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Research Paper

Structural Properties of Laterite - Quarry Dust Cement Blocks

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ABSTRACT: *The study investigated the compressive strength and static modulus of elasticity of building blocks with full replacement of river sand with a blend of laterite – quarry. Values of compressive strength and static modulus are very helpful in the analyses and design of structures as they help in avoiding unrealistic assumptions which may be misleading in design. The maximum value of compressive strength obtained from a blend of 70% quarry dust and 30% laterite was 2.56N/mm^2 at water cement ratio of 0.58 while a static modulus of elasticity of 8.86 was obtained from a combination of 75% quarry dust and 25% laterite.*

Keywords: *Compressive strength, Static modulus of elasticity, quarry dust-laterite block, density, quarry dust, laterite*

I. INTRODUCTION

Major construction works in most cities all over the world depend much on the use of river sand production of concrete and sandcrete blocks. This over dependence on river sand has impacted the environment negatively and contributed to high cost of building and construction. In order to reduce over dependence on river sand for concrete and block work, alternative materials like laterite, quarry dust and recycled aggregate etc. are being sourced for as partial or full replacement for river sand. Full replacement of river sand with a blend of quarry dust and laterite in the production of blocks is a growing phenomenon in most cities across Nigeria.

Sandcrete blocks are still extensively used as masonry units in Nigeria and given the upsurge in the number of block production industries in Calabar and other parts of the country, utilizing quarry dust, laterite and other fine aggregates as partial or full replacement for natural sand, it is, therefore, not out of place to ensure that the products of these industries are of good quality and that they meet sectorial standards and specifications so as to give satisfactory performance within the design life of buildings and other structures knowing quite well that knowledge of structural characteristics and performance of blocks made with these materials is necessary for the accurate analyses and design of structural elements in buildings. It is reported by [1] that "recent developments in the building construction industry in Calabar, southern Nigeria and its environs have witnessed an increase in the use of local laterite from borrow pits around town for block moulding and concrete works". At present, a wide variation in the strength of commercially available blocks in most parts of the country have been reported by several researchers, [2], [3] and [4]. For instance, the compressive strength of commercially available sandcrete block in Calabar Metropolis as reported by [5] is in the range of 0.23N/mm^2 and 0.58N/mm^2. These values fall below the minimum requirement of 1.75N/mm^2 recommended by [6] for individual block, and 2.5N/mm^2 by the British Standard for non-load bearing walls. These studies, however, did not cover the Static Modulus of elasticity, which is another veritable property for design of structures. Study by [7], reported a static modulus of elasticity of 6.414GPa for sand-laterite block. They also reported that "there are little documentation on some structural characteristics of block, like static modulus of elasticity."

This paper, therefore, investigates the structural properties of blocks produced using a blend of quarry dust and laterite.

II. MATERIALS

The materials used for this work are:

Cement: Ordinary Portland cement, grade 32.5 obtained from a major dealer in Calabar conforming to BS 12 was used for all the tests.

Water: Potable pipe born water supplied by the Cross River State Water Board (CRSWB) Limited was used for both specimen preparations and curing.

Laterite : Laterite was obtained from a borrow pit site at Akim- Akim in Odukpani Local Government area of Cross River State. The specific gravity of the laterite is 2.56.

Quarry dust: Quarry dust was obtained from the abundant deposits at Akamkpa quarry site in Akamkpa Local Government area of Cross River State. The quarry dust had a specific gravity of 2.52.

III. Methodology

A total of seventy, (70) hollow blocks, 450mm x 225mm x 225mm overall dimensions, were moulded using a vibrating block moulding machine. The surface area of the solid portion of the blocks is 56250mm^2, representing approximately 56% of the overall surface area of the block. The aggregates were used in their dry condition and batching was by weight. Manual mixing was employed. The blocks were cured in open air by sprinkling them with water, twice daily and were tested for compressive strength in accordance with BS 6078.

