IOP Conference Series: Earth and Environmental Science

PAPER • OPEN ACCESS

Optimizing laterite cement blocks in the construction of masonry using quarry dust

To cite this article: P Tiboti *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **802** 012056

Optimizing laterite cement blocks in the construction of masonry using quarry dust

P Tiboti[1*], J B Niyomukiza[1, 2, 3], M Kiwanuka[1, 3], J W Mbujje[4], J Baiga[1], A F Hadudu[1]

[1] Department of Civil Engineering, Faculty of Engineering, Ndejje University, Kampala, Uganda
[2] Department of Civil Engineering, Faculty of Engineering, Universitas Diponegoro, Semarang, Indonesia
[3] Department of Civil Engineering, Faculty of Engineering, International University of East Africa, Kampala, Uganda
[4] Department of Civil Engineering, Faculty of Engineering, Kabale University, Kabale, Uganda

tibotipaul2@gmail.com

Abstract. Laterite soils mixed with Portland cement are used worldwide in making blocks. However, due to the environmental effects associated with the high usage of cement, quarry dust proved to be a good substitute for partial replacement of Portland cement. This study investigates the optimisation of laterite-cement blocks as walling materials using quarry dust. Physical properties of experimental soil were determined, and other tests such as compressive strength, density, water absorption were conducted on sample blocks under curing periods of 7, 14, 21, and 28 days. The blocks comprised of different percentages of laterite soil (76%, 81%, 85% and 87%), quarry dust (9% and 10% by weight of the soil) and ordinary Portland cement (3%, 5%, 10% and 15% by weight of the soil. The results showed that cement content of 10% and 9% quarry dust was suitable for the block at any curing period above 7 days. The compressive strength increased with an increase in the curing period no matter the percentage of the materials used in the study. The study recommends the usage of quarry dust in cement laterite blocks. However, further investigation on other vital parameters like abrasion resistance test could be conducted.

1. Introduction

The increasing demand for environmentally-friendly materials necessitates cheaper construction materials [1-3]. Quarry dust (QD), regarded as a waste material, could also provide a stabilizer for laterite cement blocks. QD is a waste that is obtained during the quarrying process. According to Febin [4], manufactured sand constitutes 30-40% QD. This kind of waste turns into a fine dust when dry, thus leading to environmental pollution and causing health complications to human beings [4,5]. It becomes important to use QD at the site due to its adhesive nature, and one of the ways it could utilize it is by mixing it with cement and laterite soil to form blocks. Previously, laterite soil has been widely used with cement while making laterite cement blocks. Laterite cement blocks (LCB) are those blocks that constitute laterite soil and cement. A small amount of cement inhibits the weakening effect of water and increases the strength [6]. According to Mahalinga-Iyer and Williams [7], laterite soil is mainly found in tropical and sub-tropical regions of the globe. It is believed that their formation is due to weathered rocks under high temperature and rainfall with wet and dry spells. Aginam et al. [8] reported that wind plays a big part in transporting some lateritic soils from their place of origin. However, most of the laterite soils used for highway construction have been formed in-situ [8]. Besides road construction, laterite soils are utilized in various engineering projects like foundations for houses and embankment dams.

In the construction industry, different types of bricks are used. In Uganda, the construction sector mainly uses clay bricks, cement-sand bricks, and concrete blocks. According to Mukiibi [9], most bricks used to have different sizes and structural properties, i.e. non-standardised.

Previous studies conducted on different wastes (granite powder, marble slurry, and concrete slurry) possessing the same properties as those of QD showed good results when utilized as construction materials, for example, a study conducted by Felix [10] to determine the strength properties of concrete using granite powder showed an increase in compressive strength. The previous survey of Almeida [11] showed improved quality of concrete when utilized granite powder. This was witnessed by Ultrasonic Pulse Velocity (UPV) of blocks made of granite powder that was higher than that of conventional bricks. Another strength study by Benzy and Jacob [12] on lateritic blocks considered cement laterite blocks composed of cement, laterite soils, ground granulated blast furnace slag (GGBF) and rubber latex. The investigated properties were the compressive strength, density, water absorption and cost analysis. The use of rubber latex increased the block's porosity, hence increasing the block's water absorption [12]. This research on the use of quarry dust to optimize laterite cement blocks focused on reducing the water absorption, increasing the compressive strength, and obtaining an optimum ratio of the mix for the cement laterite blocks. Besides, this study could promote QD usage as a partial replacement of cement in block making. This will minimize environmental pollution caused by their poor disposal and environmental issues during cement production [2,3].

