ISSN: 2449 – 0539
BAYERO JOURNAL OF ENGINEERING AND TECHNOLOGY (BJET) VOL.14 NO.2, pp 109-122, AUGUST, 2019

Effect of Different Mud Brick Moulds and Mortar on Durability of Plaster Materials of Buildings

[1]Musa Y. P, [2*]Ajayi E. S and [2]B. A. Alabadan
[1]Department of Chemical and Environmental Engineering,
University Putra Malaysia, Malaysia.
pudzamusa@gmail.com
[2]Department of Agricultural and Bioresources Engineering,
Federal University, Oye – Ekiti. Nigeria.
babatope.alabadan@fuoye.edu.ng
emmanuel.ajayi@fuoye.edu.ng
*Corresponding author

Abstract

This study evaluates two different plastering materials for mud buildings. The mud was first mixed with water and treaded upon. Straw was added as stabilizers to the mud paste. A little amount of straw spread on the surface of the mixture was remixed and left for a period of one week in which the mixture was remixed at interval of three days. The moisture content of the mud paste samples were determined using oven drying method with oven temperature at 105^{o}C. Mud bricks were produced from two types of moulds made from wood and steel with 450 x 225 x 225 mm dimensions. Compression strength test using the hydraulic compression test machine were also performed on the two samples of bricks from each batch and each type of mould used. Eight different walls produced from the bricks were coated with two types of rendering materials. The first four walls have mud mortar with plaster varied with mud and sandcrete for wood and steel moulded bricks respectively. The last four have sandcrete mortar, with variation in the brick type and plaster. The walls were observed for changes due to environmental or weather conditions to note the extent of degradation and also tearing which could be on both sides of the walls. Cracks on the walls were measured by the use of thread while the wall strengths test was done by the use of rebound hammer method. The results show that walls constructed with steel moulded bricks, bounded with mud mortar and plastered with sandcrete gives the highest strength, while that constructed with wooden mould bounded with sandcrete mortar and plastered with sandcrete gives the least strength. Also, the walls constructed with steel moulded bricks, bounded with mud mortar and plastered with sandcrete gives the least amounts of cracks, while that constructed with wooden moulded bricks, bounded with sandcrete mortar and plastered with sandcrete gives the highest amount of cracks.

Keywords: Mud bricks, wall, mortar, strength, cracks.

1.0 Introduction

The meteoric rise in prices of building material possesses strong challenges to the construction industry (Abagale and Twumasi, 2013). This challenge led many researchers into finding alternative cheap materials of construction. This challenge was further emphasized in the Nigerian New National Housing Policy, where it was stated that the nation should gradually and systematically develop appropriate capabilities to reduce construction cost and achieve self-sufficiency in the production of basic building materials and components from local resources at affordable cost (Olusola *et. al*., 2006).Locally building materials commonly used are organic materials such as timbers, stalks, wood, bamboo, grasses, rubber and bitumen and inorganic materials such as concrete, sandcrete, iron, steel, earth (mud), rock, stone and lime (Alabadan, 2006, Alabadan, et. al., 2012 and Fawale, et.al., 2016).

Mud is generally more relevant to the modern building than it sometimes looks. It is primarily the most readily available materials around. Mud is used in its pure state and mixed with straw to make it more resistance to water effect because of its structural limitation. It has high thermal capacity (Abanto, et al., 2017).

Mud is cheaper and readily available, resistant to fire, easy to work, using simple tools and skills and a good noise absorbent. Mud is characterized by failure through cracking, under scouring and shrinkage, poor in durability and hence required frequent routine maintenance on the walls. Mud is generally available in all locations but varies in its quality and strength from one location to another hence the need for stabilization to increase its resistance to weather conditions. Stabilizers include grasses, fibres, bitumen, ashes, termite hills, vegetable oil, lime, Portland cement, electrolyte solution of sodium silicate salts and soil compaction (Ahmed, 1987; Ginanu, 1992, Binici, et. al., (2005) and Sruthi, 2013).

