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The Application Of Stabilised Laterite Bricks For Cost Effective Housing Rehabilitation Of Displaced Persons In Villages Affected By Insurgence In Adamawa State Nigeria

Dauda Gana

N.A. Nwankwor

T. J. Tika

Technology Education Department, School of Technology and Science Education,
Modibbo Adama University of Technology Yola

Abstract: ***The purpose of the study is to determine the suitability of laterite bricks stabilized with bitumen for building of bungalows for the resettlement of displaced persons in Adamawa villages. The design of the study was true experiment and the area of the study was Adamawa State. A disturbed laterite samples that weighs 20Kg each were collected in Mubi South, Gombi and Girei Local Governments areas of Adamawa State at a depth of 1m using pick axe, shovel, spade, head pan, jute bags and weighing scale and the sample were conveyed to the laboratory for analysis, tests and experiment which include particle size distribution analysis using 4.75mm 2.36mm, 1.18mm0.600mm, 0.300mm, 0.150mm, and 0.065mm sieve sizes. The properties of the laterite samples obtained for the study include liquid limit ranging from 40 to 45 percent, plastic limit from 20 to 25 percent, plastic index 17 to 22 percent, ultimate moisture content of 12 percent, activity ration 1.0 to 1.8 percent and free swell tests ranges from 28 to 40 percent. A total of 200 bricks were molded which were used as spacemen for the various tests conducted in the laboratory. Water absorption test by immersion in water and giving the difference in weight as percentage of the dry mass of the bricks, compressive strength test using universal compressive testing machine and density test were conducted. The ratio of bitumen to laterite content of 2:3 gave the highest compressive strength of 1.61N/mm^3 which was above 1.44 N/mm^3 recommended compressive strength for bungalows and moderate water absorption of 2.8% which was adopted by the current study for the production of the bitumen stabilized laterite bricks. The values of bitumen stabilized laterite ranges from 1.40 N/mm^3 to 1.61N/mm^3, while that of cement bricks ranges from 1.60N/mm^3 to 1.68N/mm^3. It is recommended that laterite bitumen stabilization should have no impediments above 4.75mm and silt and clay content not more than 5%, and the suitable mix ratio of 2:3 should be maintained during the production processes. It is also recommended that a minimum rate of water absorption of the bitumen stabilized bricks should not exceed 2.8% determined by soaking in water for twelve hours, and the maximum compressive strength of the bricks should not be less than 1.61N/mm^3***

Keywords: Bitumen, Stabilization, Laterite, Bricks, displaced, Resettlement.

I. BACKGROUND OF THE STUDY

Laterite is a cheap, environmentally friendly and abundantly available building material which is extensively used for wall construction in Nigeria and around the world, particularly in developing world (Umoh 2003). The notable activities of laterite as reported by Kenly (2001) are water absorption; this characteristic has been improved upon by stabilization which acts as binding material in a solid brick (Encarta 2008). Laterite stabilization involves the addition of small quantities of additives such as cement, or lime about 3-5% depending on the purpose for which the laterite is being

stabilized. Jackson and Dhir (2004) described laterite stabilization as an improvement of the cohesive strength of the laterite either insitu or when laid in an identified fill. Bitumen stabilization makes laterite bricks reduce its rate of water absorption and increases the compressive strength of the laterite bricks. Similarly, Yaser (2009) described laterite stabilization as the modification of the content of laterite in order to obtain lasting qualities which are compatible with particular application. Kenley (2001) stated that soil stabilization is the addition of certain stabilizing substance to the soil before casting it or using the soil for building works. Cement as stabilizer helps in improving the compressive strength of the soil and makes the laterite bricks more resistant to the penetration of water while lime enhances the stability and water proofing quality of the soil (Kenley, 2001).

