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CONSTRUCTION AND BUILDING MATERIALS INDUSTRY IN THE UNITED REPUBLIC OF CAMEROON .

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CONSTRUCTION AND BUILDING MATERIALS INDUSTRY IN THE UNITED REPUBLIC OF CAMEROON

by

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ABSTRACT

The United Republic of Cameroon is located between West and Central Africa. The country enjoys a tropical to subtropical climate. The country has four major regions distinguished on basis of climate and geology.... factors that influence the type and distribution of building materials. The main local building materials are : cement, sand, gravel, stone, cement blocks, clay blocks, burnt bricks, hardwood, raffia bamboo, palm leaves, grass, corrugated aluminum sheets and iron rods. The main building types are constructed by a combination of these materials. Local building materials have not been studied in great detail. However some known characteristics of cement, sand, gravel, bricks, blocks are presented. Research on local building materials is at a nascent stage as for example: research on concrete with palm nut shells as aggregate and research on lateritic concrete. Both research results are summarised in the paper. In view of the potential and low cost of local building materials serious research is called for at a national and regional level with an aim of understanding these materials and developing norms for their utility.

INTRODUCTION

The United Republic of Cameroon is situated at the extreme Eastern end of West Africa and forms a Western border to the Central Africa Region. It is thus at the boundary between West-Africa and Central Africa. It is bounded by latitude 2°N and 12°N and longitude 9°E and 16°E. The country has a triangular shape with its base parallel and almost running along latitude 2°N. The "apex" of the country is crowned by Lake Tchad. The country's south-western limits are bathed by the Atlantic Ocean. The country does thus enjoy a tropical to subtropical climate in the north.

The temperature distribution in the country varies from a mean minimum of 14°C to a mean maximum of 40°C in the north. But the mean annual temperature in the country varies from 21°C to 28°C. The low mean annual temperatures occurring in the mountainous areas of the Northwest and the Plateau areas of the Central South. The high mean values occur in the north.

The rainfall in the country varies from a minimum annual value of 300 mm (11.8 inches) to a maximum of 9000 mm (354 inches). The rainfall distribution in the country permits the distinction of four major regions :

- The Littoral, South-West and North-West region with rainfall value of from 2200 mm - 9000 mm
- The Central South region with values of 1500 - 2200 mm
- The Northern region with values of 900 - 1500 mm
- The extreme Northern region with values of 300 - 900 mm.

The Littoral, South-West and North-West region happen to coincide with a mountainous heavily forested primarily volcanic region that is fertile with the main surfacial soil types being decomposed lava, scoria, pumice and volcanic bombs yielding a dark and red-colored highly plastic clay. The presence of abundant volcanic material in this area and at the surface presents a problem on the availability of building materials. Wood and timber are thus the main local material used. To the northern part of this region more ancient volcanic rocks occur and have been heavily altered. They provide good clay-bricks commonly used in building. Local roofing material is either of thatches or grass. The Central-South region is heavily forested but is constituted of decomposed precambrian gneiss and granites weathering into bright red to dark brown laterite. The northern part of this region falls in the Savannah with rolling hills with grass caps that yield to the forests along the valleys and river beds. This region has primarily wood and timber as the major building material, but the local roofing material is either oil palm thatches or grass. The Northern-Region is semi-arid and vegetation is very sparse. The geology of this area is mainly sedimentary rocks and preCambrian granites weathering into granitic sand. Building material is mostly grass, abundant sand and mud. The extreme Northern-Region is essentially arid, practically devoid of vegetation ; the preCambrian granites and tertiary basalts weather into a fine to coarse sand and a high swelling and plastic clay known as the Karal. This clay constitutes a common building material, and is also commonly known as the "black cotton soil".

This introduction confirms the following well-known facts

- that climate influences the choice of local available building materials
- that geology and soil type may also influence the choice of building materials.

The objective of this paper is thus to examine the building material available in Cameroon, look at their geographic distribution, present some of the known characteristics of this building material, the research in progress on local building materials and the recommendations that ought to be taken into consideration in view of the transfer of foreign building technology into a Cameroon context.