The most common finishes are plastering for inside surface of a wall and rendering for outside surface of a wall. Both applications serve identical purposes to provide resistance to moisture penetration, increase the fire resistance, sound and thermal insulation properties of the wall, give a more pleasant appearance and protect the structural wall from rain and sand storms. A plaster based on Parkia biglobosa husk extract is cheaper and has been used by the Kasena-Nankana people of Northern Ghana (Abagale and Twumasi, 2013). Problems of plastering and rendering include cracks, crazing or hair cracks, shelling and bond failure (Ragsdale and Baynham 1972 and Martins, et. al., 2011).

There is the need to improve the strength, quality of the mud and the life expectancy of the mud buildings and thereby reduce the cost of maintenance carried out every year to keep the structure stable. The objectives of this study are to investigate the effect of different brick mould and mortar on durability of plastering materials on buildings most especially mud building.

2.0 Materials and Methods

2.1 Mixing and Casting of Mud Bricks

Two types of moulds made from wood and steel with 450 x 225 x 225 mm dimension were used for the casting of the bricks. Mixing was done manually. The mud was first mixed with water and treaded upon. Straw was added as stabilizers to the mud paste. A little amount of straw spread on the surface of the mixture is remixed and left for a period of one week in which the mixture is remixed at interval of three days.

To ensure workability the moisture content at each batch mixed was determined by weighing and oven drying. The consistency was also determined. After casting the first batch, the second mix was made while allowing the cast bricks to be strong enough to be moved, so that the second casting can be done. Each mixture was divided into two batches for the casting with the two moulds.

The cast from the wooden mould batch had more moisture than that of the steel mould batch so that the consistency was good enough for the paste to come off easily from the wooden mould. To avoid sticking of mud to the moulds, spent motor car engine oil was used to provide lubrication at the internal sides of the mould. The oil is also another form of stabilizer because it is derived from bituminous compounds.

Walls constructed from the mud bricks produced by using steel and wooden moulds were coated with mud and sandcrete mortars as rendering materials. The walls were observed for changes due to environmental or weather conditions to note the extent of degradation and also tearing which could be on both sides of the walls.

2.2 Consistency Test

The apparatus consist of a cone shaped metal known as the cone penetrometer, in which a reading needle is attached to it. This is held by a clamp called the holder , the whole set is attached to a cubical container which houses the mud paste, by the aid of a long straight metal which has the graduated scale on it. The cone was raised and held in position with the aid of a wing screw (Abdullahi, 1995). Mud paste was poured in the cubical container until full. The cone is released until its tip touches the surface of the paste. The position of the tip of the cone was noted on the graduated rule. It is then released fully to note the position on the graduated rule. The differences between the initial and final value is taken as the paste consistency (pc). The procedure is repeated for every batch of mud mix.

2.3 Moisture Content Determination

Mud paste samples were prepared in three containers and weighed in three replicates. Oven dried at a temperature of about 105^{o}C. The dried mud samples were removed and weighed to note the moisture loss. The moisture content is expressed as a percentage, as follows:

$$\%\,MC = \frac{W_w - W_d}{W_d} \times 100 \qquad (1)$$

where: W_w = weight of wet soil and W_d = weight of dry soil
The procedure was repeated for each batch of mud paste and for mortars and plaster.

2.4 Brick Testing

Two samples of bricks from each batch of the bricks and for each type of mould were used for compression strength test using the hydraulic compression testing machine (Wance Model HCT Type C Series, 1000-5000kN) available in the Department of Civil Engineering, Federal Polytechnic Kaura-Namoda, Zamfara State, Nigeria. Each brick was first weighed and placed on a board of the size of the brick and another placed on top of the brick. It was then mounted on the machine and tested. The deflection of the indicator was observed. Lines of cracks appear on the brick surfaces which widens until a point of failure was reached when there was no more deflection. The failure load of each brick was noted and recorded.

