Technical Sciences
Academy of Romania
www.jesi.astr.ro

Journal of Engineering Sciences and Innovation
Volume 4, Issue 4 / 2019, pp. 371-380

B. Chemical Engineering, Materials Science and Engineering

Received ***7 October 2019*** *Accepted* ***2 December 2019***
Received in revised from ***28 November 2019***

Improving the properties of clay soil by using laterite soil for production of bricks

ANTENEH GEREMEW*

Department of Civil Engineering, Faculty of Civil and Environmental Engineering, Jimma Institute of Technology, Jimma University, Jimma, Ethiopia.

Abstract. Nowadays the use of local accessible materials is an important step for the development of sustainable and economic construction materials worldwide. Among them brick is one of the widely used construction material around Jimma town due to the availability of clay soil and it is not un-common to use locally produced brick for building houses and fences. But compared to the brick produced in enterprises by the traditional method, the brick produced by non-specialized small and micro-enterprises is manufactured in smaller quantities and is of unsatisfactory quality, since it is easily breakable and has high water absorption behavior. Most of people use such bricks for decorating the outside walls of the houses and villas or only as a partition wall. The main objective of this study was to improve the properties of the clay soil, by using the laterite soil for the manufacture of bricks to be used as masonry units. In order to achieve this research, non-probability sampling techniques were used to collect samples in Jimma area, then some collected samples were prepared for various laboratory tests and for the 5%, 10%, 15% and 20% partially replacing of laterite soil with clay soil, in order to get the optimum material properties by assessing different mix ratios for compressive strength, water absorption, atterberg limits, linear shrinkage, density and efflorescence. Test results indicated that lightweight bricks could be manufactured by this method without any deterioration in the quality of bricks. Further, the compressive strength of the bricks was found optimal for the15% laterite soil replace in clay soil contents. The optimal furnace temperature for the duration required for burning the brick was 1000°C. This research has also shown that bricks made of clay-laterite can be used for building load bearing walls, rather than in decorating the facades of houses.
It is shown that bricks made of clay-laterite soil can be also used in rather than for beauty.

Key words: laterite soil, brick, clay soil, compressive strength, water absorption, sustainable, density, construction material.

*Correspondence address: antjiren@gmail.com

1. Introduction

Ethiopia one of the countries with fast economic growth in East-Africa [12]. Due to urbanization the number of populations living in town has become increasingly day by day; therefore, to achieve a sustainable standard of living in a city the construction of a home is an unquestionable necessity, although the cost of a block of housing made of concrete has increased considerably [13]. There are some small and micro-enterprises in the country that produce clay brick traditionally, without controlling the quality but only by checking the visual appearance of the brick surface; also, Jimma area benefits on a large deposit of clay soil and laterite soil.
Production of bricks by lateritic soil alone is not suitable but this soil can be used in the manufacture of good quality bricks, if modified by adding clay. On the other hand, plastic clay alone is not suitable for brick making as excessive shrinkage and warping take place in the process of drying of the brick [10]. For construction materials, many benefits could be offered by laterite earth which is often under-utilized in the developed countries despite the use of laterite earth as a low embodied material is often required [1].
Historically, laterite earth has been the oldest and most widely used building material for constructions; it has been the most important of all the building materials [2]. According to Yar'adua Muntari Mudi (2012) some recorded cases of the use of laterite bricks and clay dated back to Mesopotamia around 8000 BC. Laterite earth buildings avoided high energy demand and costs in the initial manufacturing and construction period. This lateritic soil was used for building homes, dams, for paving roads constructions and could also be recycled. Therefore, it is not surprising that many people acknowledged the value of laterite earth construction for the above reasons as well as for its durability, cheapness and physical qualities [3], being an excellent sustainable material since it can be reused following a recycling process. These qualities are reflected to the efficient use of finite resources, while minimizing pollution, waste and low carbon emissions especially in industrial countries [4]. Laterite earth as a building material is available everywhere in the world and exists in many different compositions. It is most efficiently used in developing countries such as Kano, Kaduna as well as in some towns in Northern Nigeria to house the greatest number of people for the least cost. However, it must be noted that laterite earth buildings are not widely spread only of the Third World countries, but this material is used also in developed countries [1]. Many types of laterites are suitable to be used as construction materials. To ensure an effective use, their quality have to be examined in order to identify their characteristics and assess the appropriateness for their use in common constructions. Besides the addition and removal of certain constituents, several tests need to be carried out to certify its quality. If understanding the real quality of laterite and clay, we can use them on site in a sustainable way for construction materials. Different types of laterite and clay are suitable to be used for civil and official constructions. Currently, more than two