IV. RESULTS AND DISCUSSION

Chemical Properties of cement and Quarry dust used

Table 1 shows the properties of the cement and quarry dust used in the moulding of blocks. The cement meets the requirement for Ordinary Portland cement as specified by [8]. The oxide composition of the quarry dust is also very close to that obtained by other researchers such as [1], [9] and [10] which is typical of granite. The cement and quarry dust are both suitable for general purpose concrete works.

Table 1: Chemical Properties of cement and Quarry dust used

Component	CaO	Al_2O_3	SiO_2	Fe_2O_3	SO_3	Cl	MgO	TiO_2	K_2O	LOI
Cement	64.34	4.51	20.79	2.64	1.48	0.03	1.66	-	1.26	1.7
Quarry dust	2.43	16.72	65.66	3.92	-	-	3.56	2.21	0.88	-

Physical properties of the aggregate

Table 2 shows the physical properties of the aggregate used in the moulding of blocks. The specific gravity of the quarry dust and laterite were found to be 2.52 and 2.65 respectively. These values are within the normal ranges for the respective materials. The gradation and properties of the parent rock influences the value of the specific gravity. For instance, [11] reported a specific gravity of quarry dust as 2.71, whereas [12] obtained a specific gravity of 2.63. From the table, the bulk densities of the quarry dust and laterite were found to be 1588 and 1891kg/m^3 respectively. These values are also in line with those in the literature. For example, [10] and [1] obtained the values of 1296kg/m^3 and 1230kg/m^3 for quarry dust respectively.

Table 2: Summary of physical properties of fine aggregates

Property	Quarry dust	Laterite
Specific gravity	2.52	2.65
Bulk density (kg/m^3)	1588	1891
Fineness modulus	3.57	2.82
Coefficient of uniformity, C_u	2.83	0.83
Coefficient of gradation, C_c	19.38	1.50

Density of the Blocks

The result of the dry densities of the blocks is presented in Appendix 1. The dry densities range from 1823.06kg/m^3 to 1961.822kg/m^3. These values are within the range reported by [5]. The blocks produced had densities above the minimum of 1600kg/m^3 recommended by [13] for a masonry unit.

Compressive Strength

Table 3 and Figures 1 and 2 show the result of the compressive strength for the different blend of laterite and quarry dust. The 28 day compressive strength ranges from 1.87N/mm^2 to 2.56N/mm^2. These values are within the minimum 1.75N/mm^2 specified by [6]) for load bearing sandcrete blocks. However, to attain the minimum strength of 2.5N/mm^2 specified by [14], the blend should be 70:30 for quarry dust: laterite.

Table 3: compressive strength test result

Sample	Quarry dust: laterite	Compressive Strength (N/mm^2)	
		14 day	28 day
1	100:0	1.28	2.03
2	90:10	1.45	2.50
3	75:25	1.57	2.54
4	70:30	1.67	2.56
5	60:40	1.43	2.42
6	50:50	1.14	1.87

Static Modulus of Elasticity

Table 4 shows the result of the static modulus of elasticity of the block. The values were obtained from the relationship provided by [8] between compressive strength and density of concrete reproduced as equation 1 below.

$$Ec = 1.7\rho^2 \; fc^{\,0.33} * 10^{-6} \quad (1)$$

Where
Ec = Static modulus of Elasticity, ρ = density,
fc = compressive strength

Table 4: Result of Static Modulus of elasticity

Sample	Quarry dust: laterite	Average Density (Kg/m3)	Compressive Strength (N/mm^2)	Static Modulus of Elasticity (GPa)
				28 day
1	100:0	1976.00	2.03	8.3848
2	90:10	1832.06	2.50	8.8566
3	75:25	1961.82	2.54	8.8676
4	70:30	1894.41	2.56	8.3193
5	60:40	1944.97	2.42	8.6075
6	50:50	1958.39	1.87	6.9476

The static modulus of elasticity of quarry dust–laterite blocks ranges from 6.9476GPa to 8.8676Gpa.

V. CONCLUSION

From the results of the study, the blend of quarry dust and laterite to replace conventional river sand in construction should be encouraged, especially given the environmental negative impact and degradation always associated with river sand harvest. The study provided design data for compressive strength and static modulus of elasticity. These structural characteristics are important in the analyses and design of structures.

