

GEOTECHNICAL STUDY OF LATERITIC SOILS FOR THE PRODUCTION OF EARTH BRICKS (EB): CASE OF THE LOCALITY OF MEIGANGA (ADAMAOUA-CAMEROON)

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ABSTRACT

This study was conducted on the Meiganga laterite formations in the Adamaoua region of Cameroon. To this end, 20 soil samples were taken in the Ngassiri, Yelwa, Sabongarie and Rue 24 neighborhoods. The main tests carried out were the determination of the natural water content, the determination of the specific weight, the particle size analysis, the determination of the Atterberg's limits and the test of compressive strength of the brick test pieces. The results show that the natural water contents are between 24.1% and 30.1%, the specific gravity values are around 2.53 T/m³ for all the samples analyzed. The results of the particle size analysis show curves which do not integrate the reference granular zone of the materials used for the production of compressed earth blocks according to CRATerre. The values of the average plasticity indices are 23.08% for Ngassiri; 31.56% for Yelwa; 30.24% for Sabongarie

and 28.14% for Rue 24. According to the HRB classification system, the soils of Ngassiri, Yelwa and Sabongarie are clay soils of subgroups A-7-5 and A-7-6; the soils of Rue 24 are gravels and silty or claylike sands of subgroup A-2-7. According to the GTR, the soils of the Rue 24 neighborhoods are sandy and gravelly soils with class B fines. The soils of Ngassiri, Sabongarie and Yelwa are fine soils of class A. The average resistance to compression of test pieces 7 and 14 days are 0.93 MPa and 1.45 MPa respectively for Ngassiri; 0.96 MPa and 1.42 MPa for Yelwa; 0.9 MPa and 1.53 MPa for Sabongarie and 1.15 MPa and 1.97 MPa for Rue 24. These values are low according to CRATerre and NC 102-144, for which the BTC must have a resistance greater than 2MPa. Stabilization was achieved by adding of cement at 2% and 4%, the simple compressive strengths at 2% and 4% of cement are respectively 2.49 MPa and 3.35 MPa for the soils of the Ngassiri district; 2.41 MPa and 3.22 MPa for the

soils of the Yelwa district; 2.56 MPa and 3.61 MPa for soils in the Sabongarie district and 2.89 MPa and 4.01 MPa for soils in the Rue 24 district.

Keywords: Compressed earth block; Compressive strength; CRATERre; NC 102-144; Meiganga.

1. INTRODUCTION

The city of Meiganga is located at 6.51 North latitude and 14.28 East longitude. Meiganga (Figure 1) covers an area of 7000 km², with an estimated population of around 88,745 souls [1].

In Cameroon, particularly in the city of Meiganga, the construction of houses rarely obeys technical regulations relating to the quality of materials. This is illustrated by the damage that rainwater causes each year to earthen habitats widely used by rural populations [2]. The main disadvantage of using earth in construction is that, in the raw state, this material does not always withstand weathering. Thus, the durability of the structures built is uncertain [3]. Many raw earth buildings (adobe and mud) and particularly those built with materials without any associated treatment are faced with serious problems of stability, progressive wear and even crumbling in the presence of a high humidity, mainly in countries with high rainfall [3]. It is with this in mind that we carried out the geotechnical study of the lateritic formations for the production of earth blocks (EB) in the city of Meiganga (Adamaoua-Cameroon) in order to investigate the causes of the mediocrity of earthen constructions in this environment.

Several authors have worked on lateritic soils as building materials or as supports for various civil engineering works in the Adamawa region, but no author has worked on the soils of the city of Meiganga: Taypondou (2020) [4] carried out studies on the identification of Mbé soils (Adamaoua-Cameroon) for their use in earthen constructions. Sedako (2020) [5] worked on the geotechnical study of the lateritic formations of Dir (Adamaoua-Cameroon) for the production of compressed earth bricks. It emerges from this work that the Dir and Mbé soils can be used in construction in their natural state, but with the addition of cement in small proportions. These soils offer high mechanical strengths of around 7.15 MPa at 4% cement for Mbé soils and 7.54 Mpa at 4% cement

for Dir soils. Figure 1 shows the location of the Municipality of Meiganga in the Adamawa Region.