billion people are living in buildings made of laterite earth and clay products mostly in Asia and Africa [9].

To improve their quality, the selection of building materials should meet the local conditions of the area where they will be used for improving existing structures or for building new structures. In the past, improving and developing the natural materials using new technology has created substitute materials. In addition, the energy demand to produce adobe block is only 5 (kWh)/cubic meter, while it is about 1000 (kWh)/cubic meter for fired brick and 400 to 500 (kWh)/cubic meter for concrete block [5].

Laterite earth structures are completely recyclable since sun-dried bricks return to the earth without polluting the environment [6,7]. Using laterite earth for such environmental-friendly buildings may become a strong component for the future of housing for the population. Laterite earth as a building material is available everywhere in the world and exists in many different compositions. Therefore, there is need to investigate and examine the properties and quality of laterite and clay to produce sustainable buildings for the increasingly number of population [1].

Bricks have been widely used as construction material around Jimma town. Unlike other part of our country it can be observed that presently most of new villa houses, fences and existing old buildings are intensively constructed or consolidated using brick walls and columns. Especially old buildings brick columns and walls have been proved very resistant and inspiring, without exposing significant failure and serving in good condition even today. But the study conducted by Kabtamu et al. [8] shows that brick produced around Jimma area was below the standard specification requirements. Besides this, small and micro-enterprises are currently producing clay brick for low cost houses in small amount and with unsatisfactory quality, which can easily break and poses high water absorbing behavior. It is also known that many people are not using this brick for load bearing but only for the purpose of decorating walls and fences. This study aims to demonstrate improving the physical properties of the brick by mixing clay soil with laterite soil. Based on the results of this study, it is expected to encourage the use of locally available material for the production of brick for affordable and low cost construction of housing. Also, this study may open good opportunities for creating new jobs for the society.

2. Materials and methods

2.1 Materials required

Lateritic soil and highly plastic clay soil, both collected at depth of 0.5m in order to protect other organic material.

2.2 Preparation of brick

The clay soil which was used in this study was selected to have highly plastic contents. In order to improve the property of the clay soil, different percentage laterite soil of 5%, 10%, 15% and 20% (by weight) was used to replace clay soil and finally uniform mixing was carried until a uniform color was obtained. Atterberg limit tests were performed on different percentage of lateritic soil added on clay soil. Water was added in the mixtures thus prepared until it gave a consistency workable and suitable for each different percentage of soil and proper mixing was done so as get an adequate consistency suitable for shaping the bricks. The following steps were used for manufacturing clay-lateritic brick units:

I. The collected samples of lateritic and clay soils were allowed to drying separately.
II. The dried soil samples were crushed and grinded in small particles until the required size passed through the sieve.
III. The percentages and weight required for preparing the mixtures were established, and separately for each mixture the required amount of water was added until the material achieved the favorable texture for shaping, finally the mixtures thus prepared were stored in a cool room for at least two days until uniform distribution of water was attained in the mixture.
IV. Before molding start, the moisturized soil was dipped in water in order to prevent sticking, then the mixture was poured in the mold pressing forcedly by hand until a roughly shaped was obtained. The material in excess on the top of mold was removed by a thin wire cable. Immediately; the molded brick was demolded and dried in the sun for a week. Finally, the bricks were burned at 1000°C in a furnace oven.

