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Characterization of lateritic nodules for use in concrete and comparative study of simple compressive strengths of concretes based on different lateritic nodules

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Abstract

Our research focused on the "characterization of lateritic nodules for use in concrete and comparative study of the simple compressive strengths of concretes based on different lateritic nodules". Characterization tests carried out on the constituent materials of the concrete (lagoon sand from Dêkoungbé, lateritic nodules from Avagoudo to Allada, from Avlamè to Zogbodomey, from Kika to Bétérou, from Tourou to Parakou, from Logozohè to Savalou and from Hounkpogon to Dassa) allowed us to appreciate the variation of their granulometry, to realize the concrete formulations relating to the six types of lateritic nodules, by the formula of DREUX - GORISSE and afterwards to compare the various results resulting from the tests of resistance to the simple compression performed on the cylindrical specimens made from these nodules. For this purpose, series of nine (9) cylindrical test tubes of concrete were made for each type of sample of laterite nodules. Simple compression tests were performed at various ages (7, 21 and 28 days) until breaking. The various results obtained allow us to conclude on the one hand, that the lateritic nodules can be used as aggregates instead of gravel in the concrete and on the other hand, that the compressive strengths to 28 days (fc28) concretes dosed at 350Kg/m3 based on the lateritic nodules tested are between 16.64 and 19.17MPa and therefore they can be limited to 16.70MPa during sizing.

Keywords: Lateritic nodules, lagoon sand, granulometry, concrete, simple compression, breaking stresses.

Introduction

In order to significantly and efficiently reduce the cost of building housing or housing, basic socio-community and sanitation infrastructure in underdeveloped African countries and in particular Benin, it is important to promote quality local materials serve for their realization. This promotion basically goes through the research and scientific study of these local materials which must meet the standards in the field from the point of view of resistance and behavior.

All over the world, lateritic soils have been the subject of several research projects. These lateritic soils "are common between the tropics of cancer and Tropic of Capricorn, in South America, in the heart of Africa and also in India and parts of Asia. They represent one-third of the Earth's land and feed a large part of Humanity"[1]. "They come from mineral materials"[2]. Otherwise, "laterite derives from the alteration of various materials: crystalline eruptive rocks, sediments, detritic deposits, volcanic ash etc."[3]. We have therefore decided to study the resistance behavior of different concrete types of laterite nodules extracted from these soils in several regions or departments of our country Benin where deposits of lateritic nodules are abundant. Hence our topic entitled "Characterization of lateritic nodules for use in concrete and comparative study of the simple compressive strengths of concretes based on different lateritic nodules" which comes at the right time to answer lateritic nodule substitution questions by gravel (which today is excessively expensive and is becoming scarce).

Materials and methods

In order to obtain reliable results, we have first identified the different deposits of aggregates (sands and lateritic nodules) that can enable us to produce good quality lateritic nodule concrete. We therefore chose as aggregates the lagoon sand from Dêkoungbé and the lateritic nodules from the Avagoudo quarries in Allada (Atlantic Department), from Avlamè to Zogbodomey (Zou department), from Kika to Bétérou (department of Donga), from Tourou to Parakou (Borgou department), from Logozohè to Savalou and from Hounkpogon to Dassa (Collines department).

The various career points taken and subject of this study are located on the Figure-1.

We proceeded to the different sampling samples. Then, according to the standards NF EN 933 and NF EN 1097, we have by means of laboratory tests, identified and characterized these aggregates. The tests were conducted at the Laboratory of Tests and Research in Civil Engineering (LERGC) located on the campus of the University of Abomey-Calavi (UAC) specifically to the Department of Civil Engineering of the Polytechnic School of Abomey-Calavi (EPAC).

Figure-1: Location of the deposit points of lateritic nodules studied (✚)

The results of characterization tests obtained allowed us to study their granulometry; to produce, by the formula of DREUX-GORISSE[4], the concrete formulations relating to the six types of lateritic nodules.

We then proceeded with the preparation of the concretes and the realization of the suitability tests: Abrams cone slump measurement test (NF EN 12350-2) and simple compression test (NF EN 12390-3)[5]. For this purpose, according to standard NF EN 12390-2, using the reference molds made of steel (NF EN 12390-1)[6], series of nine (9) cylindrical test tubes of concrete were made for each type of sample of lateritic nodules and have been preserved. The simple compression tests (NF EN 12390-3) were carried out at various ages (7, 21 and 28 days) until rupture. At the end of these tests, we made the comparative study of the different results from these tests.