2.5 Experiment Design for Different Wall-Plaster Combination (2^3 Factorial)

The experiment was carried out in a way that the mortars and plaster were varied for each case. For the first row of walls, the first four walls have mud mortar with plaster varied with mud and sandcrete for wood and steel moulded bricks. The last four has sandcrete mortars, with variation in the brick type and plaster. The arrangement of the walls and numbering according to the way they were constructed is shown in the Table 1.

Table 1: Wall Arrangement and Numbering

Wall No	Code	Description of wall		
1	$A_1B_1C_1$	Wooden moulded bricks	+ mud mortar	+ mud plaster
3	$A_1B_1C_2$	Wooden moulded bricks	+ mud mortar	+sandcrete plaster
5	$A_1B_2C_1$	Wooden moulded bricks	+ sandcrete mortar	+ mud plaster
8	$A_1B_2C_2$	Wooden moulded bricks	+ sandcrete mortar	+ sandcrete plaster
2	$A_2B_1C_1$	Steel moulded bricks	+ mud mortar	+ mud plaster
4	$A_2B_1C_2$	Steel moulded bricks	+ mud mortar	+ sandcrete plaster
6	$A_2B_2C_1$	Steel moulded bricks	+ sandcrete mortar	+ mud plaster
7	$A_2B_2C_2$	Steel moulded bricks	+ sandcrete mortar	+ sandcrete plaster

where: A_1 = Wooden moulded bricks (WMB) A_2 = Steel moulded bricks (SMB)
B_1 = Mud mortar B_2 = Sandcrete mortar
C_1 = Mud plaster C_2 = Sandcrete plaster

Walls one to eight are the 2^3 experimental walls while walls nine to sixteen are the replicates.

2.6 Wall Construction

Eight walls were constructed using the two types of brick and varying the plaster and mortar as shown in the 2^3 factorial experiments. For effective evaluation of the effect of these mortars and plaster, a replicate for each was also constructed with the same variation. The surface area was first cleaned, and the walls were constructed facing the direction of rainfall. Straight line was drawn using a tape, so that walls could be constructed along the line. The soil was excavated to about half the height of bricks. Mortar was laid as blinding and bricks arranged with the aid of spirit ray of bricks before the second course was laid. Each wall was made of 4 bricks for a course and 4 courses altogether as shown in Figure 1.. A total of sixteen walls were constructed in two rows. Two types of mortar, mud and sandcrete mortars, were used for joining of bricks.

Figure 1. (A) Bricks (B) Walls; Two types of mortar (mud and sandcrete), were applied to test and study the different effects each have on the resilience of the walls.

2.7 Plaster and Mortar Thickness

Two types of mortar and plaster were used: mud and sandcrete respectively. The thickness of the sandcrete plaster ranges between 10 and 30 mm while the mortar thickness for jointing ranges between 20 and 50 mm. The initial mud plaster thicknesses were recorded as the walls were being washed off by rain. This is done to know the reduction in thickness of plaster.

Walls Strengths Test (Use of Rebound Hammer Rh)

Rebound hammer is an instrument used in testing the strength of a building or wall. In case of this study, it is the index used in determining the strength variation between walls. Another index is the use of a mallet hammer. The rebound hammer is used to know the extent the walls can resist loosening their plaster due to rain and other environmental conditions. It also helps to determine the effect of cementing properties of plaster and the general strength of the walls.

Wall was divided into twelve grids and readings were taken at specific points in each grid. The rebound hammer was pressed to project a rod-like structure from the inside of the hammer. This is pressed at the point whose reading is to be taken, until the entire length of rod has gone back into the hammer. This is accompanied by a sound; a button is pressed to hold the rod-like structure from projecting outside, so that the value can be read on a graduated scale attached to the hammer. Readings were taken at interval of one week for two months.