LOCAL BUILDING MATERIAL

By "local building material", the author wishes to present all the materials existing or processed in Cameroon, that are used in the building industry. Some of this material is used for modern structures while some of it is used in more primitive structures but which have proven successful in housing the population.

1. CEMENT : Cement in Cameroon is produced by CIMENCAM a giant industry with two main production centers : one in BONABERI (south) and the other in FIGUIL (in the north). The cement produced by CIMENCAM is of the following classes : CPJ 250,a slow-setting, low resistance cement used in non-reinforced civil engineering works such soil-cement stabilisation for road works and the manufacture of cement blocks : CPA 325 (CPJ 350) : the standard cement used for reinforced concrete works and the CPA 450 :

a very rapid setting high performance cement which is commonly used in prestressed concrete works. The BONABERI and FIGUIL factories produce 350.000 tons per year, more than 85 % of this production coming from the coastal town of BONABERI.

2. SAND : Sand is one of the constituent elements of concrete. Abundant deposits exist in the northern part of the country. Most of the sand in Cameroon is river-sand and possesses varied characteristics. In general we know of the following Sands in Cameroon (cf. CRETP documents and thesis by TIMBA, ENSP/CRETP, 1978).

SANAGA Sand	WOURI Sand	BAKARA Sand
OBALA Sand	BENUE Sand	NDELELE Sand
MBALMAYO Sand	LOGONE AND CHARI Sand	
ABEM Sand	PITOA Sand	

The characteristics of these have been studied well by CRETP as a concrete constituent. The summary of their characteristics would be presented in a later part of this paper.

3. GRAVEL : The gravel used in the building industry in Cameroon is generally crushed gravel. Most of the main known quarries produce gravel for building and road projects. Thus a quarry would produce gravel with varied granulometries, the principally known granulometries being : 0/3, 0/8 (sand) ; 3/8 coarse sand/fine gravel : 8/12.5, 12.5/18 medium and coarse a gravel : 5/15 and 15/25 concrete gravel. The alluvial gravel is found in the Littoral Region, deposited by the WOURI river hence the name WOURI gravel. The summary of the characteristics of this gravel will be presented in another part of this paper.

4. STONE : The building stone used in Cameroon is a type of highly weartheered preCambrian granite (white in color) that is very easily worked even with a matchet. This stone can be shaped into various forms for building purposes. Basalt is commonly used also and a kind of sheeted granite/gneiss is used in the Central South region mostly as a wall surface dressing. In some parts of the northern province a reddish brown sandstone is used as a building stone.

5. CEMENT BLOCKS : Standard sizes are manufactured by various contractors and individuals. Cement and sand are mixed in a predetermined proportion by weight of about 1 : 13 to 1 : 12 and compacted in moulds and left to set over a long period. These constitute the main element used in modern architecture in Cameroon. The main types of cement blocks used are of the dimensions 10 x 20 x 40 cm, 15 x 20 x 40 cm. These blocks are semi-hollow.

6. CLAY BLOCKS : These are sometimes known as the "poto-poto" blocks and are widely used in many parts of the country. Plastic clay (generally lateritic) is loosened and flooded with and thoroughly mixed manually and generally by working with the legs. The material is at a plastic state and the moisture content is generally closer to its liquid limit. This ensures good workability. The thoroughly mixed paste is inserted in wooden forms of generally 15 cm x 30 cm, placed on a fairly moist and well-levelled ground surface. When the poto-poto is full in the form, it is levelled off using a straight edge. The form is then withdrawn leaving the clay block behind and the manufacture of the next block commences. The optimum moisture content for such works is such that when the form is withdrawn, the already molded block stays in shape without "slumping" due to excess water. The blocks are covered and allowed to dry slowly. Normal shrinking takes place and depends upon the shrinking characteristics of the clay soil used.

Many highly localised procedures exist. For instance, in the north and extreme north region, the poto-poto used is made of the plastic black cotton soil (karal) treated with chopped straw and used to "mud" an already wooden structure.

