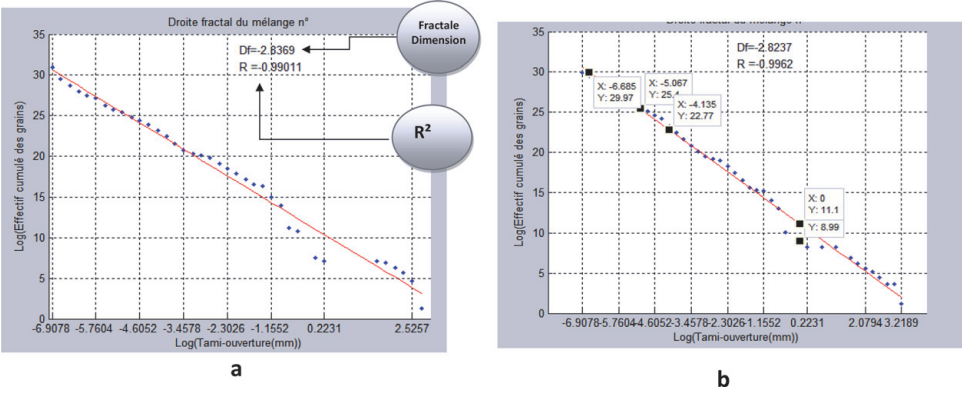
Concerning the transformation of the particle size curves to a fractal line, we adopted the method of fractal analysis carried out in the previous works [1, 29–31], as shown in **Figure 8**.

The GranuFract program allows us to easily determine the granular distribution of granular mixtures. This also helps us in the possibility of processing discontinuous grain size curves, that is to say by knowing the coordinates of each grain. It also helps to infer the variance of the coordinates to correct for items that have missing items (**Figure 10**).
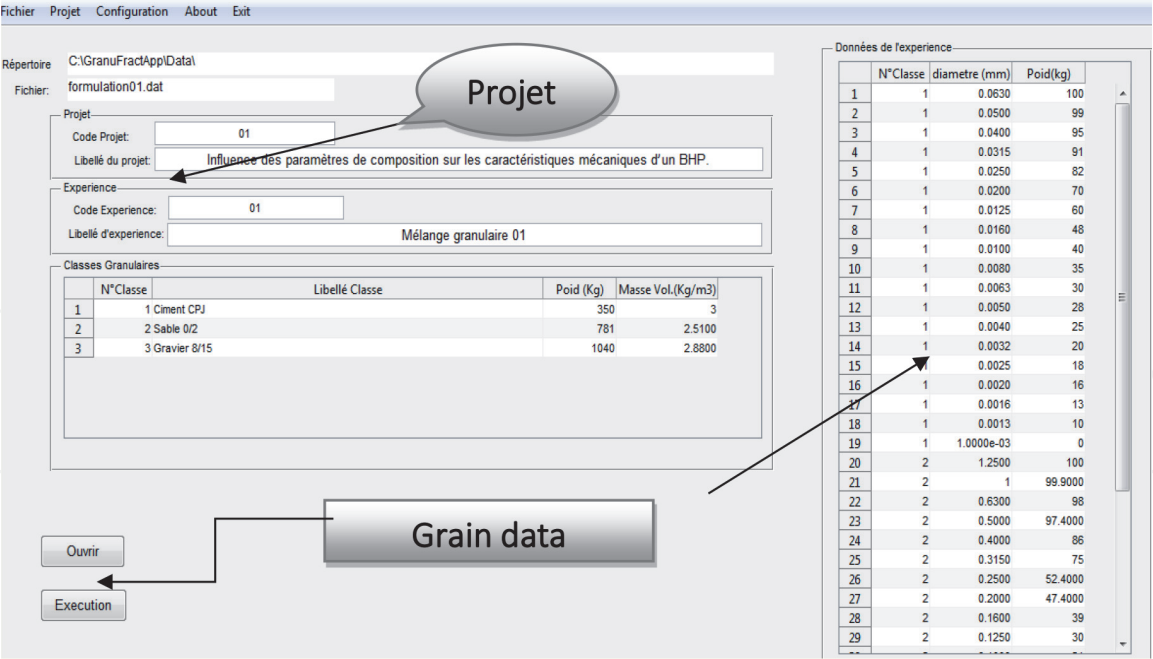
Figure 9.
Main window for entering basic information in the GranuFract software.