2.8 Measurement of Cracks

The walls plastered with sandcrete were divided into 12 grids. Measurement of cracks was by the use of thread, whose tip is knotted to serve as a reference point and a 2m long tape. For each grid, the number of cracks was measured by placing the thread on the wall following the contours of the cracks to be measured. The length obtained is placed on the tape to read the value. The sum of individual crack in each grid, gives the total length for that particular grid. The procedure was repeated five times at intervals of one to two weeks. For each case, new cracks were noted and their lengths measured, while old ones were measured some of which increase in length and some remained the same.

2.9 Measurement of Peel Area

Peeling can be described as the removal of mortars from the face of a wall due to constant wetting and drying of the wall due to too much exposure to harsh and unfavourable weather conditions and elements or the mix ratios use for the mortars. Peeling is more typical on mud plastered walls, because of the nature and binding properties of the plasters used. Mud plastered walls were observed for peels. The peels were mostly irregular in shape. A paper was placed on the peel to trace the shape of the peels. The figures obtained are sectioned to respective squares, rectangles and triangles of known dimensions. The dimensions were used to get the areas and hence, the total area of the peel.

3.0 Results and Discussions

3.1 Moisture Contents for Mud, Plaster, and Mortars

Moisture contents of samples of mud paste used for casting of bricks and for the two types of brick cast, and moisture contents of plaster and mortars used for rendering and joining of bricks are given in Table 2 and Table 3.

Table 2: Moisture Content of Mud Pastes

Brick type	Moisture Content MC (%)			Mean (%)	SD	DF	P-val	Remarks
	Test 1	**Test 2**	**Test 3**					
WMB	28.13	27.47	28.49	28.03	0.52	1	.038	Significant
SMB	24.18	24.76	25.76	24.90	0.80	1		

From Table 2, it is clear that the average value of moisture contents of the three samples of mud paste taken for wooden molded bricks are greater than that of the steel molded bricks. This is to allow for the ease of molding for the steel mould. If moisture is high for the steel mould paste, there will be sticking of the paste to the mould. The brick dimension and shape tends to be altered. There is a significant difference between the mean moisture contents of mud pastes since $p=0.038<0.05$ on statistical analysis.

Table 3: Moisture Contents of Plaster and Mortar

Plasters	Moisture Content (%)			Mean (%)	SD
	Test 1	**Test 2**	**Test 3**		
Plasters	30.86	30.14	29.64	30.21	0.61
Mortar (Mud)	29.50	-	31.29	30.40	1.27
Mortar (Sandcrete)	30.10	-	30.70	30.40	0.42

From Table 3, results show that the moisture content of mortar is greater than that of plasters, mortars are used for joining bricks which are dry, the moisture in mortars aid in effective joining, if moisture is less in mortars, bricks may not be fully joined. There are no significant difference between the mean moisture contents of the plaster and mortars at 5% level of significance
.

3.2 Consistency Test

The consistency of mud paste batches for the different casting periods and for the two types of bricks cases are given in Table 4. The result shows that the consistency of mud paste decreases with a corresponding decrease in the moisture content. This can be observed in the consistency of the steel mould paste which appears to be less than that of the wooden mould paste, because the moisture level in the wooden mould paste is higher than that of the steel mould paste. There is a significant difference in the consistency of the mud pastes used for the casting of the bricks from the two moulds since $p<0.05$ on statistical analysis.

Table 4: A t-test Analysis of Difference in the Consistency Test between Wood Mud Paste and Steel Mud Paste

S/NO	Casting	Brick type	Mud Consistency (cm)								
			Straw Stabilizer								
			X_1	X_2	Diff.	Mean	SD	df	t-cal	F-val	Remark
1.	First A_1	WMB	17.0	17.8	0.8	17.4	0.98				
2.	First A_2	SMB	13.0	13.3	0.3	13.2	0.75	1	3.46	0.036	Sig.
3.	Second A_1	WMB	14.0	14.2	0.2	14.1	0.75				
4.	Second A_2	SMB	11.0	11.5	0.5	11.3	0.40	1	3.35	0.042	Sig.
5.	Third A_1	WMB	15.0	15.3	0.3	15.2	0.47				
6.	Third A_2	SMB	11.0	11.4	0.4	11.2	0.60	1	5.20	0.019	Sig.