2. Methodology

2.1. Materials

The materials used in this study included laterite soil, quarry dust and Ordinary Portland cement.

2.1.1 Laterite soil. As shown in Figure 1, the experimental soil was a disturbing sample of laterite obtained from Seguku (Uganda) borrow pit that was being used for road construction. It was then air dried for at least 2 days, then quartered and sieved in accordance with BS 1377 [13]. Lateritic soils possess high clay content and lower cation exchange capacity [14]. The high composition of clay content in laterite soil enables them to bind well when mixed with cement.

Figure 1. Laterite soil from the borrow pit.

2.1.2. Portland pozzolana cement. The cement used as the binder was purchased from a local hardware shop in Kireka, Uganda. The type of cement was a pozzolanic 32.5 rapid setting cement.

Portland cement consists of the following compounds; tricalcium silicate (C_3S), dicalcium silicate (C_2S), tricalcium aluminate (C_3A), tetracalcium alumino ferrite (C_4AF) and gypsum (CSH_2). Different chemical and physical properties of cement were determined.

2.1.3. Quarry dust. Machine crushed quarry dust was purchased from retailers in Kireka (Uganda). The particle size distribution of the dust was carried out to find its gradation.

2.2. Methodology

2.2.1. Particle size distribution. The gradation of laterite soil and quarry dust was determined by conducting sieve analysis for particles greater than 0.075 mm using the following ASTM D 6913-04 procedures [15]. On the other hand, the sedimentation method was used on particles 0.075 mm ASTM D422-63 procedures [16].

2.2.2. Atterberg limits for batch selection. The liquid limit (LL), plasticity index (PI) and plastic limit (PL) were determined in accordance to BS 1377 [17]. The LL was determined using a cone penetrometer.

2.2.3. Stabilization with quarry dust and cement for moulding the blocks. To achieve the proper stabilization for the blocks while using a combination of cement and quarry dust, quarry dust was considered up to 10% to increase the compressive strength of the block and maintain the mixture within the envelope following Koksal for all the mix ratios while the cement was added at 3%, 5%, 10% and 15% [18]. Laterite, cement and quarry dust were mixed on a watertight none-absorbent platform until the mixture was thoroughly blended and of uniform color basing in conformity with BS 1881-108 [19]. Water was added and mixed until the mixture appeared homogeneous. The moulds were cleaned and oiled internally to lubricate the surfaces. The moulds were filled in layers and each layer compacted with about 35 strokes using a tamping rod. The top surface was then levelled and smoothened with a trowel. Once the suitable batches were obtained, 40 laterite cement test cubes of 150 mm × 150 mm × 150 mm were made.

2.2.4. Curing. The blocks were cured for 28 days. In order to achieve maximum strength, the method of curing recommended by Adams [20] was the use of tarpaulin, as seen in Figure 2. The tarpaulin covered the blocks for at least 24 hours before uncovering temporarily to allow watering twice a day for up to 28 days.

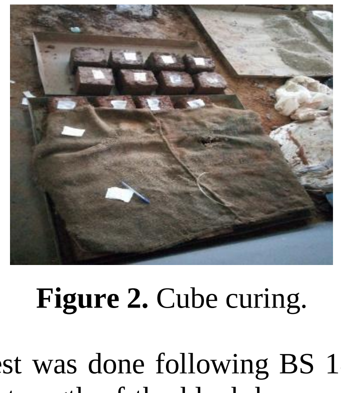

Figure 2. Cube curing.

2.2.5. Compressive strength. This test was done following BS 1881-116 standard [21]. The test was done to determine the compressive strength of the block by crushing 2 blocks per batch at 7, 14, 21 and 28 days of curing.

2.2.6. Density test. Two blocks were selected at random from each sample batch after 7, 14, 21 and 28 days of curing and their densities obtained in accordance with NIS 87 [22].

