Contents lists available at http://qu.edu.iq

Al-Qadisiyah Journal for Engineering Sciences

Journal homepage: http://qu.edu.iq/journaleng/index.php/JQES

Improving the Properties of Clay Soil by Using Literate Soil for Production of Bricks

Anteneh Geremew [a*], Yibas Mamuye [a]

[a] *Department of Civil Engineering, Jimma University, Jimma , Ethiopia*

ARTICLE INFO

Article history:
Received 18 September 2019
Received in revised form 20 November 2019
Accepted 05 October 2019

Keywords:
Literate soil
Brick
Clayed soil
Compressive strength
Water absorption
Sustainable
Construction material

ABSTRACT

Utilization of local accessible materials is an important stage for sustainability nowadays. Brick units are the most commonly used construction material around Jimma town due to the availability of clayed soil. In comparison with the traditional method, brick produced by small micros un-skill enterprises is mainly specified by less quantity and lower quality The purpose of this study was to improve the properties of clayed soil adopted in manufacturing of masonry brick units using Literate soil . In order to achieve this, non-probability sampling technique was used to collect samples from Jimma area. The collected samples were then prepared for running different laboratory tests. The samples were formulated through partially replacing literate soil by 5%, 10%, 15% and 20%, respectively. The test results showed that the procedure adopted in this study can produce lightweight brick units without any deterioration in the quality of bricks. The maximum compressive strength value was noted for the brick units formulated with lateritic soil of 15% replacing. The optimum firing furnace temperature was observed at 1000°C for 5hrs. The brick units prepared at this temperature level exhibited the highest resistance to the applied loads.

1. Introduction

Ethiopia is one of the fast economic growth in East-Africa [1]. Due to urbanization of populations living in towns becoming increases day by day; the sustainable living standards in a town constructing lead to increase the cost of concrete production [2].There are small numbers of micro enterprises working in producing clay brick in a traditional way with less quality. They only focused on the external shape of brick units. In Jimma area, large deposit of clayed soil and literate soil are available [3]. Laterite earth material was considered to be one of the oldest and commonly used building material. It was considered to be one of the most important construction material on the earth surface was widespread [4]. Unfortunately, laterite earth construction in developed country is diminishing with the abrupt changes in construction materials [5].Good quality brick units can be manufactured using lateritic soil provided that accepted clay material will be added. The use of plastic clayed alone in the production of brick may not be suitable due to shrinkage and warping effect during the drying process [6]. Partially substituting clay earth with disbursed unwanted Shea has growth scientific enactment of black of earth in decreasing the mass, improving the general performance [7]. Appropriateness of the application of biological flavours in brick earth to be established was upgraded competence and continuing. Therefore it decreases ecological effect [8] Burring the brick units of earth brick need huge amount of power estimated by 24 million tons per year which is one of major causes of environmental defect [9]. A block earth material has a numerous practices on construction industry resources [10].

According to [6], the application of lateritic brick added clay started around 8000 BC in Mesopotamia the construction of houses, dams. Due to it durability and cost effectiveness, lateritic brick is also considered an excellent sustainable materials in construction and recycling process and can minimized pollution with low carbon emission during the application [11].The application of laterite earth in building construction almost exist

* *Corresponding author.*
E-mail address: antjiren@gmail.com (Anteneh Geremew)

https://doi.org/10.30772/qjes.v12i4.611

anywhere in the world especially in third world country.in country like Kano, Kaduna and other cities in Northern Nigeria, used of this material is very effective. But it can be noted that laterite earth is also applied in developing countries [6, 12]. In many countries, such as Asia and Africa, more than two billion peoples are using in building/house construction using lateritic earth and clay products. The application of these material has earned lot of advantages in terms of quality, characteristics and application in construction. Additionally, it improve the quality of lateritic earth, additives and remove of one of its contents is also an option [13]. The reduction of energy requirement in the production of brick using lateritic soil is an advantage. It is produced using 5KWH/m^3 compared to fired brick and concrete block which consume 1000KWH/m^3 and 450KWH/^{m3} respectively. Additionally, lateritic soil structure are easily recyclable without polluting the environment [14]. Due to its availability /existence ant where in the world, its application in the environment building is very crucial. It is available in many different composition, so further investigation is added to other material such as clay to produced sustainable structure [6, 15, and 16].