Bitumen has been described by Aston (2002) as a mixture of hydrocarbon or derived compounds. They may take the form of liquid or solid or they may be viscous. The hot mix is applied or spread on the required surface and compressed by rolling a heavy object over it. Bitumen is used most recently as first class road surfacing materials and for the construction of paved lawns e.g. Lawn tennis etc. It is also used as damp proof membrane (DPM) material. They have useful physical properties as adhesives, binders, water proofing and insulating; they are flexible, durable, non toxic especially when cold

STATEMENT OF THE PROBLEM

The use of laterite soil for the construction of buildings has gained acceptance by rural and semi urban people because it is available and has workable property in moist state. Laterite soil has been used in different forms; some mould the laterite into bricks before using it to build, while some people use it to build solid laterite walls. In whichever form laterite is used for construction of buildings, it has some common characteristics that include high moisture penetration and gradual disintegration due to lack of sustained cohesion and strength as it becomes sucked with water in wet seasons. Improvement on the properties of the laterite soil is possible, so that it will be stronger and that the total water absorption of the buildings made with laterite will not lead to failure during wet seasons. The problem this study has addressed therefore is the incessant failure of laterite buildings due to high rate of moisture penetration that lead to the disintegration of laterite particles during wet seasons. This study determine the suitability of bitumen stabilized laterite for production of bricks for building bungalows for displaced persons in Adamawa State.

PURPOSE OF THE STUDY

The purpose of the study was to determine the suitability of laterite bricks stabilized with bitumen for building resettlement homes for displaced persons in village of Adamawa State Specifically the study determined the physical and mechanical properties of bitumen stabilized laterite bricks through the following specific objectives:

- ✓ To determine the particles size distribution of the laterite samples obtained for the study
- ✓ To determine the properties of the laterite samples taken for the study
- ✓ 3 To establish the suitable mix ratio of bitumen to laterite for bitumen stabilized laterite brick production.
- ✓ To establish the rate of moisture penetration in bitumen stabilized laterite bricks.
- ✓ To establish the compressive strength of the bitumen stabilized laterite bricks.

RESEARCH QUESTIONS

The following research questions served as guide to the study to determine the suitability of laterite bricks stabilized with bitumen for practical models in schools.

- ✓ What is the particle size distributions of the laterite samples obtained for the study?
- ✓ What are the properties of the laterite samples taken for the study?
- ✓ What is the suitable mix ratio of laterite to bitumen for bricks production for bungalows and for practical models?
- ✓ What are the rates of water absorption of the bitumen stabilized laterite bricks?
- ✓ What are the compressive strengths of the different mixes of bitumen stabilized laterite bricks?

II. MATERIALS AND METHODS

The study employed true experimental design as suggested by Sambo (2008) who wrote that those studies that try to establish cause and effect relationship between variables use true experimental design. The characteristic of true experiment involves subjecting samples or specimen to experimental conditions in the laboratory for observations and then conducting subsequent test on the samples or specimen. The experimental procedures which required observation include batching, mixing, molding, curing, soaking, drying, weighing and testing of bitumen stabilized bricks of various mix proportion to determine the parameters under investigation as stated in the objectives of the study. The geographical area of the study is Adamawa state. Adamawa State is situated in North Eastern Nigeria in West Africa on the glob within longitude 15^{o} South and Latitude 15^{o} North. A disturbed laterite samples were collected in Mubi south, Michika and Mubi North local government areas using Pick axe, shovel, head pan, jute bags and weighing scale. The samples weigh 20kg were conveyed for analysis, stabilization and brick production in the laboratory and workshop

PREPARATION OF MATERIALS AND BRICKS PRODUCTION PROCESS

The samples were batched and weighed using gravimetric scale. The bitumen was heated to make it flow to easily mix with the laterite and water into a paste of suitable homogenous combination. The amount of water used was carefully added to adequately make the metrics a workable paste. The inner surface of the brick mould was lubricated with lubricant to prevent the laterite paste sticking to the surface of mould. The

molding of the stabilized laterite bricks was made by hand. The wooden brick mould of 225x112x75mm was filled with stabilized laterite bricks mortar leveled and rammed to the level of the brick mould height. The brick mould was removed by lifting upward leaving a slot of stabilized laterite brick which was moved or shifted on a palate to a place of curing until it has set. The molded bricks are left to dry under shed for twenty eight days. It is dried under shed at room temperature to avoid rapid surface drying that would result to cracks. The number of bricks that were produced was 200 bricks which were used as specimen for the various tests that were conducted.