3. Results and discussion

3.1. Engineering properties of lateritic soil and clay soil

3.1.1. Engineering properties of lateritic soils

In order to assess the quality of the materials, laboratory tests were carried out. The tests involved aimed to identify the engineering properties of the lateritic soil such as its physical and mechanical properties. The lateritic soil characteristics and the results are presented in Table 3.1.

Table 3.1. Geotechnical properties of lateritic soil

S/N	*Property*	*Measured value*
1.	Classification	
	AASHTO (group index)	A-2-7
	USCS group symbol	SC
	USCS group name	poorly graded gravels
2.	Specific gravity	2.41
3.	Particle size analysis	
	Sand content % (4.75 to 0.075mm)	65

S/N	Property	Measured value
	Silt and clay content % (below 0.075mm.)	35
4.	Atterberg's Limits: %	
	Liquid limit	75.8
	Plastic limit	40.48
	Plasticity index	35.32
5.	Proctor test	
	Optimum moisture content (OMC), %	40.8
	Maximum dry density (g/cm3)	1.329
6.	California Bearing Ratio value % (Soaked)	3.92

3.1.2. Engineering properties of untreated clay soil

The tests aimed to identify some of the physical and mechanical properties of the clay soil, such as sieve analysis, Atterberg limit test, compaction test, California bearing ratio and specific gravity.

Table 3.2. Geotechnical properties of clay soil

S/N	Property	Measured value
1.	Classification	
	AASHTO (group index)	A-2-5
	USCS group symbol	CH
	USCS group name	Highly Plastic Clay
2.	Specific gravity	2.6
3.	Particle size analysis	
	Gravel content% (20 to 4.75mm.)	0.588
	Sand content % (4.75 to 0.075mm)	5.514
	Silt and clay content % (below 0.075mm.)	93.898
4.	Atterberg's Limits: %	
	Liquid limit	88.65
	Plastic limit	32.37
	Plasticity index	56.28
5.	Proctor test	
	Optimum moisture content (OMC), %	35.8
	Maximum dry density (g/cm3)	1.26
6.	California Bearing Ratio value % (Soaked)	1.5

3.2. Casting of bricks

3.2.1. Preparation of mixed clay-lateritic soil

Clay bricks were made with laterite soil separately, whereas laterite soil was added in percentage of 0%, 5%, 10%, 15% and 20% respectively. The mixtures were prepared with the pre-determined optimum moisture content values. The bricks were hand molded and were burnt in a furnace oven. The size of the brick was established as 230x110x70mm non-modular bricks, decided according to the standard IS 1077:1992. The prepared mixture was forced into the mold and after removing the mold the shaped bricks were kept for air-drying till they only 5 to 7 percent moisture content left in the material. The drying period was 1 week. After air-drying process the bricks were transported to the furnace oven, where were burned at a temperature of 1000ºC. Bricks were taken out from the furnace oven after cooling and the testing started only after 21 days of curing, in accordance with the IS standard.

3.2.2. Test methods

The bricks were tested according for determining the following physical properties: compressive strength, water absorption, efflorescence and thermal conductivity. These tests were conducted according to the standards IS 3495 (PART I-III) and IS 3346:1980.

3.3. Discussion of test results

3.3.1. Atterberg limit test and workable mixing water contents

The results of Atterberg limit tests and workable mixing water contents were calculated using the relation (3.1) and exposed in Figure 3.1. It can be noticed that both liquid and plastic limits decrease with the increasing percentage of laterite contents. But also the workable mixing water content decreases with increasing percentage laterite. The summary of the results of Atterberg limits are shown in Table 3.3.

$$\text{Plastic Index} = \text{Liquid limit} - \text{Plastic limit} \tag{3.1}$$

Table 3.3. Effect of laterite soil on atterberg limit.