X_1 = Pre-test (initial value), X_2 = Post-test (final value), SD = Standard Deviation, df = Degree of Freedom, t-cal = t-test calculated value, P-val. = 2-tailed significant value at 0.05 probability level.

The t-test calculated values between wooden mould paste and steel mould paste had 3.46, 3.35, 5.20 with corresponding p-values of 0.036, 0.042 and 0.019 less than the 0.05 level of significance for the first, second and third casting respectively. A significant difference existed in the consistency of wooden mould bricks and steel mould bricks based on the moisture content. The result shows that the consistency of mud paste decreases with a corresponding decrease in the moisture content. This can be observed in the consistency of the steel mould paste which appears to be less than that of the wooden mould paste, because the moisture level in the wooden mould paste is higher than that of the steel mould paste.

3.3 Compressive Strength of Cured Bricks

The failure loads and compressive strength of bricks cast with wooden and steel mould for samples of bricks selected at different casting are given in Table 5. The result shows that the older the bricks, the greater the failure load hence, the greater the compressive strength, the amount and type of stabilizers also affects the strength of bricks. This can be seen as in the bricks made of paste stabilized with grass alone and that stabilized with grass and used engine oil. Also the more compacted the mould is, the more the weight of the brick.

Table 5: Failure Loads of Cured Bricks

Age (Days)	Brick Type	WB (kg)	P (kN)	A (mm^2)	P/A (N/mm^2)	SD	df	t-cal	P-val	Reamrk
239	WMB	37.45	105.0	100.833	1.041	0.41				
239	SMB	39.21	115.0	102.383	1.123	0.71	237	2.13	0.027	Sig.

198	WMB	36.55	81.5	102.383	0.796	0.10				
198	SMB	37.31	94.0	100.100	0.960	0.39	197	1.90	0.133	Less Sig.
166	WMB	36.20	40.0	100.100	0.399	0.39				
166	SMB	37.41	91.0	100.133	0.909	0.33	164	2.37	0.017	Sig.

WB=Weight of Block, P=Failure Load, A=Area of Block, P/A=Stress, SD = Standard Deviation, df = Degree of Freedom, t-cal = t-test calculated value, P-val. = 2-tailed significant value at 0.05 probability level.

The result shows that the t-test calculated values had 2.13, 1.90 and 2.37 with corresponding p-values of 0.027, 0.133 and 0.017 for different casting days at the 0.05 level of significance. The analysis shows that a significant difference existed in the failure load and compressive strength of bricks cast with wooden mould and steel mould based on the stress in the block area (mm^2). The older the bricks, the greater the failure load and stress. Hence, the greater the compressive strength, the amount and type of stabilizers also affects the strength of bricks. This can be seen in the bricks made of paste stabilized with grass alone and that stabilized with grass and used engine oil. Also the more compacted the mould is, the more the weight of the brick.

3.4 Wall Dimensions

Dimensions of walls for the mud and sandcrete plastered walls before the commencement of the test and grid dimensions for the sandcrete plastered walls are given as shown in Table 6.

Results show that the change in the dimension of bricks results in the variation of the walls dimensions. This is as a result of mud paste not properly compacted during casting, inconsistency of the mixed constituents, level of moisture content of mud paste and drying effect.

Table 6a: Grid and Wall Dimensions for Mud and Sandcrete plastered Walls

Mud plastered wall dimension before commencement of test					
Wall No	Width b (cm)	Height h(cm)	Length l (cm)	b + h (cm)	Grid length (cm)
1.	23	88	192	111	49.50
2.	23	89	200	112	50.00
5.	23	89	190	112	41.20
6.	23	89	194	112	46.33
11.	24	89	191	113	48.33
12.	23	90	190	113	48.00
15.	23	93	190	116	48.00
16.	23	93	194	116	48.00