III. RESULTS AND DISCUSSION

RESEARCH QUESTION 1

What is the particle size distribution of the laterite samples obtained for the study?

	Sample A			Sample B			Sample C		
Sieve (mm)	Mass (g)	% Retained	% Passing	Mass (g)	% Retained	% Passing	Mass (g)	% Retained	% Passing
4.75	3.70	2.00	98.00	3.21	1.2	98.8	3.80	1.00	99.00
2.36	3.80	35	65.00	3.51	3.8	96.2	3.70	1.52	98.48
1.18	3.90	8	92.00	4.50	1.4	98.6	4.00	1.5	98.5
0.600	10.23	19	81.00	16.00	11.2	88.8	11.00	10.10	89.9
0.300	39.00	28	72.00	51.00	12.1	67.9	38.00	12.22	87.78
0.150	40.00	29	74	50.00	1.5	98.5	39.00	17.33	82.67
0.065 µm	50.00	95.00	5	40.00	95	5	55.00	96	4
Pan	10	7	0	9	5.0	0	8	4	0

Table 1: Particle Size Distributions for Samples A, B & C

Table: 1 is the particle size distribution for samples A, B and C, it shows the sieve sizes, the sample mass, percentage passing and percentage retained for each sieve of 4.75-0.065um. Sample A reveals that 72-98 percent of the laterite sample passed through the 150mm, 300mm, 600mm, 1.18mm, and 4.75mm sieves respectively and 2-29.00percent were retained through the same sieve sizes. Sample B had 67.9mm-98.8mm particles passing the sieve sizes of 4.75mm, 2.36mm, 1.18mm, 0.600mm, 0.300mm, and 0.150mm while 1.2mm-12.1mm was retained by the same sieve sizes. Similarly sample C shows that 82.67mm-99.00mm passed the sieve sizes of 4.75mm, 2.36mm, 1.18mm,0. 600mm, 0.300mm, and 0.150mm.This shows the grading uniformity of the three samples.

RESEARCH QUESTION 2

What are the properties of laterite samples obtained for the study?

Samples	% Liquid limit	% Plastic limit	% Plastic index	% Optimum Moisture content	% Activity ratio	% percentage free swell
A1	40	22	25	12.0	1.2	30
A2	41	20	24	12.6	1.4	35
A3	35	19	23	12.5	1.5	28
B1	41	27	20	12.3	1.0	31
B2	40	19	22	12.4	1.6	32
B3	42	25	21	12.2	1.2	30
C1	40	21	24	12.0	1.1	30
C2	42	19	22	12.1	1.5	29
C3	45	20	24	12.2	1.7	31

Table 2: Properties of Laterite Samples A, B and C

Table 2. shows the results of the properties of laterite samples obtained for the study. The percentage liquid limit ranges from 35 to 45 percent, the plastic index ranges from 17 to 25 percent. The plastic limit ranges from20 to 25 percent, the ultimate moisture content ranges from 12.0 to 12.2 percent, the activity ratio ranges 1.00 to 1.8 percent, the free swell test shows low swell of 28 to 40 percent and the dry density ranges from 1.35 to1.80 mg/m3. These result agree with ASTM standard for laterite which is suitable for brick making.

RESEARCH QUESTION 3

What is the suitable mix proportion of laterite to bitumen for bitumen stabilized Laterite bricks?