Laterite soil content (%)	Liquid Limit (%)	Plastic Limit (%)	Plastic Index (%)	Mixing Water contents (%)
0	88.65	32.37	56.28	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

Laterite soil content (%)	Liquid Limit (%)	Plastic Limit (%)	Plastic Index (%)	Mixing Water contents (%)
20	53.77	18.87	34.9	30.09

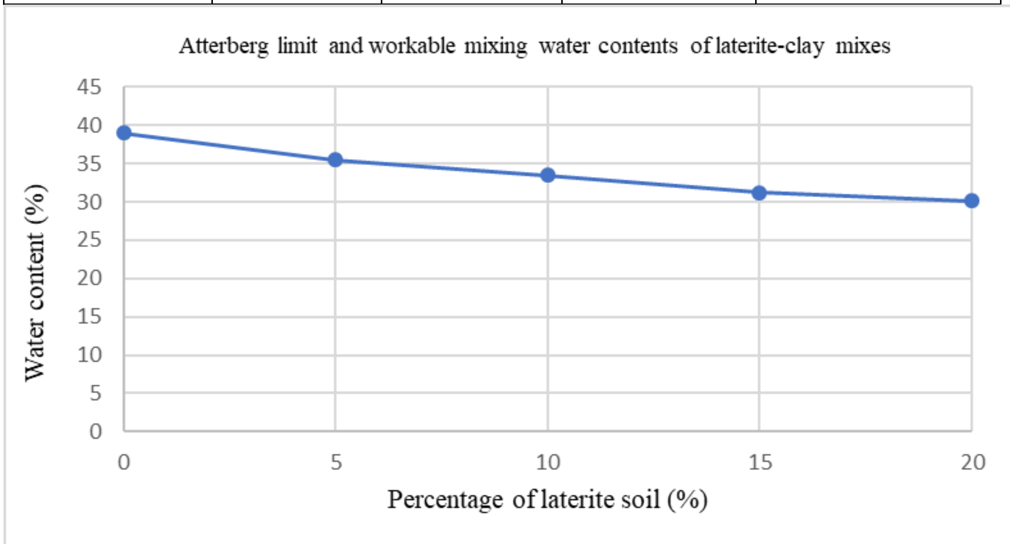

Fig. 3.1. Water contents verses percentage of laterite in clay soil.

3.3.2. Linear shrinkage and density

The summary of the results of linear shrinkage, as well as dry and firing densities are shown in Table 3.4. It can be observed that the shrinkage decreases with increase in the laterite soil contents but with decrease in dry density.

Table 3.4. Clay-laterite soil linear shrinkage, dry and after furnace densities

Laterite soil content (%)	Linear shrinkage (%)	Dry density (kg/m^3)	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% is shown in Table 3.5. The average stress (δ) is calculated with formula (3.2):

$$Average\ stress(\delta) = \frac{maximum\ load(KN)}{Average\ area\ of\ bed\ face(mm^2)} \quad (3.2)$$

Table 3.5. Compressive strength values of clay-laterite bricks with Laterite soil

Laterite soil content (%)	Compressive strength or stress, σ (MPa)	Specification
0	10.76	Compressive strength not less than 10 N/mm^2 for class designation 100 [11]
5	10.96	
10	11.19	
15	11.37	
20	11.29	