7. BURNT BRICKS : These are commonly known in Cameroon as "tile" an appellation which should not be mistaken for the tile used for flooring, even though the manufacturing processes are quite similar. A well chosen very plastic grey clay is moulded just the same as for the clay blocks. After the drying of the blocks, they are baked in huge furnaces to a reddish brown color. These bricks have almost gone out of existence. Their manufacture demands good quantities of plastic gray clay. They are very resistant against rain and heat.

8. HARWOOD (STICKS) : Many "semi-permanent" or "semi-hard" houses in Cameroon are constructed from a framework of sticks made of hard wood. The sticks are driven into the ground along the foundation plan, and at close intervals making allowances for doors etc. These vertical sticks are attached with horizontal evenly-spaced members and tied with metal strings. The wooden framework is thoroughly mudded on both sites using "poto-poto", then plombed and plastered thoroughly. Lentils are generally composed of concrete. In most areas in the Central South region, houses are constructed this way due to the abundance of good building sticks (hardwood). The structure is borne by these sticks.

Houses are built in other forested regions using sawn plank. The planks are nailed horizontally across the exterior of wooded structure. The houses are known as "karabout" houses and are abundant in the littoral and South West provinces.

9. RAFFIA BAMBOO :This material is used in the West and Northwest region. The bamboo constitutes the horizontal members that hold vertical hard wooden elements together. The bamboo is tied to the sticks in chosen designs and tightly spaced needing no "mudding" with poto-poto or loosely spaced and "mudded".

10. PALM LEAVES : This constitutes good roofing material. The leaves are either of raffia or of oil palm tree. The leaves are meticulously wooven around two or three fine wooden bars of up to 4 meters in length. Each palm leaf is folded over the bar, so that its edge overlaps the previous leaf and the loose ends in the same direction. A "sheet" of wooven palm leaves constitute what is known as a "thatch". These thatches are placed on a framed roof structure that has rafters and polines. The thatches are tied parallel to the polines with the loose ends down slope. The next thatch above is overlapped and so on. It the roof signals a leak, a thatch can be replaced by a new one to stop the leak.

11. GRASS (STRAW) : Many village roofs in the rural area of the Cameroon savannah and parts of the northen province are made of grass. During the dry season, the soft grass capping the rounded hills of the savannah dries up. This grass is cut and tied in a bundle such that the lower ends face

the same direction. These bundles are transported to the village and used as a roofing material. A series of closely arranged horizontal members (generally of raffia bamboo) are tied to the rafters. The grass, in small chunks is carefully inserted between the bamboo members leaving the loose ends down slope. A thorough tight network constitutes a good grass roof. Rainwater falls on the grass and flows downslope along a straw until it gets to the eaves. These roofs are still abundant today in Cameroon and mainly in the rural areas.

12. OTHER MATERIALS :

- Mention was not made of iron rods in concrete reinforcement works. These rods are also manufactured in Cameroon, or of
- Corrugated sheets of aluminium material manufactured locally and of varying thicknesses. This constitutes the major roofing material in the modern houses in Cameroon.

GEOGRAPHIC DISTRIBUTION OF BUILDING TYPES

One can recognise the following building types in Cameroon.

1. Concrete/Cement block Buildings : That constitute the bulk of modern architecture in the country. Such buildings are to be found in the cities and towns and a few may also be found in the villages. These buildings are normally plastered and roofed in corrugated sheets.

2. Stone Buildings : are concentrated in the area where stone is relatively cheap and the quality of stone being such that it can easily be worked. Stone buildings are abundant in the Northwest province. In the Central South and Northen province a few may also be noticed. These Buildings are commonly roofed in corrugated sheets.

3. Clay Blocks Buildings : are found primarily in the West and Northwest province and parts of the Central South province. They are roofed in corrugated sheets and in remote areas in grass and thatches.

4. Mudded Bamboo Buildings : are found practically only in the remote areas... in the villages. Generally they carry grass roofs. Since bamboo is predominant in the West, Northwest and parts of the Central South (northern part) province, the buildings are common only in these areas.