2.2.7. Water absorption test. This test was conducted by randomly selecting two blocks from each batch at 28 days and weighing each separately on a weighing scale. The blocks are then entirely immersed in water for 24 hours, after which they are removed and re-weighed. The percentage of water absorbed by the blocks was determined in accordance with BS 1881-122 procedures [23].

3. Results and discussion

3.1. Identification of laterite soil

The geotechnical properties of the laterite soil used for the study are summarized in Table 1. The soil used was a reddish brown laterite soil classified as A-2-7 using the AASHTO soil classification system.

Table 1. Properties of laterite soil

Property	**Laterite soil**
Percentage passing BS No 200 sieve (75µm)	27
Liquid Limit (%)	45
Plastic Limit (%)	24
Plasticity Index (%)	21
Linear shrinkage	12
AASHTO classification	A-2-7
Specific Gravity	2.60
Condition of sample	Air-dried
Color	Brownish-red brown

3.2. Particle size distribution of quarry dust

The particle size distribution of the quarry dust used is detailed in Figure 3. The quarry dust was uniformly graded and classified in zone 1, according to Koksal [18].

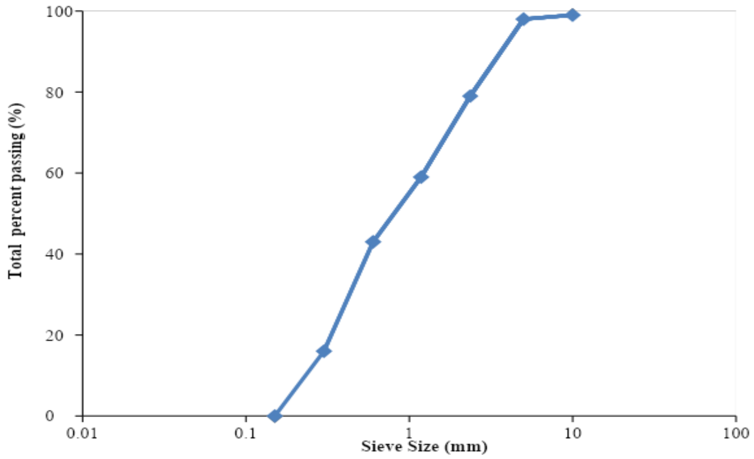

Figure 3. Grading of the quarry dust.

3.3. Cement

The test results for the cement are summarized in Table 2. The tests were carried out in accordance with EN 196 procedures [24]. This research found out that the type of cement used was suitable for making laterite cement blocks.

Table 2. Physical and chemical properties of the cement.

Test	Unit	Results
Initial setting time	Minutes	128
Final setting time	Minutes	284
Consistency	%	27
Soundness	Mm	2.0
2 days strength	MPa	17.2
21 days strength	MPa	34.3

3.4. Compressive strength

Different compositions gave different compressive strength at curing periods of 7, 14, 21 and 28, as seen in Table 3, Table 4, Table 5 and Table 6, respectively. It was observed that a composition of 10% cement, 9% QD, and 81% laterite soil produced greater strength (2.77 Mpa) than the rest of the other compositions at a curing period of 7 days. However, after a curing period greater than 7 days, a composition of 15% cement, 9% QD, and 76% gave greater compressive strength than other compositions. The blocks consistently gained greater compressive strength as the curing days increase. These results conform with the previous studies conducted by Lawane et al. [25] and Irwan et al. [5]. The increase in compressive strength with the increased curing period could be attributed to the cohesive nature of laterite soil that bounds the particles firm and cemented. UNBS [26] recommends the crushing strength of an individual load bearing block greater than 2.5 N/mm^2.

Table 3. Compressive strength and density at 7 days.

Ingredients	Weight (Kg)	Density (Kg/m^3)	Compressive strength (Mpa)
3%C,10%QD,87% S	7.2	2133	0.36
	7.0	2074	0.35
5%C, 10%QD, 85%S	7.4	2193	1.22
	7.3	2163	1.16
10%C, 9%QD, 81%S	7.4	2193	2.77
	7.4	2193	2.77
15%C, 9%QD, 76%S	7.5	2222	2.68
	7.6	2252	2.75

Table 4. Compressive strength and density at 14 days.