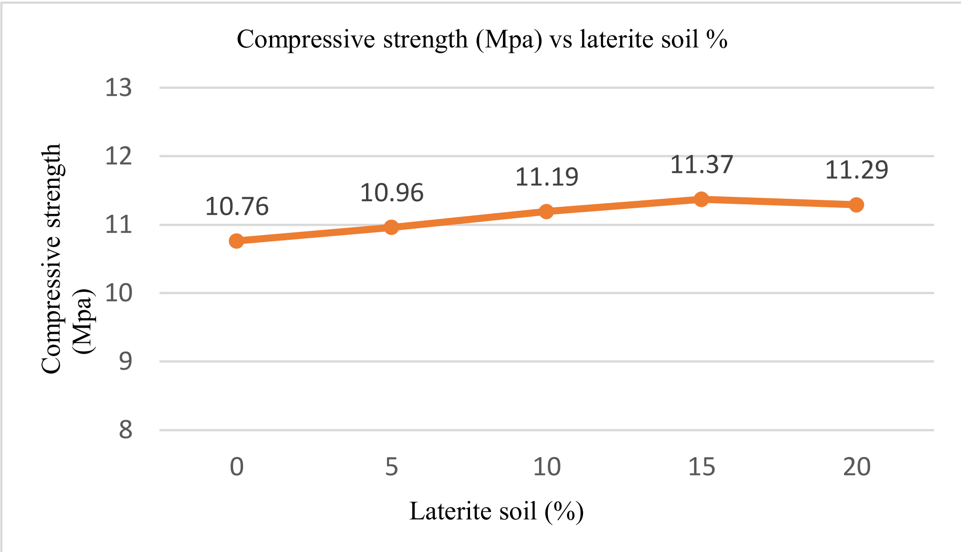

Fig. 3.2. Variation of compressive strength results of clay bricks with laterite soil.

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 shows a compressive strength higher than 10 MPa, which belong to class designation 100 as requested in the standard specification. All the modified bricks show higher strength than the control bricks.

3.3.4. Water absorption

As the percentage of laterite soil increases water absorption decreases (Figure 3.3) The results of water absorption tests are presented in Table 3.6:

Table 3.6. Water absorption test Result of produced with Clay-Laterite bricks

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

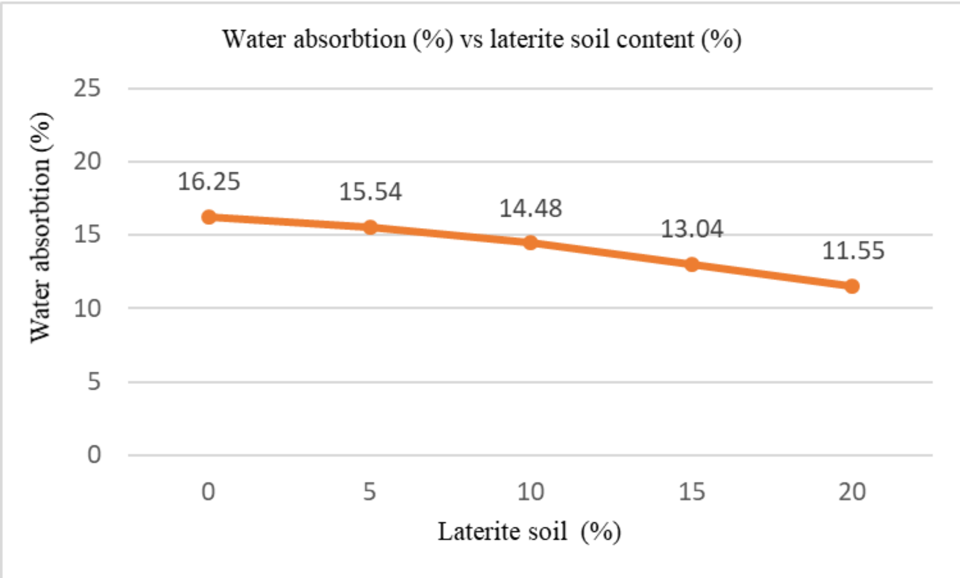

Fig. 3.3. Variation of water absorption of clay bricks with Laterite soil.

Bricks made with laterite soil have similar properties to that of control bricks. Laterite soil-clay brick shows lower water absorption rate compared to standard specification of the class.