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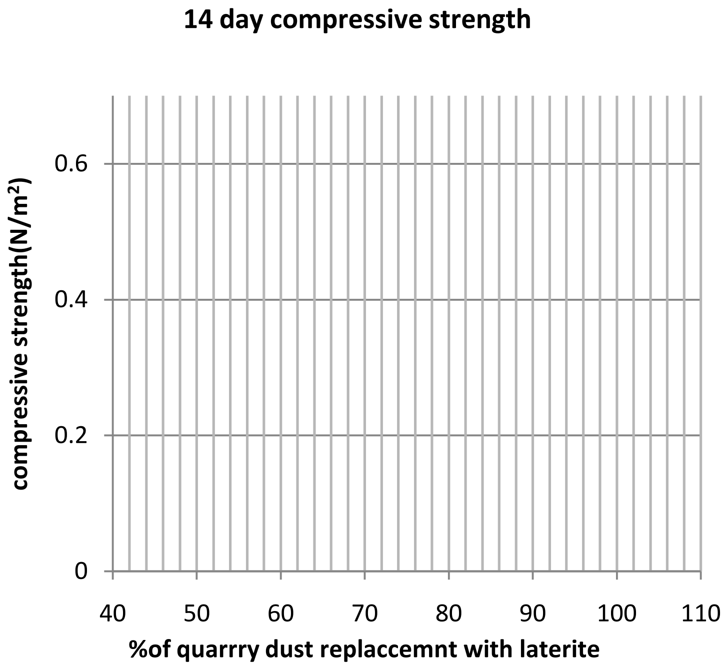