Table 6b: Grid and Wall Dimensions for Mud and Sandcrete plastered Walls

Sandcrete plastered wall dimension before commencement of test					
Wall No	Width b(cm)	Height h(cm)	Length l(cm)	b + h (cm)	Grid length (cm)

3	25	84	198	109	36.33
4	22	89	200	111	37.45
7	23	90	190	113	37.66
8	23	89	193	112	37.33
9	23	90	191	113	38.33
10	23	92	192	115	38.43
13	23	92	194	115	38.33
14	23	92	194	115	48.33

3.5 Plaster thickness for the walls

The values of plaster and mortar thickness of both mud and sandcrete and for the sandcrete plastered walls are given in the Table 7. The result shows that, there is a variation between the thickness of plasters and thickness of the rendering. This is as a result of the method of application of plasters and rendering, which was done by hand. It can be observed that the thicknesses vary between 1 cm for mud and sandcrete plastered walls and between 1.5 – 3cm for mortars for both walls.

Table 7: Plaster and rendering thickness for the walls

Wall No.	Plaster thickness (cm)	Rendering thickness (cm)	Type of Paste
1	1.0	1.5	Mud
2	2.0	2.0	Mud
3	2.0	2.0	Sandcrete
4	2.0	3.0	Sandcrete
5	3.0	2.0	Mud
6	2.0	2.5	Mud
7	2.0	2.0	Sandcrete
8	3.0	2.5	Sandcrete
9	2.0	3.0	Sandcrete
10	2.0	1.5	Sandcrete
11	2.0	3.0	Mud
12	2.0	2.5	Mud
13	1.0	2.0	Sandcrete
14	2.0	2.5	Sandcrete
15	2.0	3.0	Mud
16	1.0	2.5	Mud

The result of analysis of variance for both plaster and rendering shows no significant difference as shown in Table 8 (a and b) below:

Table 8a: t-test for Equality of Means between the sandcrete and mud wall thickness

Parameter compared		Means	F	Sig	t	df	Sig. (2-tailed)
Plaster	Sandcrete		0.692	0.419	0.424	14	0.678

thickness	Mud						

Table 8b: t-test for Equality of Means between the sandcrete and mud wall thickness

Parameter compared		Means	F	Sig	t	df	Sig. (2-tailed)
Rendering thickness	Sandcrete Mud		0.055	0.818	-0.239	14	0.815

3.6 Rebound Hammer Test

Results of walls strength test using Rebound hammer in N/mm^2 are given in Table 9. The results show that at specific points on each grid, the rebound hammers readings are not the same as a result of the inconsistency in the mixing of plaster because mixing is done by hand and due to the variations in plaster thicknesses at different points. The type of stabilizers used also affects the walls strength. Walls constructed with mud stabilized with straw and used engine oil (bituminous compounds) tends to be stronger and durable than those constructed with mud stabilized with only straw. Tukey HSD-test for equality of rebound hour thickness over five periods show that none is significantly different across the periods.

Table 9: Rebound Hammer readings

Date	Total Rebound Hammer Readings (N/mm^2)							
	Wall 1	Wall 2	Wall 3	Wall 4	Wall 5	Wall 6	Wall 7	Wall 8
02/5/2011	0.92	0.86	0.68	0.58	0.74	0.60	0.55	0.38
16/5/2011	0.89	0.99	0.85	0.43	0.61	0.72	0.73	0.67
30/5/2011	0.61	0.64	0.71	0.19	0.50	0.50	0.46	0.60
06/6/2011	0.74	0.81	0.53	0.38	0.40	0.63	0.79	0.11
20/6/2011	0.97	1.04	0.49	0.64	0.35	0.43	0.72	0.21

3.7 Cracks

The values of the total length of cracks which occurred in each wall is given in Table 10. The type of brick, mortar and plaster used, affects the amount and rate of .

cracking. The consistency in the constituents of brick and mortar also affects the binding property of plaster on walls, hence the amount and rate of cracking

Table 10: Total Crack Length for each Wall

Date	Total crack length (mm)							
	Wall 3	Wall 4	Wall 7	Wall 8	Wall 9	Wall 10	Wall 13	Wall 14