Brick extensively adopted building material round Jimma town. Unlike other than city outside of Jimma used most implemented for modern households, pale, ancient houses are intensively built by block partition and pillars. Particularly ancient structures brick pillars and partitions were precise exciting which occur today without major failure and attending still current time. The research conducted by [17] showed that the brick produced nearby Jimma area were below standard specifications. In addition, small micros are producing clay brick for low cost houses these days in small amounts and with unsatisfactory quality. This in turn gives lower strength and with high water absorbing behaviour. This study has improved the physical properties of the brick by mixing clayed soil with literate soil. This encourages the use of locally available material for the production of brick for affordable and low cost construction of houses. This considers a good opportunity for Job creation for the society living around Jimma town.

2. Materials required and Methods

2.1. Materials required

In order to achieve the objective of this study, purposively sampling techniques was implemented for the Lateritic soil samples around Jimma town . This clayed soil has high plasticity and collected at depth of 0.5m in order to protect other organic material. The samples was collected using engineering judgement by observing colour texture and index property.

2.2. Preparation of brick units

The clayed soil utilized for this particular research was selected with high plastic contents. In order to improve the property of the clayed soil, different percentages of laterite soil 5%, 10%, 15% and 20% (through mass) were used and finally uniform mixing was carried until the same colour was obtained. Atterberg limit tests was performed on different percentages of lateritic soil added to the clayed soil. Water was added for the mixes prepared until suitable consistency, and proper mixing was achieved.

The following procedure was used during production of clay-lateritic brick units:

- The collected sample were lateritic and clayed soil allowed to drying separately
- Grinding the samples in small particles until the required sieve size pass.
- Preparing mix design according to the percentage required and separately by adding the necessary amount of water for different mixes until the favorable of workability is obtained. The mixes were then stored in a cool room for at least of two days until uniform distribution of water attained in the mixture.
- Before placing; mould was dipped in water in order to prevent sticking and poured the mix in the mould by thrown forcedly by hand until the rough shaped is achived. The excess on the top of mould was removed by thin wire. Immediately; the moulded brick was demolded and dried in the sun for a week and finally the bricks were dried in furnace at 1000°c for 5hrs.

2.3. Methods and Standard Testing Procedure

Table 1 shows a summary of test method

Table 1 Summary of Test Method

Type of test	Test method/ Designations
Moisture content	AASHTO T – 265
Sieve analysis	ASTM -D422-63
Atterberg limits	ASTM -D4318-98
Soil grouping	ASTM -D2487-98
Specific gravity	ASTM -D854-83
Proctor test	ASTM -D698-98
Compressive test	IS 3495 (PART I-III) and IS 3346:1980
Preparation of samples	IS 1077:1992
Efflorescence	IS 3495 (PART III) – 1992

3. Result and discussion

3.1. Engineering Properties of lateritic soil and Clay soil

3.1.1. Identification of engineering properties of lateritic soils.

In order to control the quality of the materials, laboratory tests were carried out based on the standard specification. The experiments elaborate to classify to the belongings lateritic earth such as its physical and mechanical possessions and the results obtained are shown in **Table 2**.

Table 2. Geotechnical Properties of Lateritic soil

S/N	Type of test	Test method/ Designations
1	Catalogue	
	AASHTO	A-2-7
	USCS cluster	SC
	USCS cluster	poorly -graded sands
2	Specific gravity	2.37
3	Sieve analysis	
	Sand content % (4.75 to 0.075mm)	62.4
	Silt and clay content % (under 0.075mm.)	37.6
4	Atterberg's Limits: %	
	Liquid limit	78.54
	Plastic limit	41.19
	Plasticity index	37.35
5	Proctor test	
	Optimum moisture content (OMC), %	41.56
	Maximum dry density (g/cm3)	1.31
6	Red Literate soil	By visual inspection

3.1.2. Engineering belongings of Clayed soil.

The experiments elaborate to classify the possessions of the clayed earth such as its physical and mechanical possessions. Therefore investigations carried out on the unprocessed clay earth contains sieve analysis, Atterberg limit test, compaction test, California bearing ratio and specific gravity and the results obtained are shown in **Table 3**.