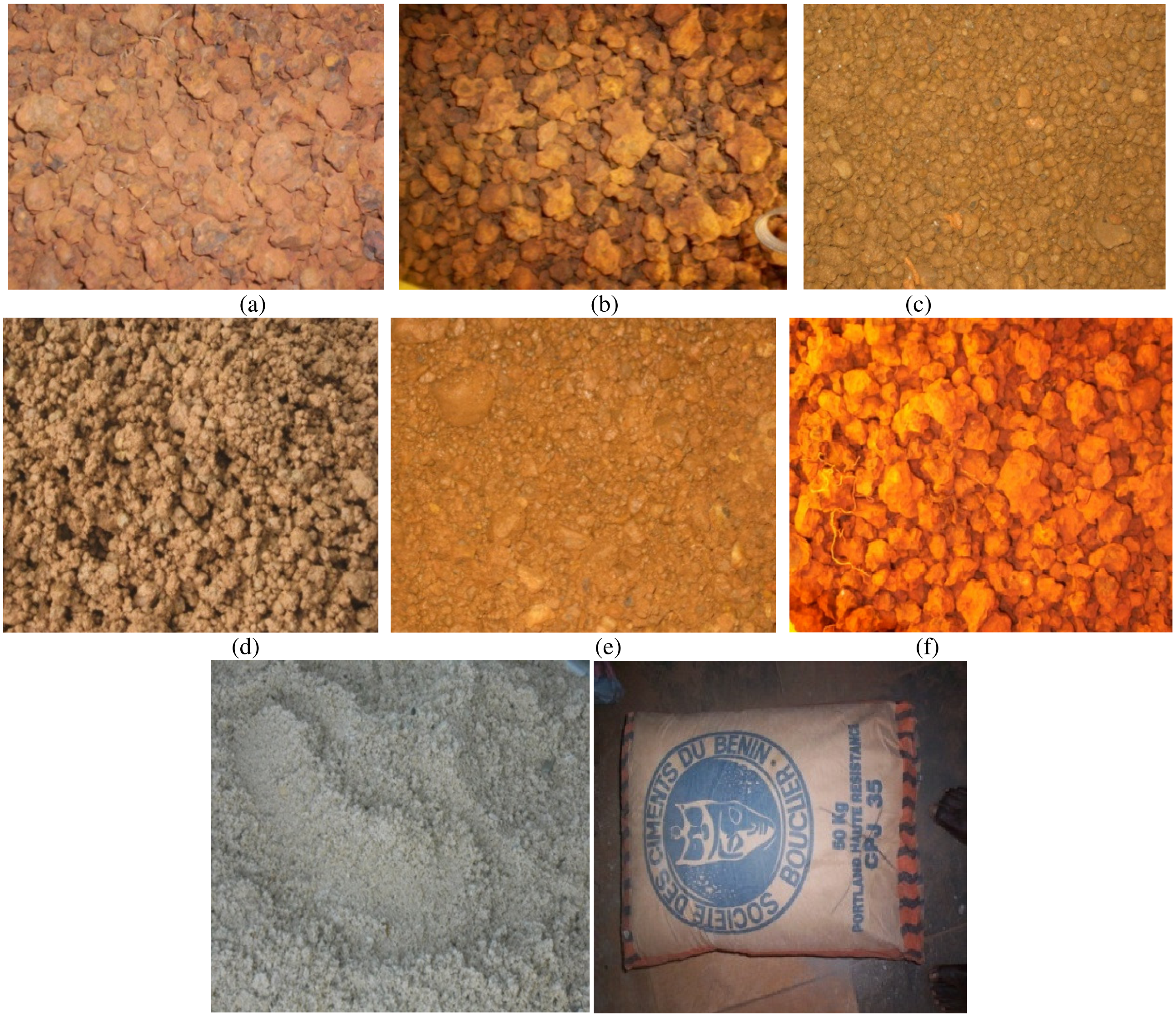
The materials selected and used for this study are shown in Figure-2 (a, b, c, d, e, f, g and h).

Granulometric Analysis : Granulometric analysis of aggregates were carried out at LERGC according to standard NF EN 933-1.

Materials and methods used: To carry out this test, we used the materials listed: i. A series of sieves: 25; 20; 16; 12.5; 10; 8; 6.3; 5; 4; 2.5; 2; 1.25, ii. An oven with thermostat at 105°C± 5°C; iii. A balance of 15Kg range and precision 5g; iv. Two trays; v. A container; vi. A bowl; vii. Separator for aggregates (lateritic nodules).

The particle size analysis is done by sieving for aggregates. The method used is to pass the material on a series of sieves whose succession defines a series of standardized intervals. The different percentages of rejects (part of the granules remaining on the sieve) and sieves (part of the granules passed through the sieve) are then obtained. These different percentages of rejects and sieves as a function of the sieves used allow us to trace the granulometric curve which reflects the weight distribution of the aggregates. It is an essential data for the formulation of concretes.

Compression tests: The tests were carried out according to standard NF EN 12390-3. Tests were carried out on samples of 7 days old, 21 days old and 28 days old. In each group of samples, we made and tried three (3) cylindrical test tubes. The material used is composed of: i. A device for surfacing cylindrical specimens; ii. A simple compression test press.



