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Study of the impact of kaolinite contained in lateritic nodules on the mechanical behaviour of concrete

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Abstract

For more than decades, research work has enabled the progressive mastery of the characteristics of lateritic concrete, although the performance of lateritic concrete is less satisfactory than that of ordinary concrete. The availability of lateritic gravel in Benin stimulated us to address the causes of this low resistance compared to common concrete. Specifically, our work concerned the impact of the presence of kaolinite naturally contained in lateritic nodules on the behavior of concretes. The mineralogical characterization of lateritic nodules and on the current aggregate showed that the kaolinite content in the nodules lateritic from Allada, Adjohoun, Houéyogbé and rolled gravel are respectively 13.00%; 21.00%; 7.00%; and 0.00%. The investigation is made on nodules which belong to the same granulometric zone and their hardness is equal to 46%. The rate of cleanliness, the absolute density of the nodules varies respectively from 96% to 97% and from 2.70 t/m^3 to 2.76 t/m^3. The compressive strength of lateritic concretes, for permanent preservation of test specimens in water, varies from 23.38 MPa to 24.42 MPa, 23.45 MPa to 24.40 MPa and 23.15 MPa to 24.15 MPa respectively at 28 days, 60 days and 360 days of ages while the strength of ordinary concrete is 27.57 MPa, 27.58 MPa and 27.58 MPa respectively at 28 days, 60 days and 360 days of ages. It appears from this analysis that kaolinite would adversely affect the mechanical performance of lateritic concrete after 60 days of storage in water. The negative effect of kaolinite on the mechanical behavior of lateritic concrete is not only related to the rate of kaolinite but also to other chemical elements contained in the nodules.

Keywords: Mineralogical Characterization, Nodule, Lateritic Concrete, Ordinary Concrete, Hardness, Mechanical Strength

1. Introduction

The studies carried out by the authors reveal that most ordinary concretes offer better compressive strength than lateritic concretes (Joseph O. Ukpata *et al*., (2012) [1], Venkata Rao M. and al., (2016) [2], Vengadesh Marshall Raman and al., (2017) [3], Ephraim M. E. and al., (2018) [4], Afolayan, and al., (2019) [5] The high cost of building structures and particularly socio-economic housing, characterized by a Soaring cost of purchasing construction materials, especially gravel, has led researchers to use lateritic nodules as a partial or total replacement for ordinary gravel. Thus, lateritic nodules are becoming more and more used in concrete due to the scarcity of current gravels.

Laterite is a construction material, ecological and available in the tropical region. Lateritic soils are widely used in West Africa for constructions with a rather light structure, Osadebe N.N. and al. (2007) [6]. The work of Nahon Daniel, (2003) [7] has shown that laterite is widespread throughout the world and particularly in the tropical region of Australia, India, South-East Asia, South America and Africa. Benin is an African country located in the inter-tropical zone and is largely covered with laterites. Several investigations have been made on the discovery of this deposit in Benin by geologists and other researchers, Sagbohan W. (1972) [8], Affaton P., and al., (1978) [9], Houéssou and Lang, (1978) [10], Gbaguidi V.S. and al. (2018) [11]. The availability of laterite has propelled researchers to focus on the causes of the low strength of laterite nodule concretes. This research aims to study the influence of the mineralogical characteristics of lateritic nodules and more precisely of kaolinite in concrete. Our experimental investigation concerns three lateritic nodules taken from three different localities and a rolled gravel. The mineralogical tests carried out on the three nodules and the rolled gravel revealed the presence of kaolinite in the various lateritic nodules and the absence of this crystalline phase in the current aggregate. The purpose of this research is to study the effect of kaolinite on the mechanical behavior of concrete and specifically to suggest a corrective solution. The methodology adopted is first of all to carry out physico-mechanical tests on the various materials used in the formulation of the various concretes. Then the making of concrete according to the Dreux Gorisse method with the same sand, cement and water. Finally, an analysis of the compressive strengths in relation to the kaolinite content in each coarse aggregate will lead us to a conclusion.

2. Materials, equipment and methods

2.1 Materials and borrow sites

Three lateritic nodules, rolled gravel and sand were the materials requested during this study. The lateritic nodules come from the lateritic gravel taken from the different sites. The following figure provides information on the localities of the samples.