Sample No.	Bitumen Content (%)	Laterite Content (Kg)	Mix Ratio	Curing Ages (days)	Weight of bricks (kg)	Load (Kg)
A1.1	2.2	10.4	1.3	14	3.5	26
1.2	2.8	10.4	2.3	21	3.6	34
1.3	3.4	10.4	1.6	28	3.8	35
A2.1	2.2	10.5	1.4	14	3.5	26
2.2	2.8	10.5	2.3	21	3.6	34
2.3	3.4	10.5	1.6	28	3.8	35
A3.1	2.2	10.7	1.4	14	3.5	26
3.2	2.8	10.7	2.3	21	3.6	34
3.3	3.4	10.7	1.6	28	3.8	35
B1.1	2.2	10.4	1.4	14	3.5	26
1.2	2.8	10.4	2.3	21	3.6	34
1.3	3.4	10.4	1.6	28	3.8	35
B2.1	2.2	10.5	1.4	14	3.5	26
2..2	2.8	10.5	2.3	21	3.6	34
2.3	3.4	10.5	1.6	28	3.8	35
B3.1	2.2	10.7	1.4	14	3.5	26
3.2	2.8	10.7	2.3	21	3.6	34
3.3	3.4	10.7	1.6	28	3.8	35
C1.1	2.2	10.4	1.4	14	3.5	26
1.2	2.8	10.4	2.3	21	3.6	34
1.3	3.4	10.4	1.6	28	3.8	35
C2.1	2.2	10.5	1.4	14	3.5	26
2.2	2.8	10.5	2.3	21	3.6	34
2.3	3.4	10.5	1.6	28	3.8	35
C3.1	2.2	10.7	1.4	14	3.5	26
3.2	2.8	10.7	2.3	21	3.6	34
3.3	3.4	10.7	1.6	28	38	35

Table 3: Sample A, B & C Suitable Mix Proportion of Laterite to Bitumen

Table 3. Shows that the bitumen content was measured in percentage, beginning from 2.2 percent 3.4 percent with an interval of 6 percent each to the measure of the subdivided samples of A, B and C into A1.1, A1.2, A1.3. A2.1, A2.2, A2.3. & A3.1, A3.2, A3.3. B1.1, B1.2, B1.3, B2.1, B2.2, B2.3 & B3.1, B3.2, B3.3 and C1.1, C1.2, C1.3. C2.1, C2.2, C2.3 & C3.1, C3.2, C3.3The bitumen contents of 2.2 percent, 2.8 percent and 3.4 percent were used to stabilize 10.4kg,10.5kg, and10.7kg respectively at the ratio of 1:4, 2:3, and 1:6.

The curing ages were 14days, 21days & 28days. The result of specimen A,B.&C shows that the mix design in

A1.2,A2.2, A3.2, B1.2, B2.2 B3.2,C1.2, C2.2 & C3.2 with their corresponding values had low moisture absorption rates of 2.8 percent and high compressive strength of 1.60Nmm^3-1.61Nmm^3 for compressive load of 26kg- 34kg.

RESEARCH QUESTION 4

What are the rates of water absorption of the bitumen stabilized laterite bricks?

Samples No.	Laterite Content (kg)	Bitumen Content (%)	Dry weight (kg)	Wet weight (Kg)	Ages of Curing (Days)	Water Absorption (%)	Water Absorption %
A 1.1	10.4	2.2	3.5	3.8	14	8.6	8.6
1.2	10.4	2.8	3.6	3.7	21	2.8	2.8
1.3	10.4	3.4	3.5	3.8	28	5.6	8.6
							5.6
A 2.1	10.5	2.2	3.6.	3.8	14	5.6	2.8
2.2	10.5	2.8	3.6	3.7	21	2.8	5.6
2.3	10.5	3.4	3.6	3.8	28	5.6	5.6
							2.8
A 3.1	10.7	2.2	3.6	3.8	14	5.6	5.6
3.2	10.7	2.8	3.6	3.7	21	2.8	
3.3	10.7	3.4	3.6	3.8	28	5.6	
B 1.1	10.4	2.2	3.5	3.8	14	8.6	
1.2	10.4	2.8	3.5	3.7	21	2.8	
1.3	10.4	3.4	3.5	3.7	28	5.6	
B 2.1	10.5	2.2	3.5	3.8	14	5.6	
2.2	10.5	2.8	3.5	3.7	21	2.8	
2.3	10.5	3.4	3.5	3.8	28	5.6	
B 3.1	10.7	2.2	3.5	3.8	14	5.6	
3.2	10.7	2.8	3.6	3.7	21	2.8	
3.3	10.7	3.4	3.6	3.8	28	5.6	
C 1.1	10.4	2.2	3.5	3.8	14	5.4	
1.2	10.4	2.8	3.5	3.7	21	2.8	
1.3	10.4	3.4	3.5	3.7	28	5.4	
C 2.1	10.5	2.2	3.5	3.8	14	5.4	
2.2	10.5	2.8	3.6	3.8	21	2.8	
2.3	10.5	3.4	3.6	3.8	28	5.4	
C 3.1	10.5	2.2	3.6	3.8	14	5.4	
3.2	10.7	2.8	3.6	3.7	21	2.8	
3.3	10.7	3.4	3.6	3.8	28	5.4	