Table 3. Geotechnical Properties of Clayed earth

S/N	Attribute	Empirical Standards
1	Catalogue	
	AASHTO	A-2-5
	USCS cluster	CH
	USCS cluster	Soft Soil
2	Specific gravity	2.485
3	Sieve analysis	
	Gravel content% (20 to 4.75mm.)	0.533
	Sand content % (4.75 to 0.075mm)	4.952
	Silt and clay content % (below 0.075mm.)	94.515
4	Atterberg's Limits: %	
	Liquid limit	87.42
	Plastic limit	31.85
	Plasticity index	55.57
5	Proctor test	
	Optimum moisture content (OMC), %	34.54
	Maximum dry density (g/cm3)	1.235
6	Red Literate soil	By visual inspection

3.2. Casting of Bricks

3.2.1. Preparation of mixed clay-lateritic soil

As a control of test a clay brick alone was prepared accordingly and shaped based on size of box and allowed to burnet to a furnace oven. Additionally to this unlike proportion of laterite earth added 5, 10, 15 and 20%. The blends were set with the pre-determined optimum moisture content values. The size of box of bricks to be casted dimension of 230 x110x70mm non-modular bricks. It's obvious as per IS 1077:1992. The arranged combination was forced into the mould and subsequently removing the mould retained it for sun drying. The prepared sample of bricks was allowed to dry until it reduces moisture content from it. Exposing to ventilation to sun drying period approximately a weeks and finally transferring the samples to the furnace oven, where they were burnt at a temperature of 1000ºC for 5hrs. Sample of bricks was taken out from the furnace oven after that allowed to cool then starting the laboratory testing started after 21 days of curing as per IS code.

3.2.2. Test Methods

The bricks were tested as per in IS code for finding the physical properties. The burned bricks were cured for 21 days and only after that testing were started. Compressive strength, water absorption, efflorescence and thermal conductivity are the tests conducted on the bricks. The experiments continuously conducted as per IS 3495 (PART I-III) and as per IS 3346:1980.

3.3. Discussion of Test Results

Clay bricks made with laterite soil were tested for analysing the physical properties of bricks such as Atterberg limit test, compressive strength, water absorption, efflorescence and thermal conductivity.

3.3.1. Atterberg limit test and workable mixing water contents

The results of Atterberg limit tests and workable mixing water contents are shown in **Table 4** and **Fig. 1** based on standard specification [19, 20]. It can be seen that both liquid and plastic limits have decreased, with increasing of percentage of laterite content. But also the workable mixing water content also decreases with increase percentage laterite.

$$Plastic\ Index = Liquid\ limit - Plasti\ limit \quad (1)$$

Table 4. Effect of laterite soil on Atterberg limits

Laterite soil content (%)	Liquid Limit (%)	Plastic Limit (%)	Plastic Index (%)	Mixing Water contents (%)
0	87.42	31.85	55.57	38.98
5	83.54	30.11	53.43	35.49
10	76.25	27.47	48.78	33.47
15	69.05	22.61	46.44	31.19
20	53.77	18.87	34.9	30.09

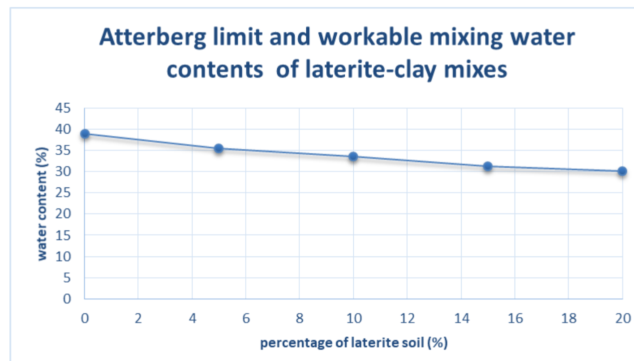

Figure 1. Water contents verses percentage of laterite in clay soil

3.3.2. Linear shrinkage and density

The summary of the results of linear shrinkage, and dry and firing densities are shown in **Table 5**, the shrinkage decreases with increase of the laterite soil contents but decreases in dry density.