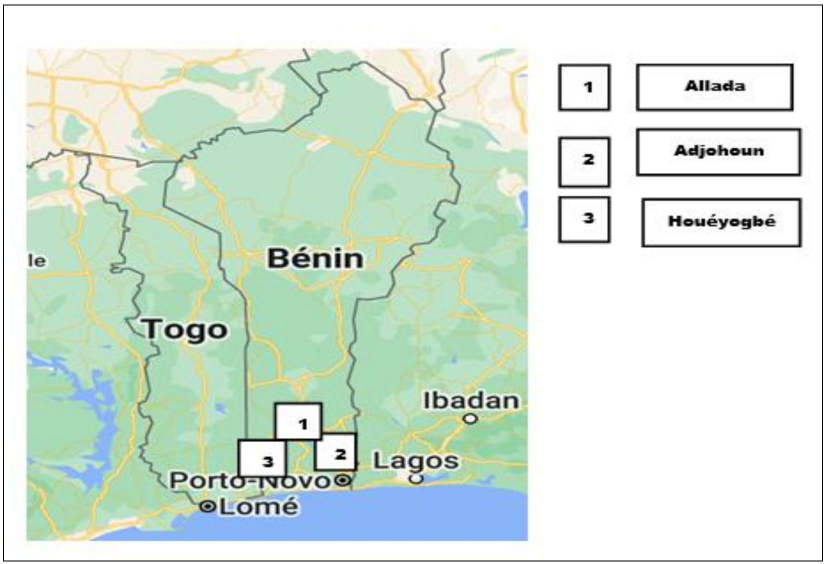

Fig 1: Localities of the samples

The photo below illustrates the lateritic nodules of the three sites.

a) Nodule of ALL b) Nodule of ADJ c) Nodule of HOU

Fig 2: Lateritic nodules of Allada, Adjohoun and Houyéyogbé

The concretes subjected to the mechanical tests are made according to the Dreux Gorisse method and kept in a water tank at a temperature of 20°C±2°C until the date of the crushing.

2.2 Experimental methods

2.2.1 Physico-mechanical characterization of nodules

The physico-mechanical characterization concerns in particular the cleanliness tests, the densities, the granulometric analysis, the hardness test of the nodules.

2.2.2 X-ray diffraction of nodules

X-ray diffraction is carried out by several authors in order to determine the various crystalline phases of lateritic nodules. Our study focused specifically on the level of kaolinite in the nodules.

Y. Milogo, (2008) [12], Gustave Mukoko Kalenda, (2014) [13] and Mahamadou Souley Issiakou and al. (2015) [14] studied the crystalline phases of laterites. The kaolinite contents of the various localities are summarized in the following table.

Table 1: Summary of the mineralogical characterization of the nodules

Localities	Sapouy	Kakanda	Kapushi	Torodi	Oullam	Say	Fillingué	Dosso
Kaolinite (%)	26.00	34.87	19.77	40.60	45.60	58.10	47.40	72.50

2.2.3 Concrete formulations

All the concretes (lateritic and common) were made with the same sand from Ahlan, the same type of Lafarge cement, the same water. All the reasoning will be carried out by considering the rate of the chemical element contained in the mass of nodule which made it possible to make a concrete specimen of 16x32 cm2. The method used is that of Dreux Gorisse and the targeted subsidence is 6 cm (J. Bolomey, (1931) [16], Dreux Gorisse, (1979), Dreux Gorisse, (1990) [17], Lanchon R. (1977) [18], Lanchon R. (1978) [19].

2.2.4 Mechanical characterization of lateritic concrete

The characterization of lateritic nodule concrete concerns in particular the performance of simple compression and tensile tests on various concrete specimens. Mechanical performance tests are carried out on concrete at 7 days, 28 days, 60 days, 90 days and at 360 days.

3. Results and discussions

3.1 Physico-mechanical characteristics of nodules

The table below summarizes the sensitive parameters for better performance comparisons of lateritic and standard concretes.

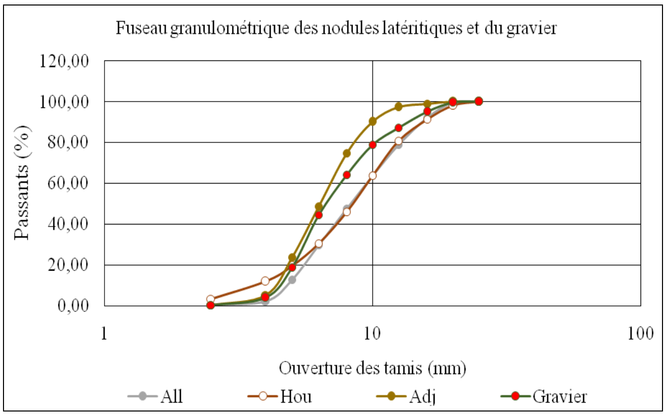

Fig 3: Particle size range of nodules

Table 2: Summary of physical parameters of nodules, gravel and sand

	N. All	N. Adj	N. Hou	Gravel
Hardness (%)	46	46	46	37
Cleanliness (%)	97	97	96	99
Absolute volumic mass (t/m^3)	2.76	2.71	2.70	2.61

The equivalent of sand is 97%. The absolute specific mass of the cement is 3.1g/cm3.