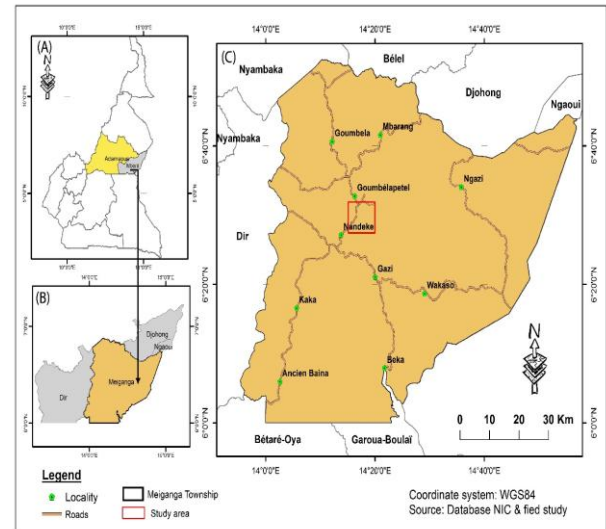


Figure 1: Location of the study area (source: field data) (a) map of Cameroon, (b) maps of the departments of Mbéré, (c) study area.

2. EXPERIMENTAL METHODS

The sampling was carried out on the soils of the following sites: Ngassiri, Yelwa, Sabongarie and Rue, at the rate of five (05) samples per district for a set of twenty (20) samples. The cement used for stabilization in this study is CIMAF CPJ CEM II 42.5R, having a compressive strength at 2 days, 7 days and 24 days of 25 MPa, 35 MPa and 45 MPa respectively [6].

2.1 Sampling

The samples were taken manually by hand using the pick, and then labeled. Wells with a cross section of about 0.30 x 1.20 m and an average depth of about 1.2 m were drilled at a sampling pitch of 100 m, with a diamond mesh. Table 1 presents the GPS coordinates of the different sampling wells.

Table 1: GPS coordinates of the different sampling wells

Quarter	Well number	Latitude (X) (UTM)	Longitude (Y) (UTM)	Altitude (m)
Ngassiri	well 1	421057	719097	900
	well 2	420996	719011	945
	well 3	421034	718896	964
	well 4	421128	718855	970
	well 5	421131	718970	973
Rue 24	well 1	422160	720268	981
	well 2	421996	720390	992
	well 3	422134	720365	988
	well 4	421941	720286	991
	well 5	422029	720218	987
Sabongarie	well 1	421071	719365	983
	well 2	421188	719365	981
	well 3	421299	719406	982
	well 4	421299	719503	984
	well 5	421200	719484	984
Yelwa	well 1	420843	720160	999
	well 2	420753	720112	995
	well 3	420749	720012	997
	well 4	420854	720066	993
	well 5	420787	719388	999

2.2 Experimentation

The natural water content of the soil in place was determined according to standard NF P94-050 [7].

The determination of the specific gravity of solid grains was measured on elements of diameter less than 2 mm according to standard NF P 94-054 [8].

The particle size analysis of the samples was done by dry sieving on the soil fraction greater than 0.08 mm according to standard NF P 94-056 [9].

The optimal compaction water content as well as the maximum dry density were determined by the modified Proctor test following standard NF P 94-053 [10].

The Atterberg's limits were determined on the fraction of soil less than 400 μm [11]. The plasticity limit (W_p) was determined by roller [11], while the liquidity limit (W_L) was determined by the Casagrande method according to standard NF P94-051 [11].

The compressive resistance study was carried out on 4x4x16cm specimens. A total of 24 test pieces were manufactured, eight (8) of which were subjected to cement stabilization in proportions of 2% to 4%. The making of these test pieces followed a traditional artisanal methodology, namely; earth extraction; its preparation (drying, grinding, sieving); mixing it with water and possibly cement; its pressing and demolding preceded by a cure and its storage.

The compressive strength of the bricks was determined according to standard NF EN 13286-41[12].

3. RESULTS AND DISCUSSION

3.1 Physical parameters

Table 2 shows the results of the physical parameters measured on the soil samples from the Ngassiri, Yelwa, Sabongarie and Rue 24 neighborhoods. The specific gravity values of the different samples vary between 2.53T/m^3 and 2.59T/m^3 . The arithmetic mean of the percentages of fine soils in the Ngassiri, Rue 24, Sabongarie and Yelwa districts are 57.48%; 32.28%; 51.26% and 55.6% respectively.

