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Structural and Dimensional Properties of Burnt-Bricks Produced at Oju, Nigeria

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ABSTRACT

Burnt-brick is one of the common walling units in building of houses in Nigeria and in many other developing countries. It is required to conform to Standards Specifications. The research assessed some properties of Oju fired clay-bricks. Some laboratory investigations on the bricks were conducted to evaluate the compressive strength, dimensional tolerance, and water absorption and initial rate of suction. The compressive strengths of bricks vary from about 4 to 9 N/mm^2. These values fall within the lower values of Singapore Standards, SS 103:1974. Water absorption for the bricks varies from 10 to 12 percent, which satisfy the requirements for the categories of SW (severe weathering) bricks in American Standard for Testing and Materials, ASTM C67-90a: 1991. The length of all the sample bricks satisfies the tolerance given in British Standards, BS 3921:1985 but the width and depth fall short. However, the Dimensional Tolerance fits the T1 category of the European Standard EN 771-1. The Initial rate of suction for the bricks varies from 1.4 to 2.0 kg/min/m^2, indicating high suction property.

Key Words: Burnt-brick, Compressive Strength, Dimensional Tolerance, Water Absorption, and Suction Rate

INTRODUCTION

Brick is a common housing material in Benue State, Nigeria. Encarta (2008) stated that the Egyptian pyramids that existed along the rocky borders of the Nile valley were examples of stone masonry. The materials used in the construction of the Great Wall of China, which is considered one of the seven construction wonders in the world, varied from tamped earth, timbers and adobe (sun-dried bricks) to local stones and kiln-fired bricks. The part of the wall that remains until today is mainly those made of bricks and granite.

According to Beall (1993), clay brick is the most extensively used type of masonry units throughout the world. Its widespread use is mainly due to the availability of clay and shale in most countries. Its durability and aesthetic appeal also contribute to its extensive application in both load bearing and non-load bearing structures.

Compressive strength of brick is an important indicator of the strength of its structure. As a result, brick strength is a requirement in brickwork design (Hendry and Malek, 1990). Hendry (1990) proposed that the compressive strength of brickwork could be approximated to the square root of unit strength and to the third or fourth root of the mortar cube strength. The Brick Development Association of UK (1974) relates bricks with compressive strength of 35 N/mm^2 to wall strength, with a ratio of 0.3 to 0.35:1.

The compressive strengths of brick vary considerably with the material used in manufacturing and the duration and degree of burning. It can be grouped into three levels: the high strength engineering brick, the medium strength brick and the low strength brick with compressive strength ranging from 55-69, 27-48 and 14-25 N/mm^2 respectively. Due to these considerable variations, strength of brick is classified accordingly to its application in construction. Bricks with compressive strengths of approximately 5 N/mm^2 are sufficient for the construction of low-rise buildings like residential houses (Hendry et al, 1981). The compressive strength can generally be high for the following cases: units made of shale by the stiff mud process, units burned at high temperatures, and units with small height (Grimm, 1975).

The compressive strength (CS) of brick is measured by loading brick in compression. Conventional tests require a brick to be loaded normal to its bed face and the faces are capped or packed before testing to reduce the effects of roughness, Soft packing has the advantage of a reduction in the time of preparation for testing and it was claimed that soft capping produced a more representative strength than hard capping (Drysdale et al., 1994).

$$CS = \frac{Maximum\ Crushing\ Load}{Surface\ Area} \quad (1)$$

Fired clay bricks vary in size due to varying property of natural clay and variations in manufacturing, drying and firing conditions. The total variation, which may take place due to variable shrinkage properties of clay during and after manufacturing, can account to approximately 5 to 15 % of original dimensions. Due to the presence of this wide range of variability, dimensional tolerances are specified in standards to achieve the desired dimensional consistency.

Water absorption (WA) of brick is defined as the weight of water in a brick expressed as a percentage of the brick's dry weight.

$$WA = \frac{W_2 - W_1}{W_1} x100 \qquad (2)$$

W_1 is dry weight of brick and W_2 is saturated weight of brick

It varies roughly from 4.5 to 21 percent; the variation is mainly due to variable raw materials and manufacturing process. The Extrusion process produces denser bricks in comparisons to the moulded bricks. Extruded-bricks contain small percentage of voids and therefore are less absorbent to water (Khalaf and Venny, 2002). Water absorption of bricks is usually measured by 5-hour boiling and 24-hour cold immersion tests. The 24-hour cold immersion test allows water to be absorbed into pores, which are easily filled under cold condition while the 5- hour boiling test gives fully saturated condition where all pores are filled up with water. The ratio of 24-hour cold immersion to 5-hour boiling (C/B ratio) water absorption, gives Saturation Coefficient, which is used to indicate bricks durability. The saturation coefficient ranges from about 0.4 to 0.95; the lower value of this range indicates high durability (Khalaf and Venny, 2002).