3.2 X-ray diffraction of nodules

The X-ray diffraction of the nodules made it possible to retain that the kaolinite content in the lateritic nodules of Allada, Adjohoun, Houéyogbé and the rolled gravel are respectively 13.00%; 21.00%; 7.00%; and 0.00%.

3.3 Physico-mechanical characteristic of the concretes

The subsidence at the cone of the lateritic concretes of Allada, Adjohoun and Houéyogbé are respectively 6.30 cm, 5.90 cm and 6.00 cm (B. Safi, (2017) [15].

Table 3: Synthesis of the density of the concretes

	All	Adj	Hou	Gra. Roulé
Densities (kg/m^3)	2467.91	2425.72	2425.31	2383.97

The equivalent of sand is 97%. The absolute specific mass of the cement is 3.1g/cm3.

3.4 Mechanical characterization of lateritic concretes

3.4.1 Compressive strength of concretes

Table 4: Compressive strength of concretes

Compressive strength of concretes (MPa) aged d days	Kaolin content (%)	Rc_7 (MPa)	Rc_{28} (MPa)	Rc_{60} (MPa)	Rc_{360} (MPa)
N. All	13.0	15.80	24.20	24.28	24.07
N. Adj	21.0	15.17	23.38	23.45	23.15
N. Hou	7.0	15.85	24.42	24.40	24.15
Gravel	0.0	19.13	27.57	27.58	27.58

The compressive strength of lateritic concretes, for permanent preservation of test specimens in water, varies from 15.17 MPa to 15.85 MPa; 23.38 MPa at 24.42 MPa, 23.45 MPa at 24.40 MPa and 23.15 MPa at 24.15 MPa respectively at 7 days, 28 days, 60 days and 360 days of age.

3.4.2 Tensile strength by splitting of concrete

Table 5: Summary of tensile strengths by splitting Rt7 and Rt28

	N. All	N. Adj	N. Hou	Gravel
Kaolin content (%)	13.0	21.0	7.0	0.0
Rt_7 (MPa)	1.60	1.55	1.63	2.12
Rt_{28} (MPa)	2.30	2.23	2.35	2.95

The tensile strength of lateritic concretes varies from 2.23 MPa to 2.35 MPa.

3.5 Kaolinite impact study

3.5.1 Impact of kaolinite contained in lateritic nodules on mechanical resistance

Assumptions: Same grain size range, LA: 46%, Pr: 96 to 97%, MVR: 2.70 to 2.76, Aff: 5.90 to 6.30 cm: Allada, Adjohoun and Houéyogbé nodule.

Table 6: Summary of the rate of change of minerals and resistances

	N. All	N. Adj	N. Hou	Rate N. Adj and N. All	Rate N. Hou and N. Adj	Rate N. Hou and N. All	Gravel
Rc_{28} (MPa)	23.38	24.20	24.42	3.39	0.90	4.26	27.58
Rc_{360} (MPa)	23.15	24.07	24.35	3.82	1.15	4.93	27.75
Rt_{28} (MPa)	2.23	2.30	2.35	3.04	2.13	5.11	2.95
Kaolinite (%)	2.23	1.47	0.79	-51.70	-86.08	-182.28	0.00