02/5/2011	-	-	-	-	-	-	-	-
16/5/2011	1915	4745	3365	4680	8815	7875	4870	5355
30/5/2011	5450	7890	5170	6695	5935	8395	5515	7075
06/6/2011	6590	13155	6720	11205	10600	10255	15645	8340
20/6/2011	7685	15170	7930	11405	11555	23860	19670	11085

3.8 Peel Area

The peel area for the walls is presented in Table 11. Results show that peels occur as a result of plaster not properly bound to the wall. It is also due to the constant wetting and drying of walls which causes the swelling and shrinking of walls. The tendency for mud plasters to stick to the wall depends on the consistency in the constituents of bricks, mortar and plasters used for construction of walls.

Table 11: Peel Area

Date	Peel Area (mm^2)							
	Wall 1	Wall 2	Wall 5	Wall 6	Wall 11	Wall 12	Wall 15	Wall 16
30/5/2011	-	-	-	535.9	-	777.2	1405.3	894.1
06/6/2011	-	-	2630.7	2094.5	2122.5	1736.7	2756.8	2384.6
20/6/2011	-	-	3410.6	3653.1	2547.9	5085.9	4939.7	2753.1

3.9 Reduction in Mud Plasters Thickness

The reduction in the mud plasters thickness is as shown in Table 12. The reduction in plaster thickness is as a result of constant washing of the surface of walls plastered with water. The main weakness of mud lies on its low resistance to water. The tendency of mud plasters to be washed depends on the stabilization, because stabilizers increase the resistance of mud plasters to weather conditions by reducing the movement of soil when moisture content varies and by cementing the particles of mud, thereby increasing the strength and cohesion of plasters.

Table 12: Reduction in Mud Plasters Thickness

Dates	Reduction in mud plasters thickness (cm)							
	Wall 1	Wall 2	Wall 5	Wall 6	Wall 11	Wall 12	Wall 15	Wall 16
30/5/2011	2.4	1.6	1.4	1.5	3.0	2.6	1.6	2.8
06/6/2011	1.9	1.1	1.0	1.2	1.0	1.3	1.4	2.5
20/6/2011	1.0	0.8	0.5	1.0	0.5	0.4	0.5	0.8
Mean	1.777	1.16	0.96	1.23	1.50	1.43	1.16	1.93

Table 12a: Summary of Analysis of Variance in Mud Plasters Thickness

Sources of Variation	Sum of Squares	df	Mean Squares	F-cal	P-value	Remark

Reduction Between Walls	7.84	2	3.920	15.253	0.010	Significant
Reduction Within Walls	5.39	21	0.257			
Total	13.23	23				

df = degree of freedom, F-cal = f-calculated value (15.253>3.47 with 2 and 21 degree of freedom), P-val. = significant value at 0.05 probability level (0.010<0.05)

Based on the analysis of variance in the reduction of mud plasters thickness, the F-calculated ratio of 15.253 with 2 and 21 degree of freedom shows a significant difference at 0.05 level of significance (p-value 0.010<0.05). The reduction in plaster thickness is as a result of constant washing of the surface of walls plastered with water. The main weakness of mud lies on its low resistance to water. The tendency of mud plasters to be washed depends on the stabilization, because stabilizers increase the resistance of mud plasters to weather conditions by reducing the movement of soil when moisture content varies and by cementing the particles of mud, thereby increasing the strength and cohesion of plasters .