Figure 10.
Application of the transformation of a particle size distribution to a fractal distribution [1]. (a) Fractal line of the mixture. (b) Presentation of their coordinates.

6. Validation of software results

It is necessary to verify the data obtained from the program GranuFract, we have adopted ... the necessary procedures to compare the results that they obtained from the proposed software GranuFract and those that they obtained in the usual way, that is ie a graphical analysis using one of the mathematical programs "Origlab" and after a series of calculations The repeated values for each component of the granular mixture shown in **Figure 11 (a)** and **(b)** [1] we give the adopted values of the fractal dimension resulting from the two methods, they obtained values with an ideal correlation coefficient, and the standard deviation is ±0.05. The values obtained by verification are:

According to 'GranuFract': DF = 2.82; R^2 = 0.99.

According to 'Originlab': DF = 2.83; R^2 = 0.99.

We draw the attention of those interested in such a study represented in the use of mathematical models to find solutions to the framework of the search for
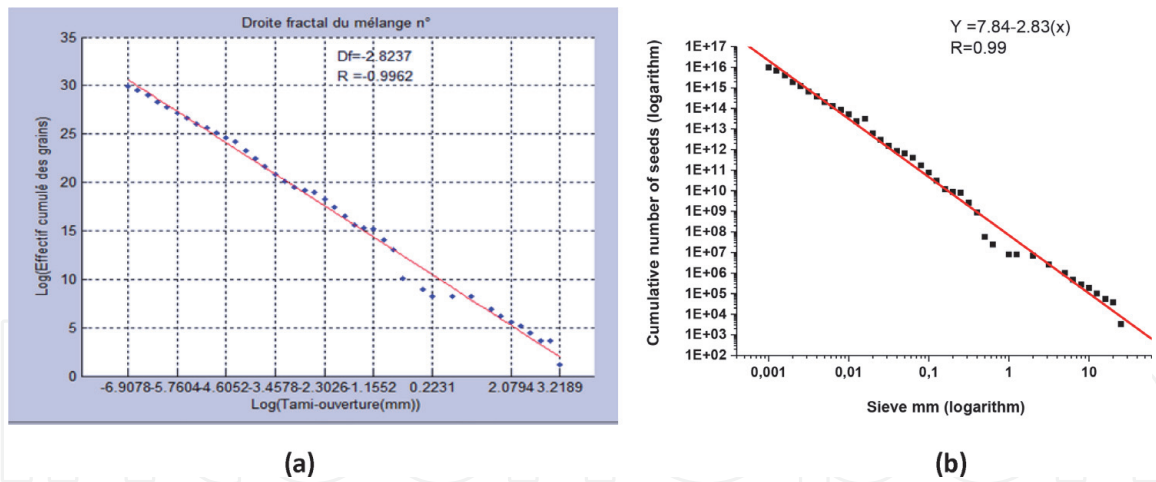
Figure 11.
Example of the validation of the transformation of a particle size curve to a fractal line [1]. a) Fractal line by GranuFract software, b) fractal line by originlab software.

concrete materials, that our main objective of this work is to highlight what we have achieved through to laboratory research and modeling in the application of the fractal analysis represented in the fractal dimension parameter and its positive results which have helped us to determine the granular distribution of the granular components of concrete through the granular mixture - the fractal line.

As for the proposed program, we look forward to improving and generalizing it by expanding a database that depends on a lot of experimental data for different components, including mineral additives and adjuvants, through which we hope to achieve a program to complete which will allow us to generalize it to all types of concrete, including innovative concrete.