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The values of optimal water contents vary between 11.2% to 17.7% for the soils of Ngassiri; 11.0% to 14.8% the soils of the Rue 24 district; 11.1% to 18.2% for soils in Sabongarie and 13.0% to 16.5% for soils in Yelwa. The values of maximum dry densities vary between 1.89 T/m^3 to 1.96 T/m^3 for the material of the Ngassiri district; 1.88 T/m^3 to 1.94 T/m^3 for Rue 24 floors; 1.91 T/m^3 to 2 T/m^3 for the soils of Sabongarie and 1.88 T/m^3 to 1.94 T/m^3 for the soils of the Yelwa district.

3.1.1. Natural water content

The values of the average natural water contents are respectively 27.57% for the soils of Ngassiri, of Ngassiri, of 26.3% for the soils of Rue 24, of 27.72% for the soils of Sabongarie and of 28.3 for the soils of Yelwa. The same variation in natural water contents has also been observed by Tejani (2008) [13] on the ferralitic soils of Bafoussam (West Cameroon) of the order of 21.03% to 48.60% with an arithmetic average of 37.12%. These very high values of natural water content in all materials, can be explained by the fact that the samples were taken in the rainy season and also due to the texture of the soil (clay texture). In addition, the percentage of fine particles in abundance (greater than 50%) in some cases, which facilitates the adsorption of a high proportion of water on the surface of the grains.

3.1.2 .Grain size analysis

Figures 2; 3; 4 and 5 present the particle size curves of the different samples projected in the granular zone of materials for the production of EB according to CRATerre.

Table 2: Values of the physical parameters of the samples from the different sampling sites

Quarter	Well number	W (%)	Specific gravity (T/m ³)	Grain size analysis			W _{optm} (%)	γ_{max} (T/m ³)
				Fines	Sand	Gravel		
Ngassiri	well 1	29.93	2.53	62.3	16.99	20.72	17.7	1.89
	well 2	26.75	2.47	56.0	20.0	24.0	13.0	1.94
	well 3	26.65	2.61	58.2	17.30	24.50	11.2	1.91
	well 4	30.0	2.43	50.7	26.6	22.70	12.94	1.96
	well 5	24.54	2.60	60.2	19.70	20.1	13.8	1.903
	Average	27.57	2.53	57.48	20.12	22.40	13.73	1.919
Rue24	well 1	24.1	2.72	38.9	32.58	28.52	14.8	1.88
	well 2	27.22	2.54	28.8	55.50	15.70	11.0	1.94
	well 3	29.6	2.67	30.7	49.90	19.40	14.2	1.92
	well 4	24.78	2.53	32.0	40.50	27.50	12.1	1.92
	well 5	25.8	2.49	31.0	54.0	15.0	12.8	1.91
	Average	26.3	2.59	32.28	46.50	21.22	12.98	1.913
Sabongarie	well 1	27.8	2.48	82.9	16.24	0.82	18.2	1.91
	well 2	26.7	2.44	51.3	35.70	13.0	13.0	1.94
	well 3	30.1	2.67	49.0	39.6	11.4	11.1	1.96
	well 4	24.98	2.59	38.1	39.20	22.70	14.3	1.98
	well 5	29.0	2.48	35.0	48.0	17.0	12.8	2.0
	Average	27.72	2.53	51.26	35.75	12.98	13.88	1.95
Yelwa	well 1	30.05	2.48	78.6	15.83	5.54	13.4	1.88
	well 2	25.76	2.51	54.9	32.10	13.0	16.10	1.9
	well 3	28.1	2.47	45.5	34.70	19.80	16.5	1.96
	well 4	29.0	2.55	42.0	35.3	22.70	13.0	1.96
	well 5	28.54	2.66	57.0	22.90	20.10	13.2	1.89
	Average	28.3	2.53	55.6	28.17	16.23	14.44	1.91

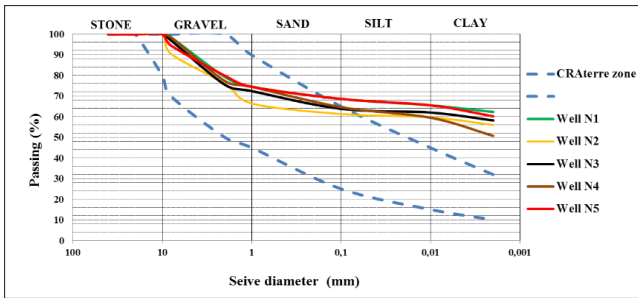


Figure 2: Particle size curves of the Ngassiri samples.