The initial rate of suction (IRS) denotes the amount of water sucked by brick upon contact with mortar during laying.

$$IRS = \frac{M_2 - M_1}{M_1} x100 \qquad (3)$$

M_1 is dry weight of brick and M_2 is wet weight of brick.

The IRS, resulting from the presence of capillary mechanism of the small pores in the bricks, is an important property in a masonry construction since it affects the bond strength between the brick and mortar thus affecting water tightness and durability of masonry. Bricks with IRS less than 0.25 kg/m^2/min. can be considered as low suction bricks whilst bricks with IRS more than 1.5 kg/m^2/min. can be regarded as high suction bricks. Tests have indicated that IRS values between 0.25 to 1.5 kg/m^2/min. generally produce good bond strength when used with the appropriate mortar designations.

MATERIALS AND METHODS

Solid Burnt-bricks, produced at Oju in Benue State of Nigeria, were used for this study. The mean dimension of the bricks is 218 x 99.8 x 99.8 mm.

Dimensional Tolerance, Initial Rate of Suction, Water Absorption and Compressive Strength Tests

Determination of Dimensional Tolerance, Initial Rate of Suction, Water Absorption and Compressive Strength were carried out according to British Standard (BS) 3921-1985; Appendix A, BS3921-1985; Appendix H; BS3921-1985; Appendix E and BS3921-1985; Appendix D respectively.

RESULTS AND ANALYSIS

Dimensional Tolerance

The results of Group (24 blocks) and Individual Dimensions of the bricks are shown in Tables 1 and 2 respectively. The width and height of the bricks largely fall below the Tolerances prescribed in Singaporean Standard, SS 103: 1974.

Initial Rate of Suction

The results of Initial Rate of Suction (IRS) tests are shown in Table 3. The average value of the IRS is 1.44. According to Davidson (1982) IRS values between 0.25 to 1.5 kg/m^2.min generally produce good bond strength when used with the appropriate mortar designations. High suction bricks absorb water from the mortar rapidly thus impairing bond properties. This water is needed for the proper hydration of cement where the mortar contacts the brick. On the other hand, low suction bricks do not absorb much water and hence the surplus water will float on to the surface of mortar to result in poor initial and final bonding strength.

Water Absorption

The results of water absorption (WA) tests are shown in Table 4. The bricks have about 10 percent mean Water Absorption. Khalaf and Venny (2002) stated that water absorption of brick varies roughly from 4.5 to 21 percent; and the variation is mainly due to the variable raw material and the manufacturing process. The extrusion process in manufacturing produces denser brick in comparison to moulded ones, and the denser brick absorbs less water due low void ratio. Kung (1987) showed that WA of brick increases with increasing content of calcium carbonate or limestone.

Compressive Strength

The Results of compressive strength are shown in Table 5. The results indicate that the brick falls under Category B (BS 3921:1985), the low strength range.

CONCLUSION

Bricks play a major role in the housing needs of humans, especially in the developing nations. A good house needs to be strong and durable; hence the importance of producing bricks that conform to standards and are durable. This research subjects the moulded burnt bricks produced at Oju village, Benue State, Nigeria to some standard laboratory checks. The results showed that the compressive strengths of bricks vary from about 4 to 9 N/mm^2. These values fall within the 'lower values' of Singapore Standards, SS 103:1974. The average water absorption for the bricks is 10 percent, which satisfy the requirements for the categories of SW (severe weathering) bricks in American Standard for Testing and Materials, ASTM C67-90a: 1991. The length of all the sampled bricks satisfies the tolerances given in British Standards, BS 3921:1985 but the width and depth were less than the standard specified. However, the Dimensional Tolerance fits the T1 category of the European Standard EN 771-1. The Initial rate of suction for the bricks varies from 1.4 to 2.0 kg/min/m^2, indicating high suction property.

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Table 1: Overall dimensions of 24 bricks (Group)

Batch	Sample	Length (mm)	Width (mm)	Height (mm)
1	1	5240	2415	2415

	2	5254	2410	2410
2	3	5216	2408	2408
	4	5263	2426	2426
	5	5241	2421	2421
	6	5243	2419	2419
3	7	5175	2405	2405
	8	5218	2412	2412
	9	5185	2413	2413
	10	5178	2397	2397
4	11	5203	2416	2416
	12	5211	2400	2400
	13	5210	2409	2409
	14	5213	2414	2414

Table 2: Individual Brick Dimensions

Batch	Sample	Length (mm)	Width (mm)	Height (mm)
1	1	218.43	100.20	100.20
	2	218.43	99.79	99.79
	3	216.58	99.00	99.00
	4	218.07	99.63	99.63
	5	216.51	98.96	98.96
	6	217.68	99.81	99.81
	7	217.68	99.91	99.91
	8	219.08	99.91	99.91
2	9	216.64	99.93	99.93
	10	215.53	99.31	99.31
	11	216.13	99.33	99.33
	12	216.35	98.85	98.85
	13	218.01	100.41	100.41
	14	217.67	100.27	100.27
	15	217.68	99.83	99.83
	16	218.82	100.15	100.15
	17	216.18	99.77	99.77
	18	218.91	100.89	100.89
	19	216.66	99.76	99.76
	20	217.74	100.22	100.22
	21	219.05	100.22	100.22
	22	217.49	101.03	101.03
	23	216.29	99.81	99.81
	24	217.91	99.91	99.91