(a) (b) (c)
(d) (e) (f)
(g) (h)

Figure-2: a) Lateritic nodules of Avlamè quarry at Zogbodomey, b) Lateritic nodules of Avagoudo quarry in Allada, c) Lateritic nodules from Kika quarry to Bétérou, d) Lateritic nodules of Tourou quarry at Parakou, e) Lateritic nodules from Logozohè quarry to Savalou, f) Lateritic nodules from Hounkpogon quarry to Dassa, g) Lagoon sand from Dèkoungbé to Godomey, h) CPJ 35 cement.

(a) (b) (c) (d)

Figure-3: a) Abrams cone slump measurement test; b) Making cylindrical concrete specimens, c) Surfacing of cylindrical specimens; d) Simple compression test press.

The surface test specimen was centered on the test press. It was gradually loaded until the break. The maximum breaking load was recorded during each test.

Results and discussions

Granulometric Analysis: The different test results obtained in Table-1. The granulometric curves resulting from these different results obtained and the characteristics resulting from these different curves are presented below as follows.

Table-1: Summary of the different percentages of sieves of lateritic nodules according to the sieve modules.

Sieve (mm)	Sieve modules	Nodules per site (%)					
		Avagoudo (Allada)	Avlamè (Zogbodomey)	Kika (Bétérou)	Tourou (Parakou)	Logozohè (Savalou)	Hounkpogon (Dassa)
1.25	32	0.79	0.00	1.73	1.35	1.41	2.26
2	34	1.01	0.28	1.88	1.45	1.62	2.33
2.5	35	1.40	0.34	2.38	1.67	2.02	2.43
4	37	5.61	0.45	7.39	6.74	7.29	4.39
5	38	12.46	0.85	22.88	15.60	13.39	8.38
6.3	39	23.91	4.43	38.35	29.80	23.00	16.97
8	40	37.21	15.28	57.84	48.40	37.35	33.68
10	41	52.47	34.55	79.22	61.48	52.59	54.35
12.5	42	68.74	59.32	91.65	73.96	65.90	74.69
16	43	81.20	84.77	98.44	87.08	80.10	88.34
20	44	95.29	97.61	99.78	95.87	93.73	95.71
25	45	100	100	100	100	100	100

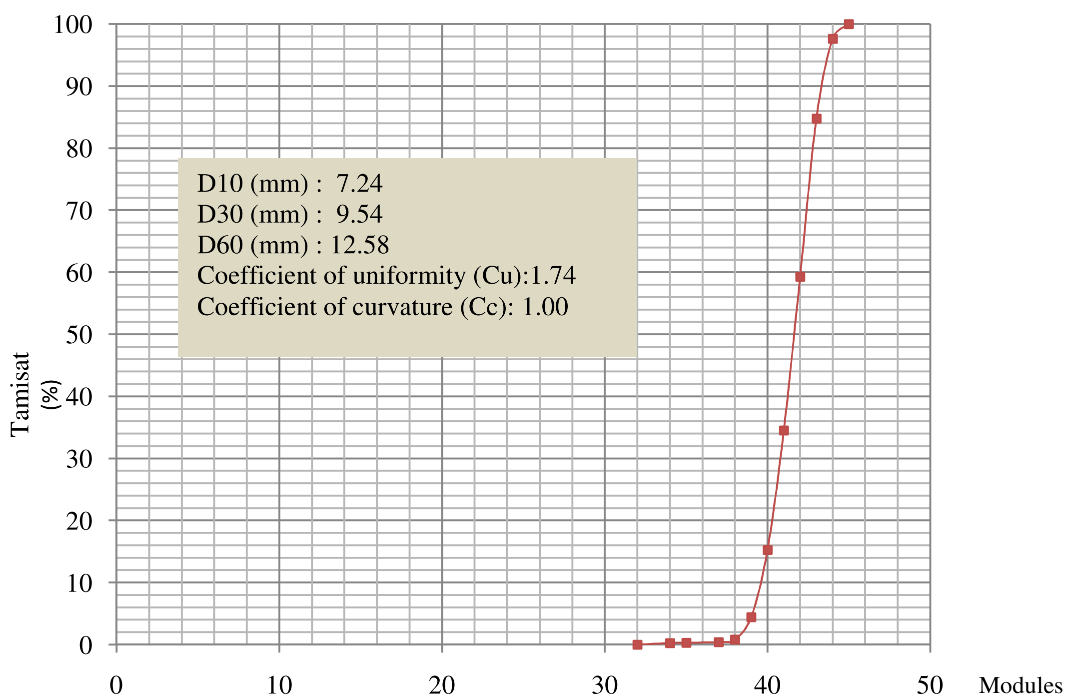


Figure-4: Granulometric curve of Avlamè's nodules (Zogbodomey).