Ingredients	Weight (Kg)	Density (Kg/m^3)	Compressive strength (Mpa)
3%C, 10%QD, 87% S	7.0	2074	2.02
	7.3	2163	1.20
5%C,10%QD, 85%S	7.0	2074	1.80
	7.2	2104	3.00
10%C, 9%QD, 81%S	7.4	2193	4.40
	7.2	2133	3.60
15%C, 9%QD, 76%S	7.4	2193	5.10
	7.6	2252	5.11

Table 5. Compressive strength and density at 21 days.

Ingredients	Weight (Kg)	Density (Kg/m^3)	Compressive strength (Mpa)
3%C, 10%QD, 87% S	7.2	2133	2.0
	6.8	2014	0.9
5%C, 10%QD, 85%S	7.0	2074	2.3
	7.1	2163	3.4
10%C, 9%QD, 81%S	7.0	2074	4.9
	7.0	2074	4.7
15%C, 9%QD, 76%S	7.2	2133	6.2
	7.4	2193	6.7

Table 6. Compressive strength and density at 28 days.

Ingredients	Weight (Kg)	Density (Kg/m^3)	Compressive Strength (Mpa)
3%C,10%QD,87% S	6.8	2015	1.5
	6.9	2044	1.1
5%C,10%QD, 85%S	7.2	2133	2.9
	7.1	2104	3.7
10%C, 9%QD,81%S	7.1	2104	5.1
	7.1	2104	5.4
15%C, 9%QD,76%S	6.9	2044	5.6
	7.4	2193	8.8

From Figure 4, it was observed that the compressive strength increases as the age of curing increase no matter the percentage of the cement added, which shows that the longer the block is cured, the higher the compressive strength attained.

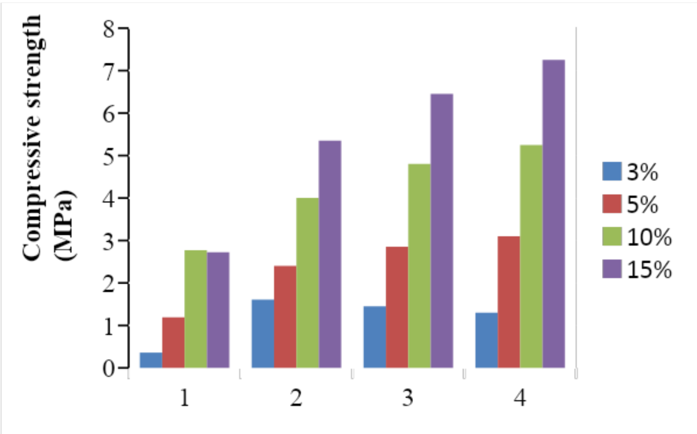

Figure 4. Compressive strengths at different curing time.

3.5. Density

The results for the densities are as shown in Tables 3, 4, 5 and 6. Generally, the density reduces as the days of curing increase, as illustrated in Figure 5. This decrease was due to the disintegration of the edges of the blocks as it was being cured. According to the UNBS [26], the minimum acceptable block density is 1600 kg/m^3, which shows that the densities of the block in any curing age conform with the standards.

Figure 5. Densities at different curing time.

3.6. Water absorption

Water absorption decreases with increased percentages of cement (see Table 7). These results were expected because the cement binds the laterite particles together and thereby reduces the sizes of the pores through which water could enter into the blocks [25]. According to the UNBS [24], the water absorption of stabilized soil blocks when determined should not exceed 15%, which was satisfied by the blocks produced by all mixtures used in this study.

Table 7. Water absorption test results.