Table 4: Result of Water Absorption Test

Table 4 shows that there was high water absorption up to 8.6 percent within 12hrs for bitumen content of 2.2 percent. The water absorption rate was reduced to 2.8percent within the same 12 hours as bitumen content increases to 2.8 percent while there were lower values of water absorption with bitumen content of 3.4percent. With regard to cost of production and strength of bitumen stabilized bricks, the bitumen content of 2.8 percent was suitable for the production of bricks to be used for the building of bungalows. The bitumen content of 2.8percent was adequate in terms of minimum water absorption. The reason for water absorption test in three categories for each sample is to determine the most suitable rate among the varying bitumen content to laterite samples. The water absorption test was carried out in accordance with BS Part 2:1990: Clause 3.2.

RESEARCH QUESTION 5

What are the compressive strengths of the different mixes of bitumen stabilized laterite bricks?

Sample	Laterite Content (kg)	Bitumen content (%)	Compression load(Kg)	Curing ages (Days)	Compressive Strength (N/mm^3)
A 1.1	10.4	2.2	26.00	14	1.40
1.2	10.4	2.8	28.00	21	1.60
1.3	10.4	3.4	34.00	28	1.45
A 2.1	10.5	2.2	26.00	14	1.40
2.2	10.5	2.8	28.00	21	1.60
2.3	10.5	3.4	34.00	28	1.45
A 3.1	10.7	2.2	26.00	14	1.40
3.2	10.7	2.8	28.00	21	1.60
3.3	10.7	3.4	34.00	28	1.45
B 1.1	10.4	2.2	26.00	14	1.40
1.2	10.4	2.8	28.00	21	1.61
1.3	10.4	3.4	34.00	28	1.45
B 2.1	10.5	2.2	26.00	14	1.40
2.2	10.5	2.8	28.00	21	1.61
2.3	10.5	3.4	34.00	28	1.60
B 3.1	10.7	2.2	26.00	14	1.40
3.2	10.7	2.8	28.00	21	1.61
3.3	10.7	3.4	34.00	28	1.45
C 1.1	10.4	2.2	26.00	14	1.40
1.2	10.4	2.8	28.00	21	1.61
1.3	10.4	3.4	34.00	28	1.45
C 2.1	10.5	2.2	26.00	14	1.40
2.2	10.5	2.8	28.00	21	1.61
2.3	10.5	3.4	34.00	28	1.45
C 3.1	10.7	2.2	26.00	14	1.40
3.2	10.7	2.8	28.00	21	1.61
3.3	10.7	3.4	34.00	28	1.45

Table 5: Compressive Strength Test Result of Bitumen Stabilized Laterite Bricks

Table 8. Reveals that the compressive strength ranges between 1.40N/mm^3 to 1.60N/mm^3 for sample A and 1.41N/mm^3 to 1.61N/mm^3 for sample B, while sample C has 1.41 to 1.61Nmm^3. The strength of the bricks increased with increase in bitumen content from 2.2percent to 2.8percent and reduced in compressive strength when the bitumen content exceed 2.8percent to 3.4 percent. Therefore to attain a maximum strength of 1.60 to 1.61N/mm,^{3} the bitumen content of 2.8 percent at treatment ages of 21days to 28 days was suitable. However, the compressive strength of the bitumen stabilized bricks at treatment for 21days and 28days was not significantly different. The values of the comprehensive strength test fall below the recommended maximum strength of 3.8N/mm for story building, (BS 3921 1974). However, the compressive strength of 1.45N/mm^3 to 1.61N/mm^3 met the strength requirement of 1.44N/mm^2 of BS 3921 (1974) minimum strength required for bungalow hence it was suitable.