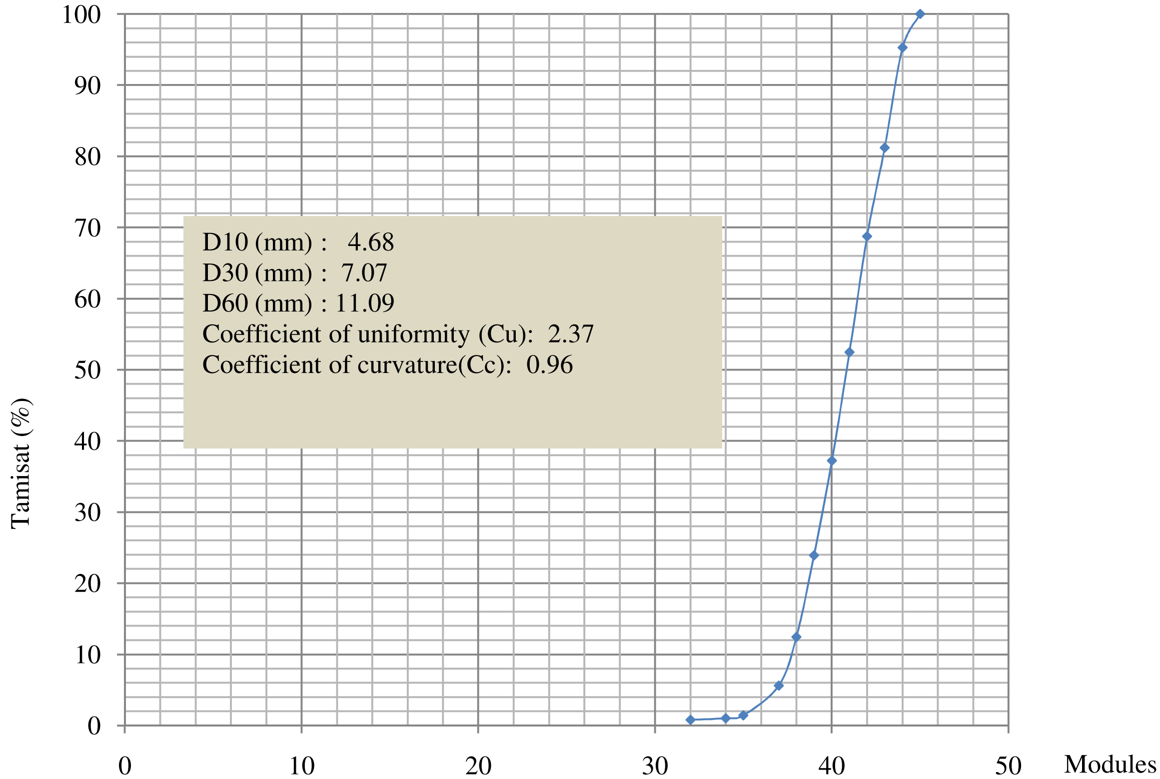


Figure-5: Granulometric curve of Avagoudo's nodules (Allada).

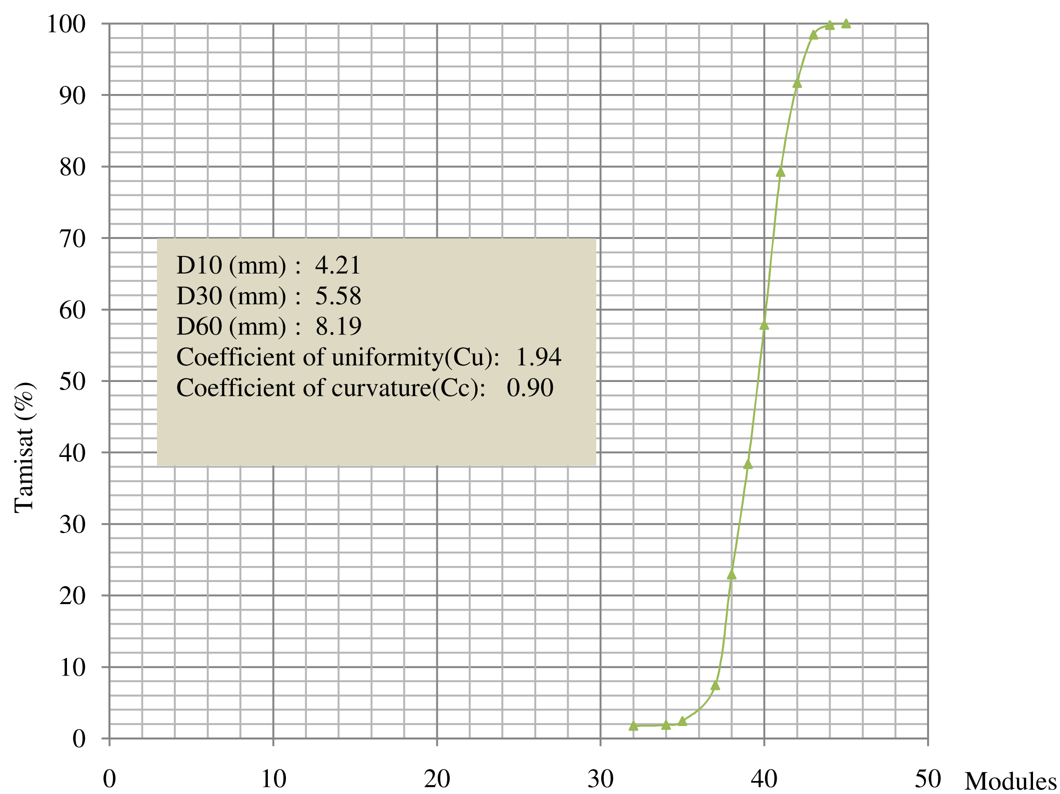


Figure-6: Granulometric curve of Kika's nodules (Bétérou).