Table 5. Effect of Laterite soil on linear shrinkage, dry and after furnace densities of clay-laterite

Laterite soil content (%)	Linear shrinkage (%)	Dry density(kg/m3)	After furnace oven (kg/m^3)
0	11.63	1820	1753
5	10.16	1756	1654
10	9.25	1611	1488
15	8.85	1523	1376
20	6.11	1402	1224

3.3.3. Compressive strength of clay bricks with Laterite soil

Compressive strength test result of produced clay-laterite bricks made with different percentages of laterite soil with 0%, 5%, 10%, 15% and 20% are shown below in **Table 6** and **Fig. 2.**

$$Average\ stress(\delta) = \frac{maximum\ load(KN)}{Average\ area\ of\ bed\ face(mm^2)} \quad (2)$$

Table 6. Compressive strength values of clay-laterite bricks with Laterite soil

Laterite soil content (%)	Compressive strength or stress, σ (MPa)	Specification
0	10.76	
5	10.96	Compressive strength
10	11.19	not less than 10 N/mm^2
15	11.37	for class designation 100 [18]
20	11.29	

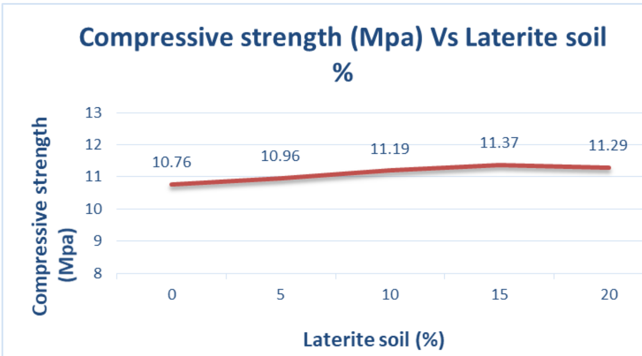

Figure 2. Variation of compressive strength results of clayed bricks with Laterite soil

The compressive strength of the bricks depends mainly on the density and porosity of the bricks. It is observed that the results of clay bricks with laterite soil show a compressive strength greater than 10 MPa, which belong to class designation 100 as per Indian standard specification. All the modified bricks showed higher strength than control bricks.

3.3.4. Water absorption

As the percentage of laterite soil increases water absorption decrease. The results obtained for the water absorption are shown in **Table 7** and **Fig.3.**

Table 7. Water absorption test Result of produced bricks with Clay-Laterite

Laterite soil content (%)	Water absorption (%)
0	16.25
5	15.54
10	14.48
15	13.04
20	11.55

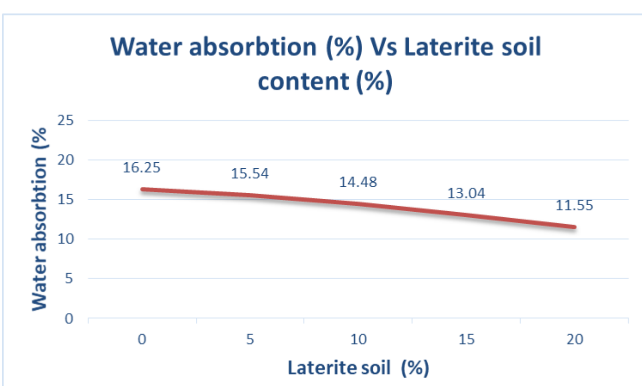

Figure 3. Variation of water absorption of clay bricks with Laterite soil

Based on the experiment achieved in laboratory for the manufactured bricks made with laterite soil have similar properties obtained as the control bricks. Laterite soil- clay brick shows lesser water absorption rate as compared to standard specification of the class.

3.3.5. Efflorescence

Efflorescence was determined to find the alkaline salt content in bricks. The test was conducted as per IS 3495 (part III) – 1992. In this experimental work, no noticeable deposit was observed on majority of samples but there is a very thin deposit of salts observed on certain brick parts.

4. Conclusion

On the basis of experiment outcomes, the resulting was summarizes as follows:

The Laterite earth soils were classified based on ASSHTO classification system as A-2-7 category with poorly graded gravel and based on the USCS as SC soil groups. The compaction test for the laterite soils yielded MDD and OMC with 1.31g/cc and 41.56% respectively. The Clay soils were classified based on ASSHTO classification system as A-2-5 category with high plastic clay and based on the USCS as CH soil groups. The compaction test for the clay soils yielded MDD and OMC which 1.235g/cc and 34.54% respectively.

The density of brick decreases with increase in laterite contents. Light weight bricks can thus be produced without any deterioration in the quality of the bricks. Modified clay bricks showed increase in compressive strength up to a particular percentage, beyond that point compressive strength decreases. This is due to the less bonding between clay-laterite and lesser density of the modified bricks. Water absorption decreases with increase the percentage addition of laterite soil. This is due to the coarser soil particles in bricks; this results in less water absorption. Samples of bricks have minor efflorescence content observed on the face of brick. This in turn means that the alkaline salt content in those bricks is lesser.