IV. FINDINGS OF THE STUDY

- ✓ It was found that all the laterite samples had particles sizes of 1.00 to 2.00 percent above 4.75mm, particle size of 2.36mm ranges from 1.52 to 3.8 percent, paticle size of 1.18mm ranges between 1.4 to 1.8 percent. Particle sizes of 0.600mm, 0.300mm and 0.150mmforms the larger amount of particles. The particle sizes of 0.065mm are the micro sizes that form the particles containing silt and clay and this forms not more than the average of 5 percent indicating that the laterite are well graded.

- ✓ The properties of the laterite samples obtained for the study include liquid limit of 35 percent to 45 percent, plastic index of 17 to 25 percent. The plastic limit of 20 percent to 25 percent, the Ultimate moisture content of 12.0 percent to 12.2 percent. It also has low activity ratio of 1.00 to 1.8 percent and free swell of 35 percent to 40 percent, which is above the maximum of 50 percent. This shows that the properties of the laterite obtained for the study was suitable for bitumen stabilization.
- ✓ The result of mix ratio experiment on Table 5 shows that the various mix ratio of 2.2, 2.8 & 3.4 percent bitumen content to 10.4kg, 10.5kg, and 10.7 kg laterite samples were stable, well shaped green bitumen stabilized laterite bricks. Therefore, the maximum ratio of 2:3 was adopted as suitable design for the production of bricks for bungalows.
- ✓ The water absorption test shows a range of water absorption rate as high as 8.6 percent and as low as 2.8 percent. The highest absorption was at bitumen content of 3.4 percent and lowest absorption rate 2.8 percent at bitumen content of 2.8 percent. The water absorption rate reduced to 2.8 percent with increase in bitumen content to 2.8 percent from 8.6 percent at 2.2 percent. Lower values of absorption rate were associated with increased bitumen content of 3.4 percent.
- ✓ It was found out that the compressive test result shows variation from 1.40N/mm^3 to 1.61N/mm^3 with varying percentages of bitumen content from 2.2 percent to 3.4 percent. The compressive strength of the laterite stabilized bricks increases with increase in bitumen content from 2.2 percent to 2.8 percent and the compressive strength reduces when bitumen content exceed 2.8percent. The maximum strength of 1.60N/mm^3 to 1.61N/mm^3 was achieved at the mix ratio of 2:3, at treatment ages of 21 to28days which was suitable enough for the production of bitumen stabilized laterite bricks for bungalows.

V. DISCUSSION OF FINDINGS

The particle size distribution analysis ensures that the particle content of sand, clay, silt and gravels are well graded to form a workable laterite material that can allow the permeation of bitumen emulsion during the stabilization process. Houben and Guiland (2004) shows a similar understanding of the purpose of laterite particles analysis when they posited that a poorly graded laterite sample can impede the purpose of stabilization. The laterite samples obtained for this study were well graded as indicated by the result of the particle size analysis. The particle size distributions of the samples were adequate for bitumen laterite stabilization for brick production that could be used for the building of bungalows.

The rate of water absorption becomes a very critical factor for the stability of laterite, Bitumen is mainly oil based material which repels water hence the reason for the choice of bitumen for laterite stabilization. The water absorption test shows a moderate rate of water penetration 2.8 Percent at 2.8percent of bitumen content, it also shows that with more than 2.8percent bitumen content there were lower rate of water absorption but has a low values of compressive strength

The suitable proportions of bitumen to laterite according to Yaser (2009) depends largely on the properties of green or fresh prepared bitumen stabilized laterite and hardened laterite bricks depend upon the relative proportions of the component ingredients in fresh bitumen stabilized laterite. The laterite materials are suspended in the bitumen emulsion; in this state bitumen emulsion should not only coat the laterite particles but also should fill the voids between them. The consistency of the mix is controlled by the fluidity of the paste and gradation shape of the laterite particles.