Table 2: Individual Brick Dimensions Continues

Batch	Sample	Length (mm)	Width (mm)	Height (mm)
3	25	215.74	99.73	99.73

	26	214.62	99.53	99.53
	27	215.09	99.81	99.81
	28	214.67	99.90	99.90
	29	215.43	99.67	99.67
	30	216.26	100.45	100.45
	31	214.71	99.38	99.38
	32	215.71	100.27	100.27
	33	215.19	99.39	99.39
	34	215.45	99.99	99.99
	35	215.13	99.03	99.03
	36	215.10	98.70	98.70
	37	216.06	99.82	99.82
	38	214.98	99.22	99.22
	39	214.77	99.59	99.59
	40	215.18	100.17	100.17
4	41	216.42	100.23	100.23
	42	216.23	99.78	99.78
	43	215.63	99.63	99.63
	44	215.09	98.89	98.89
	45	215.09	98.73	98.73
	46	215.69	99.43	99.43
	47	215.72	99.13	99.13
	48	216.18	99.15	99.15
	49	216.92	100.23	100.23
	50	214.57	99.01	99.01
	51	216.83	100.03	100.03
	52	217.00	99.73	99.73
	53	215.83	99.96	99.96
	54	215.36	99.48	99.48
	55	216.14	100.27	100.27
	56	216.28	99.80	99.80
Mean		216.42	99.73	99.73
St. Dev.		1.91	1.12	1.13

Table 3: Results of Initial Rate of Suction (IRS)

Batch	Specimen No.	Dry Mass (g)	Wet Mass (g)	IRSgross (Kg/m^2.min)	IRSnet (Kg/m^2.min)
A	1	2445	2485	1.80	2.12
	2	2390	2420	1.40	1.67
	3	2415	2450	1.61	1.90
	4	2370	2400	1.41	1.68
	5	2435	2485	2.20	2.60
	6	2430	2465	1.58	1.86
	7	2440	2490	2.27	2.68
	8	2435	2455	0.93	1.10
	9	2415	2450	1.61	1.91
	10	2410	2435	1.16	1.37
B	11	2380	2410	1.61	1.65
	12	2420	2455	1.16	1.91
	13	2485	2515	1.39	1.63
	14	2430	2450	1.61	1.12
	15	2410	2445	1.62	1.91
	16	2465	2500	1.63	1.94
	17	2460	2490	1.38	1.64
	18	2410	2435	1.16	1.37
	19	2370	2400	1.38	1.64
	20	2370	2410	1.84	2.18
C	21	2410	2440	1.39	1.65
	22	2420	2455	1.62	1.91
	23	2435	2490	2.55	3.03
	24	2400	2425	1.16	1.38
	25	2430	2470	1.90	2.26
	26	2410	2445	1.63	1.93
	27	2410	2445	1.62	1.92
	28	2415	2450	1.63	1.92
	29	2440	2485	2.06	2.44
	30	2440	2475	1.62	1.93
Mean				1.44	1.81

Table 4: Results of Water Absorption

Brick Sample No.	Dry Weight (g)	Saturated Weight (g)	Water Absorption (%)
1	2415	2670	10.56
2	2460	2710	10.16
3	2380	2640	10.94
4	2370	2670	12.66
5	2410	2640	9.54
6	2370	2645	11.60
7	2370	2625	10.76
8	2410	2665	10.58
9	2440	2775	13.73
10	2485	2745	10.46
11	2390	2590	8.37
12	2435	2760	13.35
13	2415	2665	10.35
14	2435	2650	8.83
15	2465	2700	9.53
16	2430	2720	11.93
17	2420	2675	10.54
18	2430	2625	8.02
19	2410	2690	11.62
20	2445	2740	12.07
Mean			10.78

Table 5: Compressive Strength Test Results

Brick Sample No.	Base Area (mm^2)	Maxim. Load (KN)	Compressive Strength (N/mm^2)
1	21511.90	160.00	7.46
2	21000.48	200.00	9.52
3	21799.36	200.00	9.19
4	21894.05	160.00	7.38
5	22085.67	190.00	8.81
6	21824.43	150.00	6.91
7	22012.70	200.00	9.09
8	22208.34	200.00	9.06
9	22279.25	180.00	8.17
10	21516.07	36.50	5.41
11	21385.10	36.10	5.36
12	21716.66	34.40	5.13
13	21431.47	41.00	6.20
14	21660.57	26.70	4.06
15	21830.44	34.10	5.03
15	21861.45	31.70	4.63
16	21647.42	34.90	5.11
17	21938.56	31.60	4.62
18	21528.45	28.00	4.25
19	21295.70	70.80	10.63
20	21763.22	37.30	5.60
Mean			7.08