5. Plank or Karabout Buildings : are found in the forested areas where wood is cheap. They are thus to be found in the Southwest, Littoral, Central South and East provinces.

6. Stabilised Clay Buildings : Clay is mixed with chopped straw into a good paste and "bukaroos" are constructed with it. Generally the roofs are of straw and occasionnaly of corrugated sheets. These round buildings are found mostly in the North and extreme Northern part of the country.

7. Burnt Brick Buildings : are practically out of date in Cameroon due to the lack of primary material in the production areas that are normally around the towns. A few old houses in the Northwest province and Central-South still stand today constructed of burnt brick. In most cases, the roofs are also made of tile.

CHARACTERISTICS OF SOME BUILDING MATERIALS

1. CEMENT : The three classes of cement manufactured in Cameroon have the the following compositional characteristics

CPA 450	: 96 %	clinker
	4 %	gypsum
		no secondary constituents
CPA 325 (CPJ 350)	: 86 ± 5 %	clinker
	10 ± 5 %	secondary constituents either pouzzolan from Djoungo or of natural highly siliceouse sand.
	4 ± 1 %	gypsum
CPJ 250	: 66 ± 5 %	clinker
	30 ± 5 %	secondary constituents of either pouzzolan from Djoungo or natural highly siliceouse sand.

Abundant data on the mechanical characteristics for Cameroon's cements is for the CPA 325 (CPJ 350) which is the class of cement that has been controlled systematically and carefully by our laboratories. We summarize the results for the BONABERI factory and the FIGUIL factory as follows.

BONABERI

	Age	Range (bar)	Mean (bar)	Coefficient of variation
Compressive resistance	2 days	77 - 252	158	0.22
	7 days	181 - 403	281	0.17
	28 days	259 - 548	379	0.14
Tensile resistance	2 days	20 - 56	35	0.16
	7 days	34 - 71	52	0.11
	28 days	51 - 82	65	0.08

FIGUIL

	Age	Range (bar)	Mean (bar)	Coefficient of variation
Tensile resistance	2 days	53 - 224	122	0.27
	7 days	124 - 383	251	0.19
	28 days	52 - 86	65	0.09

The chemical analysis on the cement (CPA 325 CPJ 350) manufactured by CIMENCAM and controlled by our laboratories present the following results.

BONABERI FACTORY

Chemical composition	Range	Mean	Standard deviation
Loss in fire	1.89 - 3.89	2.77	0.59
Insolubles	0.14 - 9.84	2.09	2.14
Total Silica	19.03 - 22.58	21.37	0.86
Iron oxide	1.92 - 3.28	2.59	0.39
Alumina	4.98 - 6.80	5.87	0.48
Lime	56.94 - 64.89	61.72	2.38
Free lime	1.02 - 2.67	1.75	0.47
Sulphuric anhydride	1.47 - 3.06	2.31	0.50
Magnesium	0.67 - 2.45	1.58	0.56
Sodium oxide	0.08 - 0.42	0.22	0.10
Potassium oxide	0.46 - 1.00	0.69	0.16
Titanium oxide	0.22 - 0.56	0.35	0.10
Manganese oxide	0.00 - 0.10	0.05	0.03
Phosphates	0.00 - 1.02	0.12	0.22

The chemical analyses were carried out in our associated laboratory in Paris.

FIGUIL FACTORY

Chemical composition	Range	Mean	Standard deviation
Loss in fire	1.45 - 4.61	2.77	0.94
Insolubles	0.12 - 15.95	3.40	3.93
Total Silica	19.78 - 30.97	23.03	2.64
Iron oxide	1.82 - 2.87	2.42	0.29
Alumina	4.20 - 6.12	5.26	0.54
Lime	52.07 - 65.39	61.06	3.01
Free lime	0.37 - 3.50	1.61	0.87
Sulphuric anhyhride	0.57 - 3.25	1.83	0.70
Magnesium	0.67 - 2.55	1.27	0.63
Sodium oxide	0.18 - 6.18	0.56	1.24
Potassium oxide	0.47 - 1.22	0.64	0.18
Titanium oxide	0.12 - 0.41	0.29	0.09
Manganese oxide	0.00 - 0.22	0.11	0.05
Phosphates	0.00 - 1.85	0.72	0.55

2. SAND : The wide geographic distribution of building sand in Cameroon accounts for the highly varied characteristics of this sand. We present here in a table form a summary of the characteristics of some sands in Cameroon.