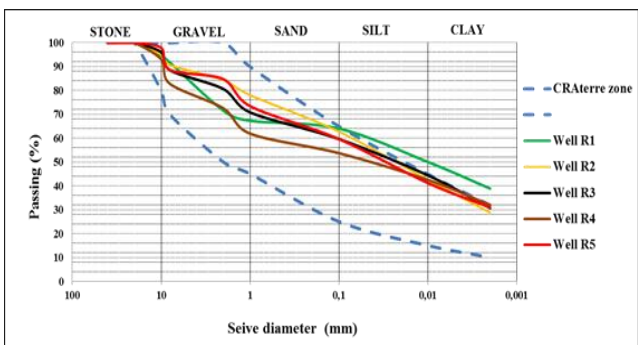


Figure 3: Particle size curves of Rue 24 samples

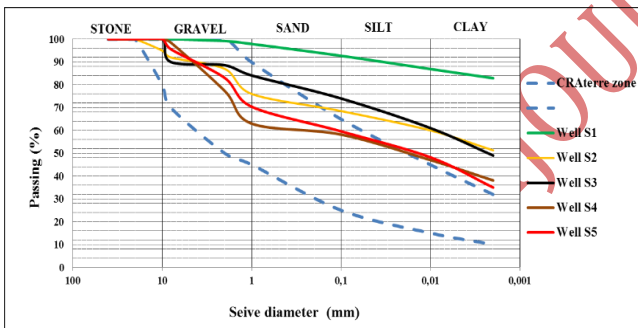


Figure 4: Particle size curves of Sabongarie samples.

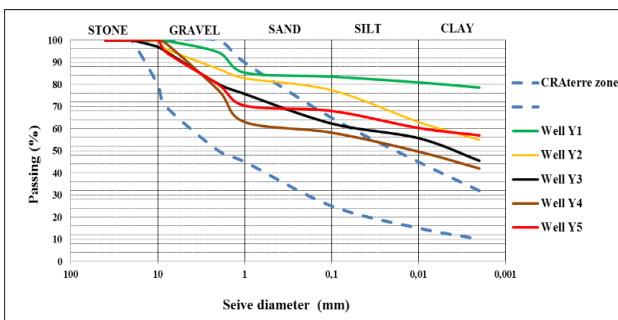


Figure 5: Particle size curves of the Yelwa samples.

Analysis of Figures 2; 3; 4; and 5 shows that only the materials from the Rue 24 district are entirely suitable for the production of EBs according to CRATERre. The other granulometric curves of the materials of the Ngassiri, Yelwa and Sabongarie districts show a poverty in large particles, this requires a correction of their granulometry in order to bring them back in the reference granular zone for the production of CEB according to CRATERre.

3.2. Mechanical parameter test results

3.2.1. Limits of Atterberg

The Atterberg’s limit values are presented in Table 3.

Quarter	Well number	Limit liquid W_L (%)	Plastic limit W_P (%)	Plasticity index (I_p) (%)
NGASSIRI	well 1	46	24.8	21.2
	well 2	51	28.6	22.4
	well 3	56.3	30.8	25.5
	well 4	49	22.6	21.3
	well 5	46.9	21.9	25
RUE 24	well 1	51.6	26.3	25.3
	well 2	53.6	22.1	31.5
	well 3	50.4	24.3	26.1
	well 4	55.2	25.1	30.1
	well 5	56.4	28.84	27.7
SABONGARIE	well 1	60.2	28.6	31.6
	well 2	57.0	27.3	29.7
	well 3	60.4	28.2	32.7
	well 4	55.0	26.4	28.6
	well 5	49.5	20.4	29.1
YELWA	well 1	65.6	32.5	33.1
	well 2	55.3	25.9	29.4
	well 3	47.5	19.8	27.7
	well 4	66.0	31.0	35.0
	well 5	59.0	26.4	32.6

The analysis in Table 3 shows that, in Ngassiri, the values of the plasticity index vary from 21.2% to 25% with an arithmetic mean 23.08%. At Rue 24, they vary between 25.3% to 31.5% with an arithmetic average 28.14%. In Sabongarie, they are in the interval 28.6% to 32.2% with an arithmetic average 30.24% and in the

Yelwa district, the plasticity index is between 27.7% and 35% with an arithmetic average 31.56%. These values are in the same proportions as that obtained by Taypondou [4] (5% to 34.5%) on the laterite soils of Mbé which are also formed on metamorphic rocks (gneiss) and these values are much higher than that obtained by Djambou [14] (0.92% to 3.12%) and Sedako [5] (2.3% to 16.5%) on hard soils on basalt respectively from Banka (West - Cameroon) and Dir (Adamaoua-Cameroon). All these values of the plasticity index do not agree with the standards of CRATERre [15] and the Cameroonian standard NC 102-114 [16], as shown in Table 3. In fact, according to CRATERre [15] and NC 102-114 [16] standards, the best soil use in earth bloc production should have a plasticity comprise between 2 and 30, which is not the case on this study.