7. Conclusion

This work allowed us to open a new window on the methods of concrete formulation using the granular distribution of granular mixtures to determine important properties in the definition of concrete, and we knew the efficiency of using modeling fractal to determine these granular mixtures of dry concrete for different concrete. It is now easy to know these granular mixtures according to their fractal dimension and their granular extent (FD, d/D).

Through this study, we show the contribution of an additional parameter for the formulation of concrete. It has already been mentioned that all concrete formulation methods depend on the granulation curve of the gravel mixture (sand gravel) to determine the gravel doses using the OAB grain reference curve, and the fractal model. Allow to determine the latter as a reference curve in the fractal dimension.

We initially proposed the "GranuFract" program, which converts the measurement curve of the grains of granular mixtures into a fractal line. This same program facilitates calculations and determination of the fractal distribution.

First of all, this work must be followed by careful empirical study to control the determination of granular aggregates with a concrete fractal line, in order to determine the dosages of the components of the concrete.

Secondly, we also aspire to extend this work by developing the "GranuFract" software in order to build an electronic database based on fractal modeling and obtained from particle size analysis in general.

Nomenclature

C	Cement dosage
E	Effective water dosage
d	Minimum grain size
D	Maximum grain size
d/D	Granular extent
E/C	Cement on water dosage report
G/S	Gravel on sand dosage report
N	Numbers of grains
N_c	Cumulative numbers of grains
EC	Cumulative workforce
ES	Sand equivalent
MF	Fineness modulus
ST_g	Total area of grains (mm^2)
FD	Fractal dimension
R^2	Correlation coefficient
SC	Crushed sand
SD	Dune sand
FDc	Fractal dimension of cement
FD_b	Fractal dimension of concrete mix
FD	Fractal dimension

Author details

Mhammed Abdeldjalil
Laboratory of Sustainable Development and Computer Science (LDDI), Civil
Engineering, University of Ahmed Draia Adrar, Algeria

*Address all correspondence to: abdeldjalilmed@univ-adrar.edu.dz

IntechOpen

References

[1] Abdeldjalil M, Yousfi S. dentification of sands of dune and concretes using a granular model - Case of arid region – Case Studies in Construction Materials 13 (2020) e00458. doi:10.1016/j.cscm.2020.e00458

[2] Chouicha K. La dimension fractale et l'étendue granulaire comme paramètres d'identification des mélanges granulaires, Mater Struct. 39 (2006) 665–681. doi:10.1617/s11527-006-9113-0

[3] De Larrard F. Structures granulaires et formulation des bétons. LCPC Nantes, France. 2000

[4] Gamil Y, and al, Simulation and Development of Instrumental Setup to Be Used for Cement Grouting of Sand Soil. Italian Journal of Science & Engineering Vol. 1, No. 12017.

[5] L. Qing, Q. Qingli, Z. Jun, W. Jiyang, Z. Qiang. Fractal dimension of concrete incorporating silica fume and its correlations to pore structure, strength and permeability Constr Build Mater 228 (20) (2019) 116986. https://doi.org/10.1016/j.conbuildmat.2019.116986

[6] L. Dan, N. Ditao, F. Qiang,L. Daming. Fractal characteristics of pore structure of hybrid Basalt–Polypropylene fibre-reinforced concrete. Cem Concr Compos, 109 (2020) 103555 https://doi.org/10.1016/j.cemconcomp.2020.103555

[7] Z. Di, S. Weidong, F. Jianxin, X. Gaili, L. Jiajian, C. Shuai. Research on mechanical characteristics, fractal dimension and internal structure of fiber reinforced concrete under uniaxial compression. Constr Build Mater 258 (20) (2020) 120351. https://doi.org/10.1016/j.conbuildmat.2020.120351

[8] Z. Peng, G. Zhen, S. Yan, L. Yuqiang, L. Jiazheng. Effect of large broken stone content on properties of roller compacted concrete based on fractal theory. Constr Build Mater (30) (2020) 120821 https://doi.org/10.1016/j.conbuildmat.2020.120821

[9] A. Rezaie , JP .Mauron Antoine, K. Beyer, Sensitivity analysis of fractal dimensions of crack maps on concrete and masonry walls, Autom. Constr. 117, (2020) 103258. https://doi.org/10.1016/j.autcon.2020.103258.