Sample	Water Absorption (%)	Average Water Absorption (%)
3%C, 10%QD, 87% S	13.9 12.7	13.3
5%C, 10%QD, 85%S	8.4 7.9	8.1
10%C, 9%QD, 81%S	5.5 4.4	4.9
15%C, 9%QD, 76%S	4.2 4.1	4.1

4. Conclusions

The study presented the feasibility of optimising masonry laterite blocks using quarry dust. Different tests were conducted on varying percentages of cement, quarry dust and laterite soil. It was concluded that the laterite was highly plastic well-graded with considerable natural moisture content, a specific gravity of 2.6, implying that there is low porosity of the soil. The quarry dust used was uniformly graded, and the cement was rapid setting with a strength of 34.3MPa. Therefore, gravelly lateritic soils classified as A-2-7 under the AASHTO classification system are suitable materials for the production of laterite cement blocks for walling units in buildings. The compressive strength increased as the age of curing increased. Hence the longer the block is cured, the higher compressive strength attained. Generally, the density of the block reduces as the days of curing are increased. For well-graded laterite soil and uniformly distributed quarry dust, cement content of 10%, 9% QD, and 81% laterite soil was suitable for the block at any curing age above 7 days. The study recommends further investigation on other properties of laterite cement blocks stabilised by quarry dust, like wet compressive strength, abrasion resistance test, and drying shrinkage.

References

[1] Kongkajuna N, Laitilab E A, Ineure P, Prakaypand W, Cherdhirunkorna B and Chakartnarodome P 2020 *Case Stud. Constr. Mater.* **13** e00448
[2] Niyomukiza J B, Wardani S P R and Setiadji B H 2020 *IOP Conf. Ser. Earth Environ. Sci.* **448**

1-10
[3] Niyomukiza J B, Wardani S P R and Setiadji B H 2021 *IOP Conf. Ser. Earth Environ. Sci.* **623** 1-9
[4] Febin G K, Abhirami A, Vineetha A K, Manisha V, Ramkrishnan R, Sathyan D and Mini K M 2019 *Constr. Build. Mater.* **228** 1-9
[5] Irwan J M, Othman N and Koh H B 2020 *Int. J. Sustain. Constr. Eng. Technol.* **2** 13–22
[6] Aguwa J I 2010 *J. Pract. Technol.* **9**(16) 189–200
[7] Mahalinga-Iyer U and Williams D J 1997 *Eng. Geol.* **46**(2) 71–80
[8] Aginam H C, Nwakaire C and Nwajuaku A I 2015 *Int. J. Soft Comput. Eng.* **4**(6) 1–6
[9] Mukiibi S 2015 *Int. J. Technoscience Dev.* 2015 2(1) 84–92
[10] Felix T K 2013 *Int. J. Eng. Sci.* **2** (12) 36–50
[11] Almeida N, Branco F and Santos J R 2007 *Build. Environ.* **42**(2) 810–819
[12] Benzy A, Pradeep A, Mathews J and Jacob J M 2016 *Int. J. Sci. Technol. Eng.* **2** 338–341
[13] British Standards 1992 *Soils for civil engineering purposes* BS882:1992 **3**(1)
[14] Ko T H 2014 *Sci. World J.* **2014** 1-4
[15] ASTM International 2009 *Standard test methods for particle-size distribution (gradation) of soils using sieve analysis* (Conshohoken PA: American Society for Testing and Materials) D6913-04
[16] ASTM International 2002 *Standard Test Method for Particle Size Analysis of Soils* (West Conshohoken PA: American Society for Testing and Materials) ASTM D422-63
[17] British Standards 1990 *Soils for civil engineering purposes* BS1377-2:1990 **3**(1)
[18] Koksal A 2002 Specification for aggregates from natural sources for concrete
[19] British Standards 1983 *Method for making test cubes from fresh concrete* BS 1881-108 London
[20] Adam E A and Agib A R 2001 *Compressed Stabilized earth Block Manufacturing in Sudan* - UNESCO - Technical Note No. 12
[21] British Standards 1983 *Methods for determining compressive stregth of concrete cubes* BS 1881-116
[22] Nigerian Industrial Standard 2004 *Standard For Sandcrete Blocks* NIS 87 (Niger)
[23] BS 1881-122 1983 *Testing Concrete: Method of Determining Water Absorption* (London: Br. Stand. Institution)
[24] EN196-3 2016 *Methods of testing cement: determining the standard consistence, setting times and soundness of cement* (Eur. Comm. Stand.)
[25] Lawane A, Minane J R, Vinai R and Pantet A 2019 *in. Sci. African* **6** 1–19
[26] UNBS 2009 FDUS 849 *Specification for stabilized soil blocks* (Kampala)