Figures 6; 7; 8 and 9 respectively present the variation of the plasticity index as a function of the liquidity limit of the different sampling sites.

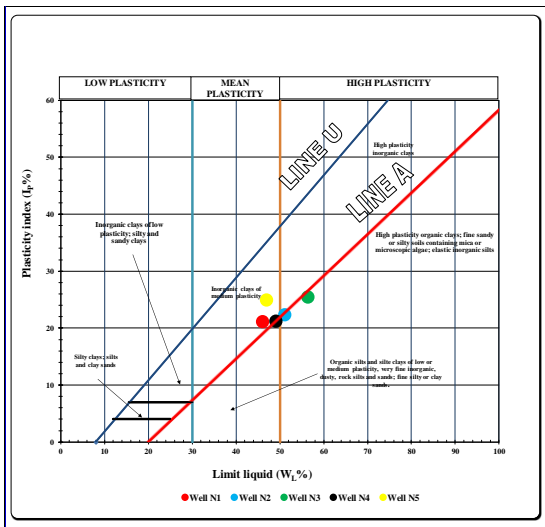


Figure 6: Casagrande plasticity diagram applied to Ngassiri soils.

Figure 6 shows that all the wells (N1, N2, N4, N5) are part of the Casagrande abacus with the exception of well N3, we deduce its classification as an inorganic clay of average plasticity according to the classification system unified soil of USCS [17]. This material is well in the admissible range to constitute blocks of compressed raw earth. For this reason, this type of clay is preferred for raw earth construction because it confers strong bonds between the grains without inducing volume variations when exposed to water

[18].

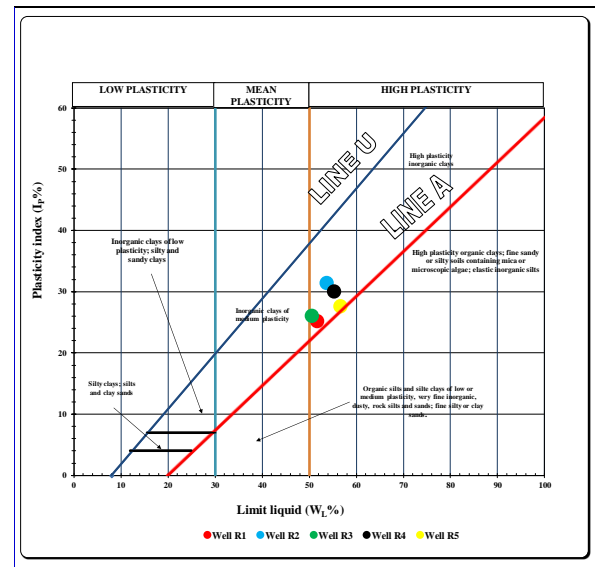


Figure 7: Casagrande plasticity diagram applied to Rue 24 soils

Figure 7 defines the plasticity map of CRATERre, domains of soil validity for use as a building material [13, 19, 20]. By including the results of the plasticity tests carried out on Rue 24 materials, the samples (R2, R4, R5) do not fall within the interval prescribed for manufacturing, with the exception of samples R1 and R3, this which allows to classify it as an inorganic clay of average plasticity according to the USCS (Unified Soil Classification System) [17]. This material is not located in an eligible region to constitute blocks of compressed raw earth.