3.3.5. Efflorescence

Efflorescence test was performed to determine the alkaline salt content in bricks. The test was conducted according to IS 3495 (part III) – 1992. In this experimental test no perceptible deposit could be observed on majority of samples but a very thin deposit of salts could be noticed on some parts of samples.

4. Conclusion

On the basis of experimental results, the following conclusions can be drawn:

1. The laterite soils were classified based on ASSHTO classification system as A-2-7 category with poorly graded gravel and based on the USCS classification system as SC soil groups. The compaction test for the laterite soils yielded maximum dry density (MDD) of 1.329 g/cc and optimum moisture content (OMC) of 40.8%. The clay soils were classified based on ASSHTO classification system as A-2-7 category with high plastic clay and based on the USCS classification system as CH soil groups. The compaction test for the clay soils yielded MDD of 1.26 g/cc and OMC of 35.8%.

2. 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.
3. Modified clay bricks show 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 lower density of the modified bricks. Water absorption decreases with increase percentage addition of laterite soil. This behavior is due to the courser soil particles in bricks which results in less water absorption. All the bricks have slight efflorescence content. This indicates that the alkaline salt content in bricks is low.
4. Bricks made of clay-lateritic soils mixture can be used also for load bearing walls.
5. Further studies should be carried out in order to identify the long-term effects that clay-laterite soil may have on the durability of brick and also further studies should be made on chemical composition of clay-laterite soil.

References

[1] A.A.A. Yar'adua Muntari Mudi, *An examination of the properties of literate and clay as*, chez University Tun Hussein Onn Johor, Malaysia, Nigeria, July 2012.

[2] M. S., M. M. A.K. Kasthurba, *Investigation of laterite stones for building purpose from*, Construction and Building Materials, p. 73–82, 2007.

[3] C. J. K.K.G.K.D. Kariyawasam, *Cement stabilized rammed earth as a sustainable construction material*, Construction and Building Materials, vol. 105, p. 519–527, 2016.

[4] A.U.K. Muntari Mudi Yar' Adua, *Sustainable environment: laterite as sustainable*, International Journal of Advances in Mechanical and Civil Engineering, vol. 3, n° %12, p. 2394-2827, April 2016.

[5] E.A.C.O.O. Peter O. Akadiri, *Design of a sustainable building: a conceptual framework for implementing sustainability in the building sector*, buildings, n° %12075-5309, p. 126-152, 2012.

[6] *Correlation between total water absorption and wet compressive strength of compressed stabilised peat bricks*, International Journal of the Physical Sciences, vol. 6, n° %11992 - 1950, p. 2432-2438, 18 May, 2011.

[7] B. Bayizitlioğlu, *Conservation and maintenance of earth constructions*, The Historic Environment: Policy & Practice, vol. 8, n° %14, pp. 323-354, 2017.

[8] A. M. Kabtamu Getachew, *Laboratory Investigation of Locally Produced Clay Brick Quality and Suitability for Load Bearing Element in Jimma Area, Ethiopia*, International Journal of Engineering Research & Technology (IJERT), vol. 6, n° %15, p. 809-817, 2017.

[9] SKAT et 1988, *Appropriate building materials: a catalogue of potential solutions*, 1988.

[10] M. A. Rahman, *The Potentials of Lateritic Soil-Clay and Clay-Sand Mixes in the Manufacturing of Bricks for Masonry Units*, Building and Environment, vol. 22, n° %14, p. 325-330, 1987.

[11] B. o. IS 1077, Bu*rea of Indian Standards,Common Burnt Clay Building Bricks –Specification [CED30 Clay and stabilized Products for Construction*, New Delhi ,India., 1992.

[12] B. C. Giles, *Ethiopia is now Africa's fastest growing economy*, CNN, Updated 1031 GMT (1831 HKT) April 24, 2018.

[13] https://www.open.edu/openlearncreate/mod/oucontent/view.php?id=79941&printable=1, Land Use and Urban Planning, 12 Aug 2019, 06:44.