SANAGA SAND

Characteristics		Range	Mean	Standard deviation
Finess Modulus		2.07 - 3.95	2.87	0.33
Percent passing 80 μ		0.00 - 2.90	0.72	0.76
Sand Equivalent	- visual	75.1 - 98.0	93.7	3.9
	- piston	81.9 - 96.0	-	-
Specific gravity		2.61 - 2.71	2.67	0.04
Apparent density tons/m3		1.36 - 1.60	1.50	0.04

OBALA SAND

Characteristics		Range	Mean	Standard deviation
Finess Modulus		0.90 - 2.14	1.65	0.33
Percent passing 80 µ		1.2 - 23.4	9.66	6.30
Sand Equivalent	- visual	20.2 - 80.1	42.1	13.8
	- piston	-	-	-
Specific gravity		2.60 - 2.76	2.67	0.03
Apparent density tons/m3		1.22 - 1.54	1.40	0.06

MBALMAYO SAND

Characteristics		Range	Mean	Standard deviation
Finess Modulus		1.72 - 1.96	1.88	0.14
Percent passing 80 µ		9.0 - 11.3	10.2	1.6
Sand Equivalent	- visual	27.2 - 95	50.6	23.9
	- piston	-	-	-
Specific gravity		2.60 - 2.72	2.66	0.05
Apparent density tons/m3		1.30 - 1.50	1.38	0.08

ABEM SAND

Characteristics		Range	Mean	Standard deviation
Finess Modulus		1.01 - 1.80	1.32	0.20
Percent passing 80 µ		0.1 - 9.8	3.46	2.41
Sand Equivalent	- visual	51.6 - 79.9	68.3	7.1
	- piston	-	-	-
Specific gravity		-	-	-
Apparent density tons/m3		-	-	-

WOURI SAND

Characteristics		Range	Mean	Standard deviation
Finess Modulus		1.75 - 4.60	3.13	0.59
Percent passing 80 µ		1.0 - 5.0	-	-
Sand Equivalent	- visual	39.0 - 96.2	77.6	18.8
	- piston	37.1 - 94.0	73.3	18.4
Specific gravity		2.41 - 2.70	-	-
Apparent density tons/m3		1.03 - 1.71	-	-

BENUE SAND

Characteristics		Range	Mean	Standard deviation
Finess Modulus		1.88 - 3.71	2.75	0.50
Percent passing 80 µ		0.7 - 2.6	-	-
Sand Equivalent	- visual	55.0 - 96.5	83.5	10.4
	- piston	84.5 - 93.2	-	-
Specific gravity		2.47 - 2.68	2.60	0.07
Apparent density tons/m3		1.30 - 1.57	1.43	0.07

3. WOURI GRAVEL : This alluvial gravel has variable granulometry and this depends upon the exploiters. For concrete studies two granulometries are usually used : 0.25/10 and 12.5/25. Generally the percent passing 5 mm varies from 5 % to 45 %. In concrete for foundation we generally recommend mixes with largest gravels sizes possible, and this, after verification of the rod network for the part of the structure concerned. In general the specific gravity of this gravel varies from 2.555 - 2.67 with an apparent density of 1.49 to 1.615 tons/m3.

4. YAOUNDE GRAVEL : One of the largest quarries for crushed gravel is found in Yaounde. The quarry produces gravel for highway and concrete works. For concrete works the gravel generally is of the granulometry 5/15 and 15/25. The specific gravity of the gravel is 2.88 to 2.905. The apparent density is 1.50 tons/m3. The Los Angeles Abrasion Coefficient varies from 38 to 42.2. The volumetric coefficient is around 0.18.