Bricks prepared of clay-lateritic combinations also utilized for high resisting capacity for simple structure except for underground structures. More research must be conducted in order to recognise the long-term effects of clay-laterite block on the toughness of bricks and also examine its chemical composition of clay-laterite soil materials.

References

[1] UNDP, "ETHIOPIA: Country Economic Brief," UNDP Ethiop. Policy Advis. Unit, no. 1, pp. 1–15, 2014.

[2] Asian Development Bank, "Urbanization and Sustainability in Asia: Case Studies of Good Practice," Adb, p. 516, 2006.

[3] Unido, OCCASION This publication has been made available to the public on the occasion of the 50. 2007.

[4] A. K. Kasthurba, M. Santhanam, and M. S. Mathews, "Investigation of laterite stones for building purpose from Malabar region , Kerala state , SW India – Part 1 : Field studies and profile characterisation," vol. 21, pp. 73–82, 2007.

[5] M. A. Rahman, "The potentials of lateritic soil-Clay and clay-sand mixes in the manufacturing of bricks for masonry units," Build. Environ., vol. 22, no. 4, pp. 325–330, 1987.

[6] M. Mudi and A. A. Aliyu, "an Examination of the Properties of Literate and Clay As Construction Materials for Sustainable Buildings in Kano and Kaduna Metropolis , Nigeria," no. July, pp. 1–7, 2012.

[7] A. N. Adazabra, G. Viruthagiri, and N. Shanmugam, "An assessment on the sustainable production of construction clay bricks with spent shea waste as renewable ecological material .," vol. 1, no. 2, 2018.

[8] J. A. Lozano-Miralles, M. J. Hermoso-Orzáez, C. Martínez-García, and J. I. Rojas-Sola, "Comparative study on the environmental mpact of traditional clay bricks mixed with organic waste using life cycle analysis," Sustain., vol. 10, no. 8, 2018.

[9] M. L. Mary, C. Peter, K. Mohan, S. Greens, and S. George, "Energy efficient production of clay bricks using industrial waste," Heliyon, vol. 4, no. 10, p. e00891, 2018.

[10] Zultiniar, A. Fadli, S. R. Yenti, Drastinawati, and M. R. A. Thariq, "Fabricaton of brick

without burning process," IOP Conf. Ser. Mater. Sci. Eng., vol. 345, no. 1, 2018.

[11] K. K. G. K. D. Kariyawasam and C. Jayasinghe, "Cement stabilized rammed earth as a sustainable construction material," Constr. Build. Mater., vol. 105, pp. 519–527, 2016.

[12] A. U. Kakale, "SUSTAINABLE ENVIRONMENT : LATERITE AS SUSTAINABLE," no. 2, pp. 70–73, 2016.

[13] S. Gallen, "SKAT Swiss Centre for Development Cooperation in Technology and Management," 1993.

[14] P. O. Akadiri, E. A. Chinyio, and P. O. Olomolaiye, "Design of A Sustainable Building: A Conceptual Framework for Implementing Sustainability in the Building Sector," pp. 126–152, 2012.

[15] B. Bayizitlioğlu, "The Historic Environment : Policy & Practice Conservation and Maintenance of Earth Constructions : Yesterday and Today Conservation and Maintenance of Earth Constructions : Yesterday and Today," Hist. Environ. Policy Pract., vol. 7505, no. December, pp. 1–32, 2017.

[16] S. Deboucha and R. Hashim, "Correlation between total water absorption and wet compressive strength of compressed stabilised peat bricks," vol. 6, no. 10, pp. 2432–2438, 2011.

[17] K. Getachew and A. Mosisa, "Laboratory Investigation of Locally Produced Clay Brick Quality and Suitability for Load Bearing Element in Jimma Area, Ethiopia Alemu Mosisa," Int. J. Eng. Res. Technol., vol. 6, no. 5, pp. 809–817, 2017.

[18] IS-1077, "Common Burnt Clay Building Bricks -Specification," Bur. Indian Stand., 2007.

[19] ASTM C67-90. (1996). Standard test method for the properties of fired clay bricks "Annual Book of American Society for Testing and Materials''.

[20] Ethiopian Standards Agency (ESA). (2011). Solid clay bricks, ES 86:2001, Ethiopian Standard, Second edition 2001-06-27.