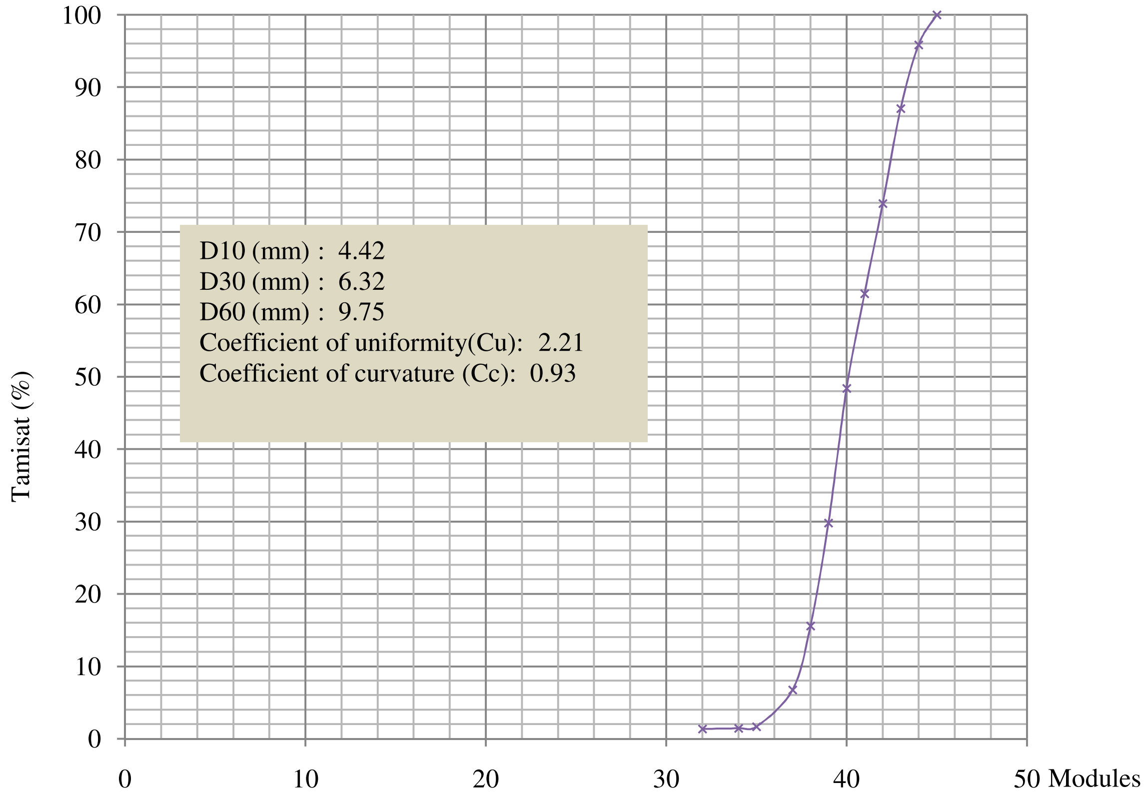


Figure-7: Granulometric curve of Tourou's nodules (Parakou).