5. BURNT BRICKS : Very little is known on the mechanical properties of burnt bricks in Cameroon. A study carried out by CRETP for the Department of Construction in June 1972 presented the following characteristics for bricks manufactured in Nkolbisson near Yaounde.

Format	Weight	Compressive strength (bars)
15 x 20 x 38 cm (with holes)	14.4 kg	6.3
10 x 20 x 38 cm (with holes)	9.1 kg	43.5
3 x 6 x 21 cm	0.72 kg	197.2

A recent study on a series of burnt bricks produced in the same factory in Nkolbisson, gave the following mean results :

Format	Compressive strength in bars
10 x 20 x 38 cm (with perforations)	13.0
15 x 20 x 38 cm (with holes)	8.0
21 x 20 x 55 cm (full)	9.5

6. CEMENT BLOCKS : No recent systematic study has been carried out on cement blocks. But the same study for the Department of Construction in 1972 gave the following results on randomly collected cement blocks from private manufacturers in the Yaounde area.

Format	Manufacturers	Mean compressive Resistance (bars)
10 x 20 x 40 cm	SCBM	11.0
10 x 20 x 40 cm	TSINGA	7.6
10 x 20 x 40 cm	NKOMKANA	10.6
15 x 20 x 40 cm	NKOMKANA	16.6

7. CLAY BLOCKS : Results of the study for the Department of Construction in 1972 were as follows for ordinary clay blocks and clay stabilised with chopped straw, and 28 days old.

Format	Density	Moisture content	Compressive strength (bars)
11.5 x 13.5 x 28.5 cm (ordinary)	1.51 T/m3	12.0 %	23.3
11.5 x 13.5 x 28.5 cm (stabilised)	1.50 T/m3	10.4 %	31.5

Thus clay blocks stabilised with some straw gave higher strengths than ordinary bricks. However a systematic study to determine optimum straw content was not studied and calls for further research in this aspect since the compressive strengths seem to be quite high thus presenting the possibility of their use in pilot housing projects. It must be understood that with different clay soils composed of different mineralogic constituents, the ordinary or stabilised clay blocks may present different results. There is thus the necessity to carry out a systematic study with the aim of proposing norms for the manufacture and control of these blocks.

CURRENT RESEARCH TRENDS

It is generally believed by many people that research is a luxury in a developing country. This, in this authors opinion, is erroneous. It is when country dominates and controles its own research that is orients foreign technology to fit its needs and development trends. Technology is thus not simply transfered and implanted, it is modified and adopted to specific needs.

In the domain of building materials, the Republic of Cameroon, has initiated research aimed at developing local building techniques using local material. This is proven by the fact that the Department of Construction (Buildings) of the Ministry of Equipment and Housing funded a research project carried out by the Centre de Recherches et d'Etudes des Travaux Publics - CRETP, aimed at preparing a Manual on Low Cost Housing. This manual is not yet in its final form but would serve to illustrate the need by the Cameroon government to develope building techniques using local material.

The same Centre (CRETP) has in conjunction with the National Polytechnic School of the University of Yaounde carried out research projects aimed at developing the Building Technology using local materials. In the paragraphs that follow, the author presents a summary of the findings from these research projects.

Concrete with vegetal constituents and characteristics of concrete with palm nut shells as aggregate

This study was carried out by Fidele Nguena, as a thesis at the National Polytechnic School in Yaounde.

Building costs in Cameroon call for the necessity of looking for cheaper concrete constituents. The necessity of looking for concrete constituents of local origin and which can constitute lightweight concrete is evoked.

More than 48.400 tons of oil were exported from Cameroon in 1975 by two of Cameroon's giant agro-industrial companies - the C.D.C. (Cameroon Development Corporation) and SOCAPALM (Société Camerounaise de Palmeraies). In the next fourth five year development plan, oil production is expected to reach 80.000 tons per year. The palm nut shells account for about 15 % to 40 % by weight of the oil produced and thus form an important industrial waste.