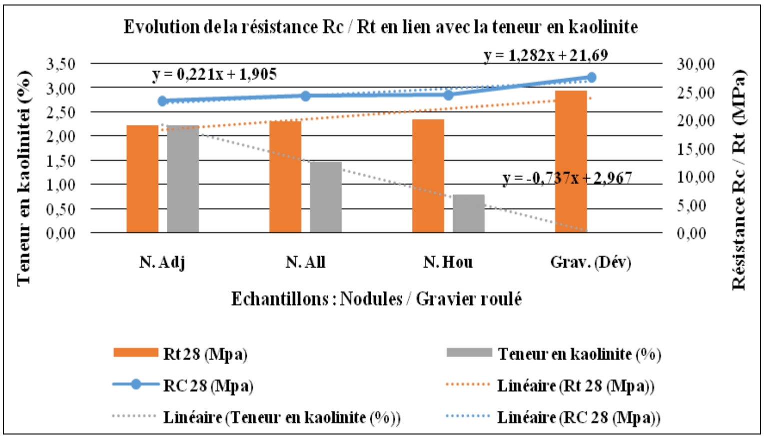

Fig 4: Effect of kaolinite on lateritic concretes aged 28 days

We retained that the N. All, N. Adj and N. Hou have the same hardness, the same degree of cleanliness, the same density and that the contents of SiO2, Al2O3, Fe2O3, quartz, and kaolinite are respectively 2.20 at 5.07%, 1.65 to 1.82%, 4.33 to 7.16% and 7.01 to 7.68%.

TKaolinite All>TKaolinite Adj and Rc28 All<Rc28 Adj. A 51.70% decrease in kaolinite results in a rate of strength increase of 3.39% despite the lateritic nodule concrete of Allada being more plastic (slump, 6.30 cm).

TKaolinite Adj>TKaolinite Hou while Rc28 Adj<Rc28 Hou. For a sharp drop in kaolinite (85.08%), there is an improvement in compressive strength of 0.90% although the Adjohoun nodules are cleaner.

TKaolinite All>TKaolinite Hou whereas Rc28 All<Rc28 Hou. A very strong drop in the rate of kaolinite (182.28%) caused a slight improvement in the mechanical behavior of the concrete (4.26%) although the nodules of Allada are cleaner and denser.

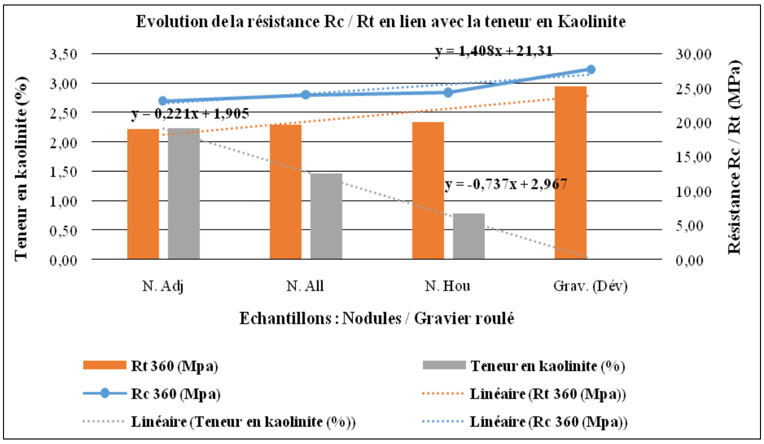

Fig 5: Effect of kaolinite on lateritic concretes aged 360 days

For permanent imbibing of the concrete specimens, we obtained between 28 days and 360 days: Rc28 All>Rc360 All. A 2.23% drop in kaolinite in the Allada nodules causes a 0.99% drop in compressive strength. Rc28 Adj>Rc360 Adj. A decrease rate of 0.54% of the compressive strength is obtained for a kaolinite content of 1.47% in the Adjohoun nodules. Rc28 Hou>Rc360 Hou. A decrease of 0.28% in the compressive strength is obtained for a kaolinite content of 0.79% in the Houéyogbé nodules. 3.2 Comparison of lateritic concrete and standard concrete after 60 days of storage in water TKaolinite Gravel is 0.00% and Rc28 Gravel equals 27.58 MPa. The absence of kaolinite would also have contributed to the good quality of current concrete. Common concretes offer better mechanical performance than lateritic concretes (Akpokodje E. G., and al., (1992) [27], M. Venkata Rao and al., (2016) [2], Ephraim M. E. and al., (2018) [4]. My results confirm the he ideology according to which the compressive strength of lateritic concrete is generally lower than standard concrete. However, the resistance of lateritic concrete may prove to be better (Laquerbe M., Cisse I., Ahouansou G. (1995) [28]).

4. Conclusion

In terms of the impact of kaolinite contained in nodules on the mechanical performance of concrete, it should be noted that the presence of kaolinite in lateritic nodules negatively affects the mechanical strength of lateritic concretes when they are permanently stored in the water until the day of the crash. - The mineralogical study reveals the presence of kaolinite in most lateritic nodules. - Kaolinite is clay, which in contact with water, lowers the resistance of lateritic concrete, after 60 days of age when the specimens are kept permanently in water. - The unfavorable effect of kaolinite on the mechanical behavior of lateritic concrete is not only linked to the rate of kaolinite but also to the other chemical elements contained in the nodules.

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