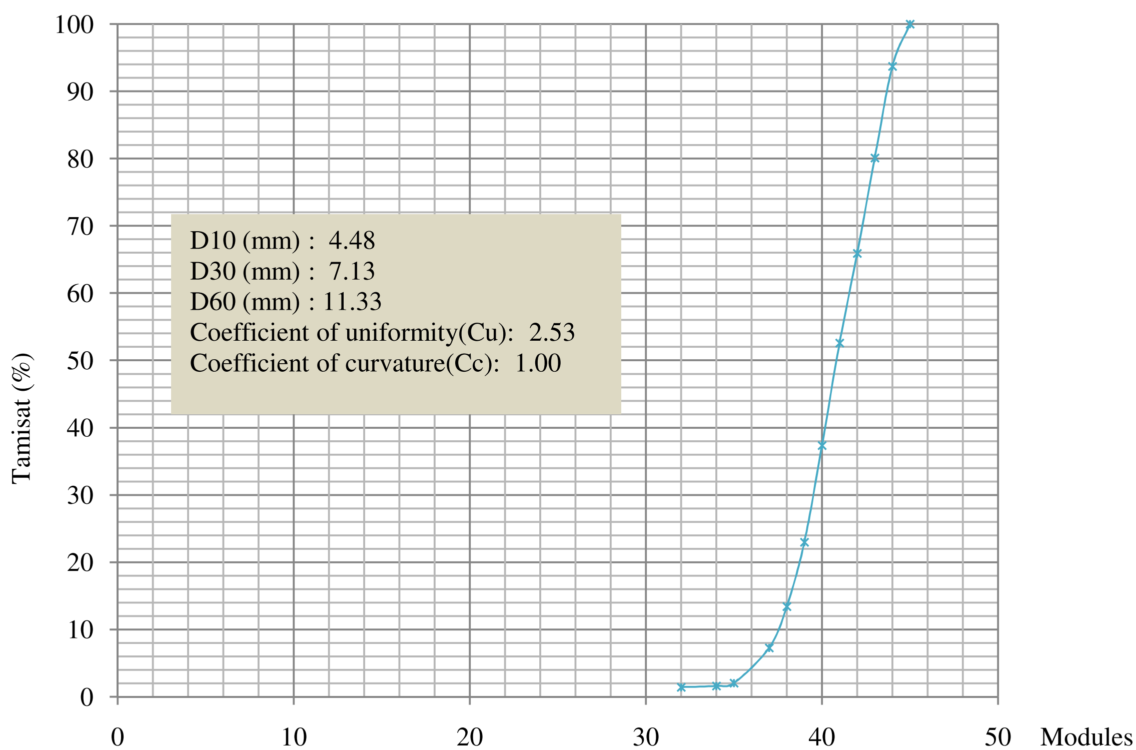


Figure-8: Granulometric curve of Logozohè's nodules (Savalou).

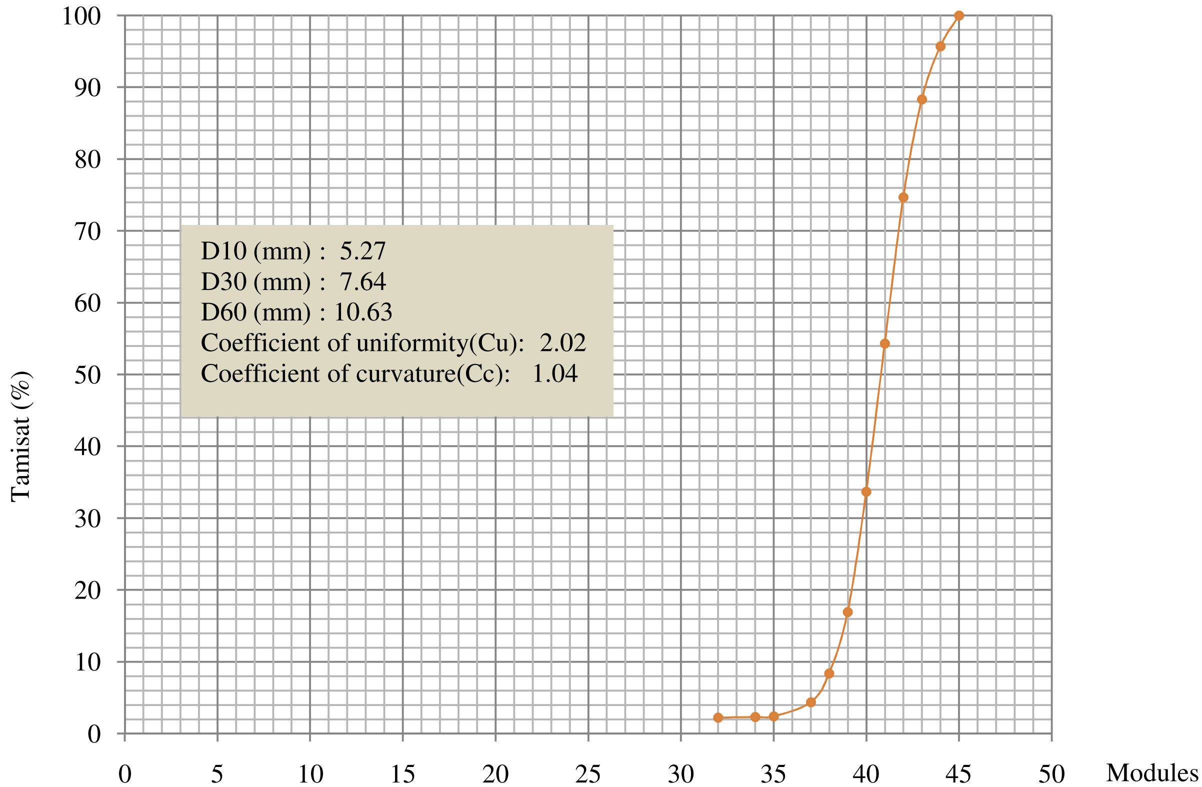


Figure-9: Granulometric curve of Hounkpogon's nodules (Dassa).