[10] Y. Xu ang, W. Mingzhi. Fractal dimension analysis of aggregate packing process: A numerical case study on concrete simulation. Constr Build Mater 270 (8) (2021) 121376 https://doi.org/10.1016/j.conbuildmat.2020.121376

[11] Féret R. Sur la compacité des mortiers hydrauliques. Annales des Ponts et Chaussées. Édition Paris, Vve C. Dunod, Série 7 vol. 4, 1892; pp. 5-164.

[12] Fuller. S.Thompson Proportion for concrete. Am Contractor, pp28-66,. 1907

[13] Abrams Duff A. Design of Concrete Mixtures. Bulletin No. 1, Structural Materials Research Laboratory, Lewis Institute, Chicago, 20 pp, 1918, (consulted le 2016). https://www.forgottenbooks.com/es/download/DesignofConcreteMixtures_10276916.pdf.

[14] Bolomey J. Granulation et prévision de la résistance probable des bétons, Bulletin technique de la Suisse romande, N°7, 62eAnnée, (1936) pp. 73-78. https://www.e-periodica.ch/cntmng?pid=bts-002:1936:62:95

[15] Caquot A. Role of inert materials in concrete. Memory of the society of civil engineers of France. 1937

[16] Faury J. Concretes: Influence of its inert constituents, rules to adopt for its best composition, its preparation and its

transport to construction sites: Hachettes. 1944

[17] Joisel A. Compositions of hydraulic concrete" Annals of the ITBTP (58), Series: Concrete and reinforced concrete. 1952

[18] Cassagnabere F. Produits prefabriques en béton file : vers l'amélioration des performances du matériau pour mieux gérer le procède de production. [thesis] Université de Toulouse III France. 2007

[19] Dreux G, Festa J. " Nouveau guide de béton " Eyrolles. 1995

[20] Baron Lessage J. The composition of hydraulic concrete: from the laboratory to the site. LCPC research report (64). 1976

[21] NF P18 452 "Measurement of the flow time of concretes and mortars with the maneuverimeter", AFNOR sagaweb,

[22] B. Mandelbort, Fractal objects, shape, chance and dimension. Flammarion Editions

[23] Sebsadji S.K, Chouicha K. Determining periodic representative volumes of concrete mixtures based on the fractal analysis, J Sold Struct, 49 (2012) 2941–2950.

[24] Marmi S. Dimension Fractal, [thesis] ; Mohamed Khider University, Biskra Algeria 2019

[25] Lecomte A, Thomas A. Caractère fractal des mélanges granulaires pour bétons de haute compacité. Mater Struct. 25 (5) (1992) 255–264. https://doi.org/10.1007/BF02472666

[26] Ansari A. ARTS, study report on the composition of the project concrete in Adrar, Algeria 2014

[27] Benhassen Y LECT, study report on the compositions of concrete at (Adrar, Tinerkouk, Tsabit, Cherouine, B B Mokhtar, Inzegmir), Adrar Algeria. 2012

[28] Mounir A. LAMCO, study report on the composition of the project concrete in Adrar, Algeria. 2013

[29] Abdeldjalil M. La compacité optimale des mélanges granulaires secs; application de l'analyse fractale. [thesis]; University of the U.S.T.O. Oran Algeria 1999

[30] Achouri F. Lecture des méthodes de formulation du béton à l'aide du modèle fractal de l'empilement granulaire, [thesis] ; University of the U.S.T.O. Oran Algeria 2011

[31] Bouregba A. Benarba M. Analyse fractale et compacité des mélanges granulaires secs, application au béton de sable. [thesis] ; University of the U.S.T. O. Oran Algeria 1998.