The apparent density of cracked palm nut shells varies from 0.56 ton/m3 to 0.66 ton/m3. The real density is 1.33 tons/m3. The nut absorbs water and tends to stabilise after 30 days at a percentage of from 22 % to 24 %. The behavior of the nut under influence of chemical elements show it very resistant to acid attack. The acid attacks mostly the exterior fibers but does not attack the actual shell. There is thus the need to destroy the tiny fibers or the nut before use for fear of attack from chemical activity of the setting cement.

Concrete was composed using DREUX's method and using natural sand of granulometry 0/1 and 0.2/2.5 ; and CPA 325 cement manufactured by CIMENCAM, Bonaberi, in Cameroon. Two mixes were studied. One with cracked shells with a granulometry of 2/12.5 and the other with the granulometry of 1.25/5. In the case of the concrete with 1/12.5 nuts, the following mixes were studied : 300, 350, 400, 450 kg of cement per cubic meter of concrete. The results of the first two dosages were too low. Only results of the 400 and 450 kg/m3 of cement are presented as follow.

Cement dosage	7 days	14 days	28 days
400 kg/m3	(26 bars, slump : 0 cm	33 bars	35 bars
	(30 bars, slump : 4.3 cm	36 bars	40 bars
	(38 bars, slump : 0.8 cm	50 bars	53 bars
450 kg/m3	41 bars, slump : 2.1 cm	44 bars	55 bars

The mortar constituent was later increased (sand raised to 45 % and the nut 55 % by volume). The results are as follows :

Cement dosage	7 days	14 days	28 days
300 kg/m3	10 bars, slump : 5.8 cm	15.0 bars	22.0 bars
450 kg/m3	(29 bars, slump : 3.0 cm	37.5 bars	47.0 bars
	(40 bars, slump : 6.8 cm	63.0 bars	74.2 bars

The average Young's modulus of elasticity measured using extensometers was 60.000 bars in 28 days.

A micro-concrete was also studied with the same nut shells but of granulometry 1.25/5 and natural sands of 0.2/2.5 and 0/1, for a composition of 300 and 350 kg of cement per cubic meter of concrete and the following results were obtained :

Cement dosage	7 days	28 days
300 kg/m3 of cement	(37.0 bars	62.0 bars
	(40.0 bars	81.0 bars
	(44.0 bars	115.0 bars
350 kg/m3 of cement	(36.0 bars	87.5 bars
	(-	106.0 bars
	(-	81.0 bars

Using both mixes the tensile strength varied from 8 to 13 bars at 7 days and 10 to 20 bars at 28 days.

In genral thus the compressive and tensile strength of this industrial waste material is very low. In no case was it observed that the nuts themselves were sheared or broken during the compressive tests. There is thus the possibility of poor adhesion between the cement and the nut. The nut is generally smooth at the surface and this probably accounts for the poor compressive and tensile stength.It is possible to use this lightweight concrete of palm nut shells for structures and buildings and for elements that support their weight only. There is however the need for further research in this area.

Contribution to the study of a new material : lateritic concrete

This study was carried out by P. DJEUKAM as a thesis at the National Polytechnic School in Yaounde. His study was a local follow-up of a similar study carried out by Dr. ADEPGBA of the University of Lagos, Nigeria.

More than 70 % of the land surface of Cameroon is covered with lateritic material. The need to exploit this cheap material for the building industry is manifest.

Lateritic concrete is a mixture of lateritic gravel, sand, cement and water in such a way that its mechanical characteristics approach those of classic concrete. The laterite used in the study come from the Yaounde area. The samples are collected, sieved and the granular constituents were used. The laterites in this area have the following geotechnical characteristics :

Classification	HRB	A-2-7 (0 to 4)
Liquid Limit	30-95	mean 65
Plastic Limit	15-32	mean 32
Plasticity index	15-43	mean 33
Optimum dry density	1.8-2.3 ton/m3	mean 2.05 t/m3
Optimum moisture	7-16	mean 13 %
CBR (4 days soak)		
at 90 % opm	5-50	mean 20
at 95 % "	30-90	mean 40
at 100 % "	40-120	mean 70
Compressive strength (soaked CBR samples) : 3 bars		