Plastic consistency according to Aston (2002) is highly desirable in the mix as too wet or too dry a mixture produces defective products. In case of hardened bricks, strength and porosity is a function of the density of paste which in turn is controlled by ratio of bitumen to laterite in the mix. The general proportion of mixes which are of the same consistency has the ratio of bitumen to laterite varying from 1:4 to 2:6. The values of laterite varies from 10N/mm^2 to 20N/mm^{2,} a lean mix contains larger amount of laterite to the amount of bitumen content.

A maximum brick compressive strength of 1.60Nmm-1.61N/mm^3 was achieved with mix ratio of 2:3 as indicated by the different mix designs on table 5 for samples A1.2, A2.2, A3.2, B2.1,B2.2 B3.2 C2.1,C2.2 &C3.2. The curing ages of 21& 28 days was adequate drying to achieve a constant dry mass before determining the rate of water absorption by soaking for 12 hours and weighing to show the difference in weight which was expressed as percentage of the dry brick mass.

According to Mamu, Baidan, Amissah, Bwadi and Amos (2009) at 28 days curing, the compressive strength of between 1.80N/mm^3 and 3.5N/mm^3 was achieved with 5 to 9 percent bitumen emulsion with 3kg of cement. Similarly Jackson and Dhir (1996) reported that a compressive strength above 2N/mm^3 qualifies laterite compressed bricks to be used for building application. The optimum stabilization level for bungalows using the suitable laterite characteristics was identified. The values recoded for each category were compared with the values of BS. 3921 (1974) recommended strength of bricks used for bungalows. Therefore, the likely suitable optimum strength of stabilization of 1.44N/mm^3 which is within the range of the current 1.41-1.61N/mm^3 compressive strength recommended for bungalow. The Bitumen to laterite optimum stabilization level ranging from 2.2percent to 2.8percent and 10.4Kg to 10.7kg of laterite provided a suitable compressive strength required for building of bungalows.

VI. CONCLUSION

From the result of this study it can be concluded that; the study was successful, this is evident in the findings of the study which is a reflection of the purpose of the study and have provided answers to the research questions and solutions to the problems of the study. The particle size distributions of the samples taken were well graded and suitable for bitumen laterite stabilization. The suitable mix ratio experiment of 2:3

was achieved after applying varying percentages of bitumen content to different laterite samples measured in kilogrammes as indicated in the methodology.

VII. RECOMMENDATIONS

- ✓ Every laterite sample to be used for bitumen stabilization has to be analyzed to determine the particle size distribution because the particle size distribution of laterite sample to be considered for bitumen stabilization should not contain more than 5% clay and should not be too sandy. Samples should be fairly graded to ensure the absence of impediments against rapid mixing, adequate permeation of bitumen emulsion and efficient cohesion of the laterite materials.
- ✓ The bitumen to laterite stabilization ratio of 2:3 at curing ages of 14,21,or 28 days is adequate and should be maintained for the production of stabilized laterite bricks that will be effectively used building of bungalows and for practical models. Water should be added just sufficient enough to make the mortar workable
- ✓ The water absorption rate of the bitumen stabilized laterite bricks should not exceed 2. 8 percent of the dry mass of the bricks to avoid failure due to high water absorption rate that may affect the performance of the bricks during construction work and during use.
- ✓ During construction, the Chocking between bricks, rendering and plastering of wall, the mortar should have the same mix ratio as the bricks
- ✓ The people that are saddled with the responsibility for rehabilitation of displaced persons should consider the use of stabilized laterite bricks for rehabilitation of displaced persons and be able to achieve the objectives set by federal Government for resettlement of displaced persons in the north eastern Nigeria.

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