4.0 CONCLUSIONS

i. Moisture contents

Moisture content of bricks cast with wooden mould was found to be 28.04 % while that of steel mould was about 24.9 %. This is due to the difference in the constituencies of the mud pastes. The moisture content of the mortar for brick laying was found to be 30.4 %, while that of plaster for rendering was about 30.2 %.

ii. Compressive Strength

The compressive strength of bricks cast with steel mould gave a higher value ranging from 0.909 – 1.123 N/mm^2, while that of wooden mould ranges from 0.399 – 1.041 N/mm^2.

iii. Strength of walls

The average rebound hammer values between designed walls and replicates were 0.75N/mm^2 for walls 4 and 0.6N/mm^2 for walls 7 and 9, 0.58N/mm^2 for walls 3 and 14 and 0.52N/mm^2 for walls 8 and 10 respectively. The designed experiment of different wall combination shows that walls constructed with steel moulded bricks, bounded with mud mortar and plastered with sandcrete gives the highest strength, while that constructed with wooden mould bounded with sandcrete mortar and plastered with sandcrete gives the least strength.

iv. Cracks

It was found that walls constructed with steel moulded bricks, bounded with mud plaster and plastered with sandcrete gives the least amounts of cracks, while that constructed with wooden moulded bricks, bounded with sandcrete mortar and plastered with sandcrete gives the highest amount of cracks.

v. Area of Peel

It was found that walls constructed with wooden moulded bricks, bound with sandcrete mortar and plastered with mud has the highest amount of peel.

References

Abagale S.A. and S. K. Twumasi (2013). Use of Parkia biglobosa based Wall-Plaster for Plastering Mud Walls: A General Review of Mud buildings and the Simulation/Chemical Analyses of Parkia biglobosa based mud-wall-plaster. LAP Lambert Academic Publishing. 100pp

Abanto, G. A., M. Karkri, G. Lefebvre, M. Horna, J. L. Solis, and M. M. Gómez (2017). Thermal properties of adobe employed in Peruvian rural areas: Experimental results and numerical simulation of a traditional bio-composite material Case Studies in Construction Materials 6 (2017) 177–191. journal homepa ge: www.elsevier.com/locate/cscm

Abdullahi, M.I. (1995). Evaluation of Mud as a Construction Material for Grain Storage Structures. An unpublished PhD Thesis, Ahmadu Bello University, Zaria.

Ahmed, R.M. (1987). The use of local materials in the Hausa traditional building. A project report submitted to Department of Building Technology, Ahmadu Bello University, Zaria.

Alabadan B. A. (2006). Evaluation of Wooden Silo during Storage of Maize (*Zea mays*) in Humid Tropical Weather. Agricultural Engineering International, the International Commission of Agricultural Engineering (CIGR) E-journal. BC 05 013: vol. VIII. (2006)

Alabadan B.A., Musa J. J. and L. Enemaku (2012). Studies on Lime treated Termite Mound Soil as a low cost and Energy efficient Alternative Building Material. Nigerian Journal of Soil and Environmental Research. ABU Zaria.10:14-18

ASTM. Methods of Sampling and Testing Brick. American Society for Testing and Materials, Philadelphia, ASTM Designation C67-66, 1966.

Binici, H., O. Aksogan and T. Shah (2005). Investigation of fibre reinforced mud brick as a building material. Construction and Building Materials. 19 (2005) 313–318

Fawale, B.L., Ajayi, J.O. and P.O. Oyedemi (2016). Evaluation of Effectiveness of Strawbale as a Building Materia*l*. *www.*engineeringcivil.com Accessed on February 5, 2016

Ginanu M.S (1992).Evaluation of three different stabilizers on the structural properties of mud as a farm building material.

Martins, M., L. Nunes and F. Branco (2011). Plastering and Rendering Mortars Incorporating Regranulated of Expanded Cork to Improve Durability. XII DBMC, International Conference on Durability of Building Materials and Components. Porto, PORTUGAL, 2011

Olusola, K.O.,Olanipekun, E.A., Ata, O. and Olateju, O.T. (2006): Studies on termite hill and lime as partial replacement for cement in plastering. Building and Environment 41:302–306

Ragsdale, L.A. and Baynham E.A. (1972). Building Materials Technology. Second edition, Edward Arnold Publishing Ltd., London.

Sruthi, G. S. (2013). Mud Architecture. International Journal of Innovative Research in Science, Engineering and Technology 2(1):47-52