Fig1: 14 day compressive strength

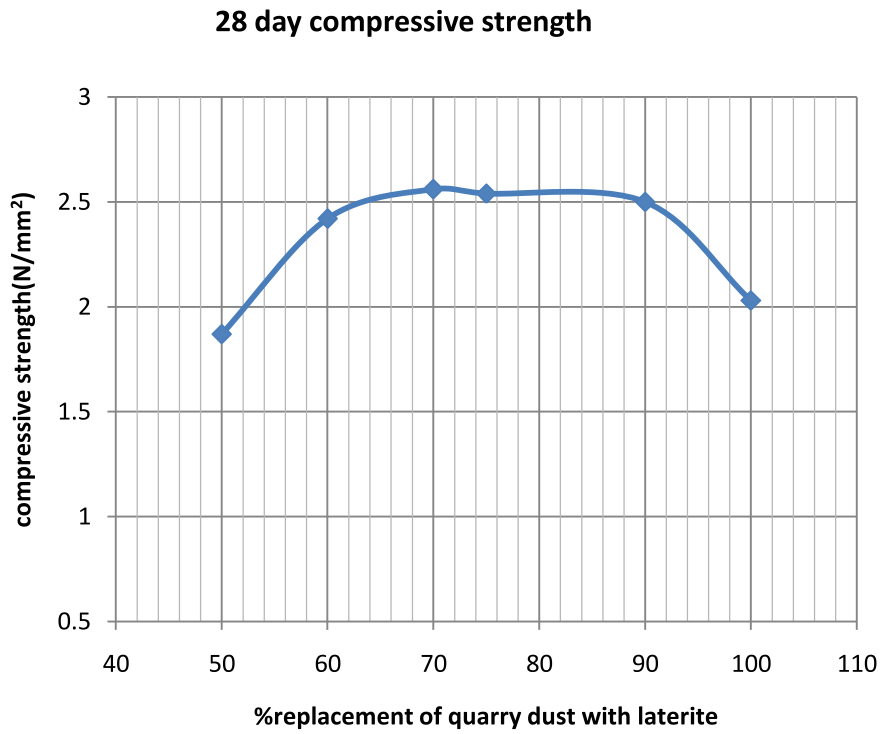

Fig: 28 day compressive strength

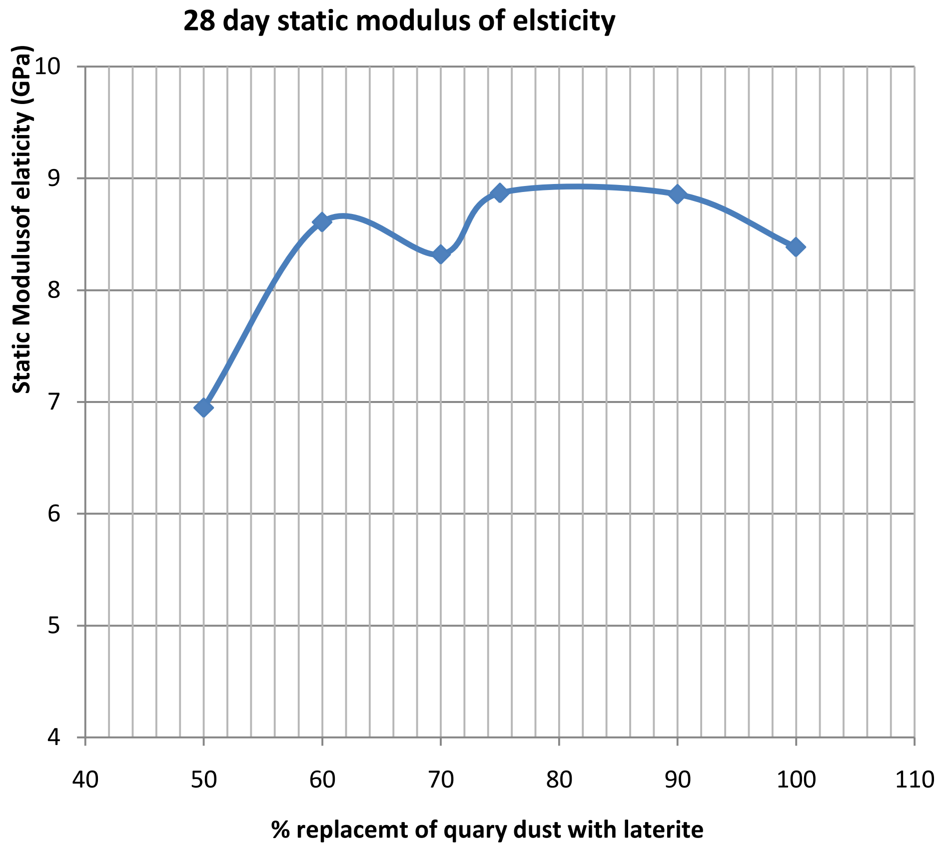

Fig1: 28 day Static Modulus Elasticity

Appendix1

S/N	Sample	Mass (kg)	Density (kg/m^3)	Average density (kg/m^3)	Failure load (kN)	Cross-sectional area (mm^2)	f_c (Nmm^{-2})	Av. f_c (Nmm^{-2})
1	A	22.84	1804.11	1823.065	102.7	56250	1.826	1.87
	B	23.23	1834.91		107.2	56250	1.906	
	C	23.17	1830.17		105.7	56250	1.879	
2	A	24.96	1971.56	1961.822	140.63	56250	2.501	2.5
	B	24.75	1954.98		135.8	56250	2.414	
	C	24.8	1958.93		146.2	56250	2.596	
3	A	24.86	1963.67	1944.971	133.5	56250	2.373	2.42
	B	24.49	1934.44		130.5	56250	2.32	
	C	24.52	1936.81		144.5	56250	2.5687	
4	A	24.31	1920.22	1894.418	144.3	56250	2.565	2.56
	B	23.62	1865.72		142.5	56250	2.533	
	C	24.02	1897.31		144.9	56250	2.576	
5	A	24.92	1968.404	1958.399	139.2	56250	2.475	2.54

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	B	24.79	1958.136		148.8	56250	2.645	
	C	24.67	1948.657		140.6	56250	2.5	
6	A	24.78	1957.346	1960.769	150	56250	2.667	2.56
	B	24.86	1963.665		142	56250	2.524	
	C	24.83	1961.295		139.5	56250	2.48	