Table 2: Summary of different characteristics of lateritic nodules

Designation	Nodules per site					
	Avagoudo (Allada)	Avlamè (Zogbodomey)	Kika (Bétérou)	Tourou (Parakou)	Logozohè (Savalou)	Hounkpogon (Dassa)
D10 (mm)	4.68	7.24	4.21	4.42	4.48	5.27
D30 (mm)	7.07	9.54	5.58	6.32	7.13	7.64
D60 (mm)	11.09	12.58	8.19	9.75	11.33	10.63
Coefficient of uniformity (Cu)	2.37	1.74	1.94	2.21	2.53	2.02
Coefficient of curvature (Cc)	0.96	1.00	0.90	0.93	1.00	1.04

Note that: Coefficient of Uniformity[7] (Cu) is the ratio $\frac{D60}{D10}$

Coefficient of Curvature[7] (Cc) is the ratio $\frac{(D30)^2}{(D10)\times(D60)}$

Where: D60, D30, and D10 are the particle diameters corresponding to 60, 30, and 10% fineron the cumulative particle-size distribution curve, respectively.

The analysis of the different curves and the characteristics relating to the different lateritic nodules enables us to conclude and retain the following: i. The granular class of the different lateritic nodules tested is: 1.25mm/25mm because for each type of nodule, we have[8]: (a) The refusal on the sieve of mesh D = 25mm is lower than 15% (D>1.56d), (b) Screen sieves of mesh size=1.25mm are less than 15% (D>1.56d), (c) The refusal on the mesh sieve 1.56D=1.56x25mm=39mm is equal to 0, (d) The sieve under the sieve of mesh 0.63d=0.63x1.25mm=0.79mm is equal to 0 (<3%), ii. There is a quasi-superposition of grain size curves; iii. All grain size curves are continuous[9]. iv. Cu> 2 for lateritic nodules of Avagoudo; from Tourou. Logozohè and Hounkpogon; their particle size is therefore spread. On the other hand, for the Avlamè and Kika nodules, their granulometry is uniform because Cu<2.[10] v. All six types of lateritic nodules

studied are clean severely graded because for each type of nodule, there are:[11] (a) More than 50% of the elements are greater than 0.08mm and have a diameter greater than 2mm, (b) Less than 5% of elements are less than 0.08mm, (c) Cu<4.
In sum, lateritic nodules can be used for aggregates in place of gravel in concrete.

Simple compression tests: The different test results obtained in Table-3.

Table-3: Summary of the simple compressive rupture loads according to ages.

Samples based on nodules	Breaking load (KN)		
	7 days	21 days	28 days
Avagoudo (Allada)	244.36	349.15	369.00
Avlamè (Zogbodomey)	256.60	366.52	387.33
Kika (Bétérou)	252.33	338.50	377.00
Tourou (Parakou)	236.33	320.93	340.33
Logozohè (Savalou)	234.00	322.50	357.34
Hounkpogon (Dassa)	252.00	321.67	351.68

The different breaking stresses and maturation speeds obtained and recorded in the table are as follows:

$\sigma_{rup} = \frac{F_{max}}{S}$ and $V = \frac{C_i - C_j}{n_i - n_j}$ with S the fracture section, C_i and C_j the breaking stresses at i and j days; n_i and n_j the numbers of days.

Table-4: Table of rupture stresses and maturation speeds.

Samples based on nodules	Breaking Stress (MPa)			Maturation Speeds (MPa/day)	
	7 days	21 days	28 days	7 to 21 days	21 to 28 days
Avagoudo (Allada)	11.94	17.06	18.03	0.366	0.139
Avlamè (Zogbodomey)	12.70	18.14	19.17	0.389	0.147
Kika (Bétérou)	12.47	17.31	18.64	0.346	0.190
Tourou (Parakou)	11.62	15.91	16.81	0.306	0.129
Logozohè (Savalou)	11.58	16.08	17.65	0.321	0.224
Hounkpogon (Dassa)	12.39	15.99	17.51	0.257	0.217

The curves of breaking stress according to age are as follows:

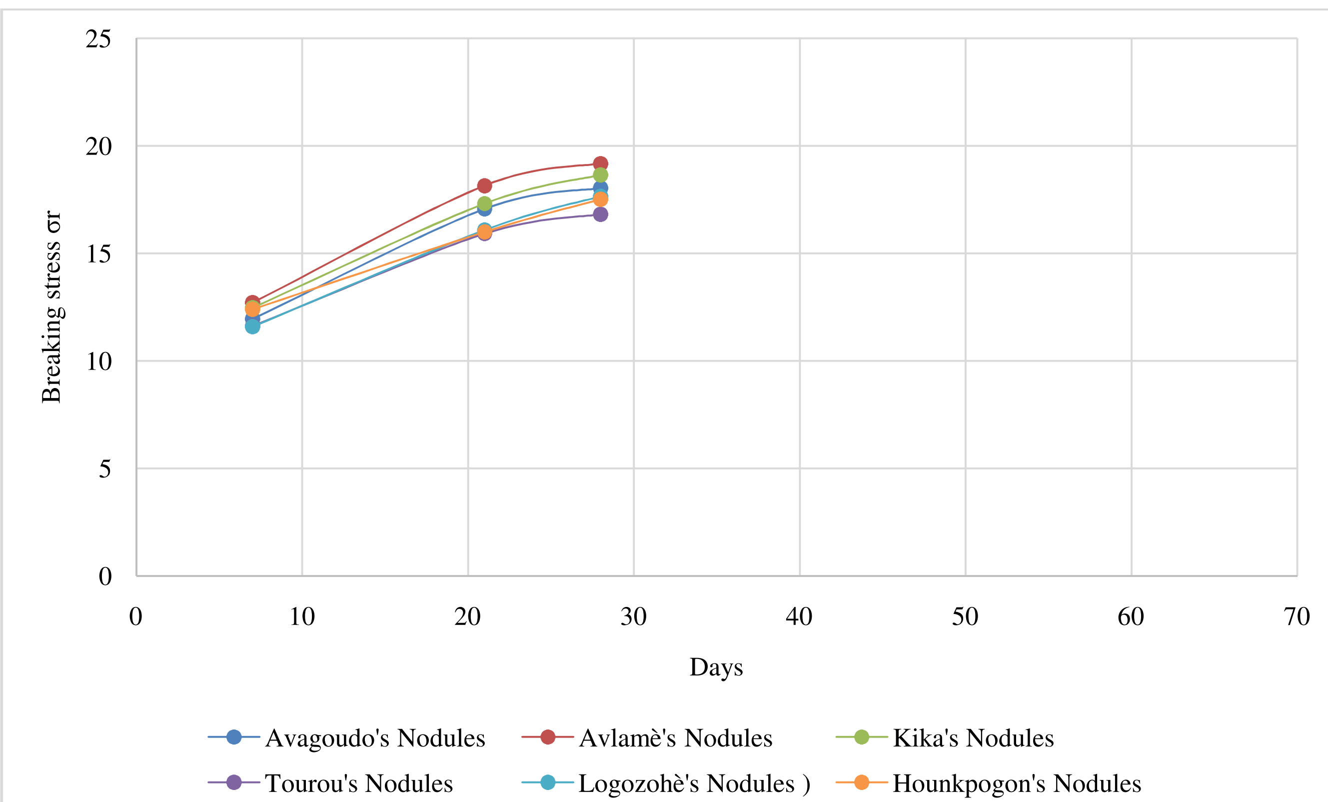


Figure-10: Different curves of breaking stress according to ages.

Based on results from simple compression tests, we find that at 28 days of age; the different breaking stresses of concrete specimens of laterite nodules dosed at 350Kg/m^3 are between 16.64 and 19.17MPa.

Determination of the characteristic value of the concrete compressive strength of laterite nodules at 28 days according to the normal law (Laplace-Gauss law)[12-13].

Let f_k denote the characteristic compression resistance at the risk of 5% and admit that the values of the constraints obtained by crushing are distributed according to the normal law. Let m and s be the mean and standard deviation of the data, respectively.

According to Eurocode, characteristic value of resistance at the risk of 5% is given by $P(X < Z_k) = 5\%$[14]. So we have:

Table 5: Calculation table of the mean and standard deviation

No. of samples	$Xi = \sigma_{c28}$	Xi - m	(Xi - m)²
1	18,03	0,06	0,00
2	19,17	1,20	1,44
3	18,64	0,67	0,45
4	16,81	-1,16	1,34
5	17,65	-0,32	0,10
6	17,51	-0,46	0,21
Mean (m)	17,97		
Variance (s²)	0,59		
Standard deviation(s)	0,77		

With $m = \frac{1}{n}\sum_{i=1}^{n} X_i$ and $s^2 = \frac{1}{n}\sum_{i=1}^{n}(X_i - m)^2$. By asking $Z = \frac{f-m}{s}$, we have $Z_k = \frac{f_k - m}{s}$

According to the normal law table, $P\left(Z < \frac{f_k - m}{s}\right) = 0,005$. So we have: $\frac{f_k - m}{s} = -1,645$ and $f_k = 16,70\text{MPa}$.

It may therefore be necessary to limit the compressive strengths at 28 days (f_{c28}) to 16.70 MPa for concretes based on lateritic nodules of the different quarries tested.

Conclusion

Nowadays, the socio-economic realities in Africa and particularly in Benin, health, environmental and housing problems are concerns that must be answered. It is necessary that the politics will involved in the popularization of local materials. At the end of our study which focuses on "Characterization of lateritic nodules for use in concrete and comparative study of the compressive strengths of concrete based on different lateritic nodules", we can generally conclude, on the one hand, Lateritic nodules can be used for aggregates in place of gravel in concrete and on the other hand, that the 28 days compressive strengths (f_{c28}) of lateritic nodule concretes measured at 350Kg/m^3 are between 16.64 and 19.17MPa. Therefore, they can be limited to 16.70MPa during sizing.

It will be possible to envisage for the continuation, the study of the conditions of use of this type of concrete in the houses with light load-bearing structures in our villages for the happiness of our populations especially rural.

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