The material is sieved and fractioned as follows : class : 0/3, 3/15 and 15/25. DREUX's mix design method was used and the lateritic concrete was composed of the following constituent :

Cement dosed at 350 kg/m3

Sanaga sand

lateritic gravel 5/15

water

Fourteen test samples were prepared and the following results were obtained :

Mean 28 days compressive resistance : 240 bars

Variation : 226 - 263 bars

Variance : 9.42 bars

Coefficient of variation : 40 %

These results were compared to the results of classic concrete using crushed gravel and with similar dosages. The following results were obtained :

Type of concrete	σ_3/σ_{28}	σ_7/σ_{28}	σ_{14}/σ_{28}	σ_{21}/σ_{28}
Concrete of reference	0.48	0.69	0.81	0.92
Lateritic concrete	0.50	0.70	0.83	0.93

These results show that the evolution in strength of lateritic concrete is similar to that of classic concrete.

Another aspect studied was the variation in strength as a function of cement dosages. The following results were obtained :

Dosage in cement	Compressive Resistance in bars				
	σ_3	σ_7	σ_{14}	σ_{21}	σ_{28}
300 kg/m3	105	145	180	-	225
350 kg/m3	120	170	200	225	242
400 kg/m3	130	180	220	-	260

An increase in cement content thus increases the concrete resistance just as in the case of classic concrete.

The tensile strength of this lateritic concrete was also studied. The mean 28 days tensils strength is 17.56 bars. The relation between the tensile strength (T28) and the compressive strength is expressed in the formula :

$$T_{28} = 14.56 + 0.013 \quad \sigma_{28}$$

For classic concrete, the CCBA 68 : French recommendations propose :

$$T_{28} = 7 + 0.06\ \sigma_{28}$$

The adherence of lateritic concrete to reinforcement bars was also investigated. The results are as follows :

TYPE OF ROD	Mean Adherence re-sistance
Smooth reinforcement bars	23.60 bars
High performance ref. bars	41.33 bars

RECOMMENDATIONS : TRANSFER OF FOREIGN BUILDING TECHNOLOGY

The price of transplanted technology is too high to be paid by a developing country. Technology needs to be adapted and with a general philosophy of reducing costs. In the Building industry in Cameroon, there is the tendency for the "modern" buildings to be made of foreign raw and primary materials even though some of these materials are available in Cameroon - they are still processed using techniques available in advanced countries. An average modern building becomes exhorbitantly expensive.

There is the psychological bloc wherein residents of developing countries feel "modern" when they utilise foreign material, or locally processed material using techniques in advanced countries, in the building of their houses. This bloc must be combatted with vulgarisation of research results on local material and abundant publicity. As an example, it is considered more modern to build a concrete/cement block building than a mudded building.

In view of the fact that our governments need scientific and technological data on which to base their decision making processes, it is thus recommended that research be intensified and regionalised on certain local building materials. For instance what infact are the geotechnical, mechanical and structural characteristics of a mudded bamboo building. How can a structure or house of this nature be reinforced against natural forces etc. These are just some of the questions that need to be answered by such local or regional research programs.

In processing of local materials, it is necessary that researchers come up with a low cost method of processing these material. As was mentioned in the paper the"poto-poto" used in mudded houses is worked with the legs, thereby slow, tiring and of low efficiency. Can this process be mechanised to yield good results : that is increase efficiency and rationalise the process ? Can grass be better treated to yield good results ? Is special grass necessary ? These questions can be answered only by a rationalised technological research process.

These preceding comments suggest the urgent need of intensive research in low cost housing and their need to regionalised, and exchange scientific information on the subject.

With the little and scanty scientific date so far available, it is recommended by the author that governments consider building pilot housing projects with local available building material.

It is recommended that technologically advanced countries set up and help to sponsor projects wherein certain manufacturing processes for building materials permit their adaptation to local products.

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