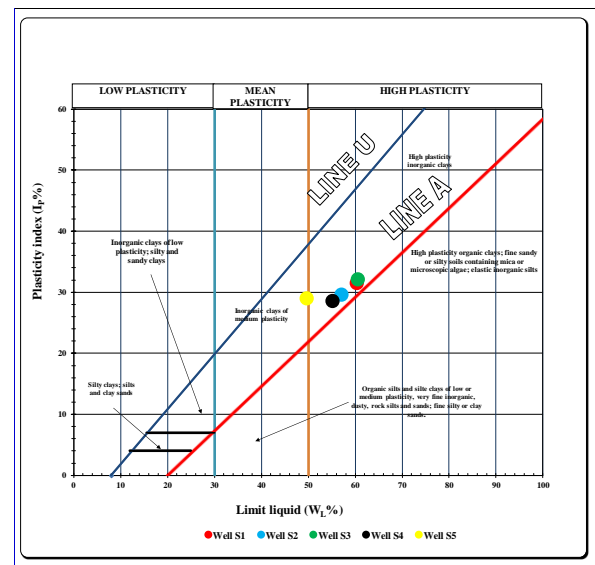


Figure 8: Casagrande plasticity diagram applied to Sabongarie soils

According to Figure 8, samples S1, S2, S3 and S4 are excluded from the recommended interval for materials corresponding to the manufacture of CEB and sample S5 is at the limit for CEB, From the point of view plasticity, we see that the soil of Sabongarie does not meet the requirements of plasticity, and does not integrate into the plasticity spindle of CRAterre. According to the USCS [17], this material is an organic clay of high plasticity.

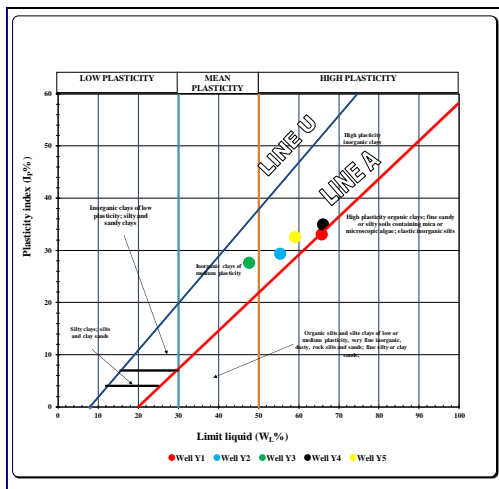


Figure 9: Casagrande plasticity diagram applied to Yelwa soils

Figure 9 presents the comparison between the values of the indices of plasticity and liquidity of soils studied, with CRAterre [15] and NF EN ISO 13786 [21] standards aimed at helping to identify suitable soils for earth construction. It can be noted that only the material Y3 is located inside the admissible limit, while the materials Y1, Y2, Y4 and Y5 are located outside the zone recommended by CRAterre. We deduce its classification as organic clay of high plasticity according to the unified classification system of soils of the USCS [17]. It can be concluded that, from the point of view of the Casagrande plasticity diagram, the soils of the Yelwa district are not suitable for making compressed earth blocks.

3.2.2 HRB and GTR classification of Meiganga soils

According to the Highway Research Board classification system (HRB) [22], the soils of the Ngassiri, Yelwa and Sabongarie neighborhoods are

clay soils, of the subgroup A-7-5 and A-7-6. The soils in the Rue 24 district are classified in the group of gravels and silty or clay sands, of subgroup A-2-7. The classification system GTR (Guide de Terrassement Routier) [22] meanwhile classifies them in class B sandy and gravelly soils with fines for the soils of the Rue 24 district and the soils of Ngassiri, Yelwa and Sabongarie are classified in the class A fine soils.

3.2.3 Simple compression test

The simple compressive strength was determined at 7 days and 14 days of age. The samples from each sampling area were finally homogenized to have a representative sample of the area.

Fig. 10 shows the values of the compressive strengths at 7 days and at 14 days of age of the test pieces.

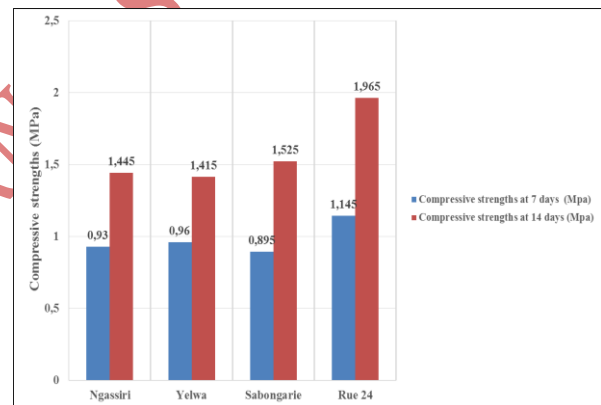


Figure 10: Histogram of resistance to compression at 7 and 14 days

The average compressive strengths at 7 days and 14 days are 0.93 MPa and 1.45 MPa respectively for the Ngassiri soils; 1.15 MPa and 1.97 MPa for the floors of the Rue 24 district; 0.9 MPa and 1.53 MPa for the soils of Sabongarie and 0.96 MPa and 1.42 MPa for the soils of Yelwa.

Analysis of the histogram in Fig. 10 shows that the values of compressive strength at 7 days of treatment are less than 1 MPa, with the exception of the materials taken at Rue 24. At 14 days of treatment, all the resistances obtained are between 1.42 MPa and 1.97 MPa. These values show notable dispersions between them. These values do not agree with those obtained by Sedako [5] on the lateritic soils of the locality of Dir, where the resistance to simple compression at 0%

cement varies between 6.44 MPa and 7.33 MPa. This difference in values can be attributed to the difference in the geological formations on which the laterites developed. Indeed, in Dir, the laterites are developed on basalt while in Meiganga, it comes from the alteration of the gneiss.

Stabilization was carried out by adding cement at proportions of 2% and 4%, in order to improve the mechanical performance of the bricks.

Figure 11 shows the variation in compressive strength of blocks of earth stabilized with cement after 28 days of treatment.

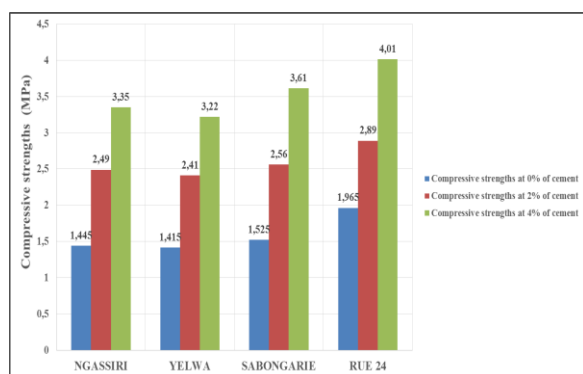


Figure 11: Histogram of compressive strengths at 28 days with the addition of cement

The compressive strength of the different samples varies depending on the cement dosage. The simple compressive strengths at 2% and 4% of cement are respectively 2.49 MPa and 3.35 MPa for the soils of the Ngassiri district; 2.89 MPa and 4.01 MPa for the soil in the Rue 24 district; 2.56 MPa and 3.61 MPa for Sabongarie soils and 2.41 MPa and 3.22 MPa for Yelwa soils. The same variations in resistance to compression after 28 days of cure by adding cement were observed by Sedako [5] and Taypondou [18] on the soil of Dir and Mbé respectively. On Dir's soils, Sedako [5] carried out stabilization at 4%, 6% and 8% of cement, he obtains values of compressive strength at 28 days of age after 4% and 6% of cement respectively of 7.1 MPa and 7.54 MPa. On the soils of Mbé in Adamaoua Cameroon, Taypondou [4] also carried out cement stabilization with cement percentages of 4%, 6% and 8%. At 4%, it obtains an average compressive strength of 6.55 MPa and at 6% of cement an average compressive strength of 7.58 MPa. These differences in values may be due, on the one hand to the nature of the soil, and on the other hand, to the quality of cement

used for the works. The cement dosage and the compactness have a strong influence on the compressive strength, plus the dosage the higher the resistance, the same is true for the compactness [23].

There is a marked increase in resistance depending on the cement dosage. These values are higher than 2.4 MPa recommended by the standard with regard to stabilized earth blocks [24].

4. Conclusion

At the end of this study, it emerges that Meiganga soils can lend themselves to the manufacture of earth bricks without adding cement, but have good qualities when stabilized. The problem with these materials is their resistance to bad weather when they are used for construction. According to these results, the values of compressive strength obtained after stabilization are much higher than the minimum resistance (2.4 MPa) imposed by the Cameroonian standard and that of CRATerre, which shows that the blocks obtained from these materials from the city of Meiganga can be used in construction regardless of the stabilization rate. According to CRATerre standards, the blocks have compressive strength values greater than 10 kg/cm^2 , which means that they cannot be considered as blocks of low resistance. These bricks can be used for the construction of simple and individual houses with large roofs since their values of resistance to compression is between $26 \text{ kg/cm}^2 < R_c < 40 \text{ kg/cm}^2$.

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