



**QUEEN'S
UNIVERSITY
BELFAST**

Restoring The Past Experience Of Stone Masonry In Burkina Faso For Fostering The Use Of Local Materials

Lawane, A., Pantet, A., Vinai, R., & Thomassin, J-H. (2016). Restoring The Past Experience Of Stone Masonry In Burkina Faso For Fostering The Use Of Local Materials. In Proceedings of the 13th International Congress on the Deterioration and Conservation of Stone (pp. 1181-1188). University of the West of Scotland.

Published in:

Proceedings of the 13th International Congress on the Deterioration and Conservation of Stone

Document Version:

Publisher's PDF, also known as Version of record

Queen's University Belfast - Research Portal:

[Link to publication record in Queen's University Belfast Research Portal](#)

Publisher rights

© 2016 The Authors.

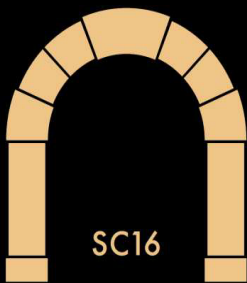
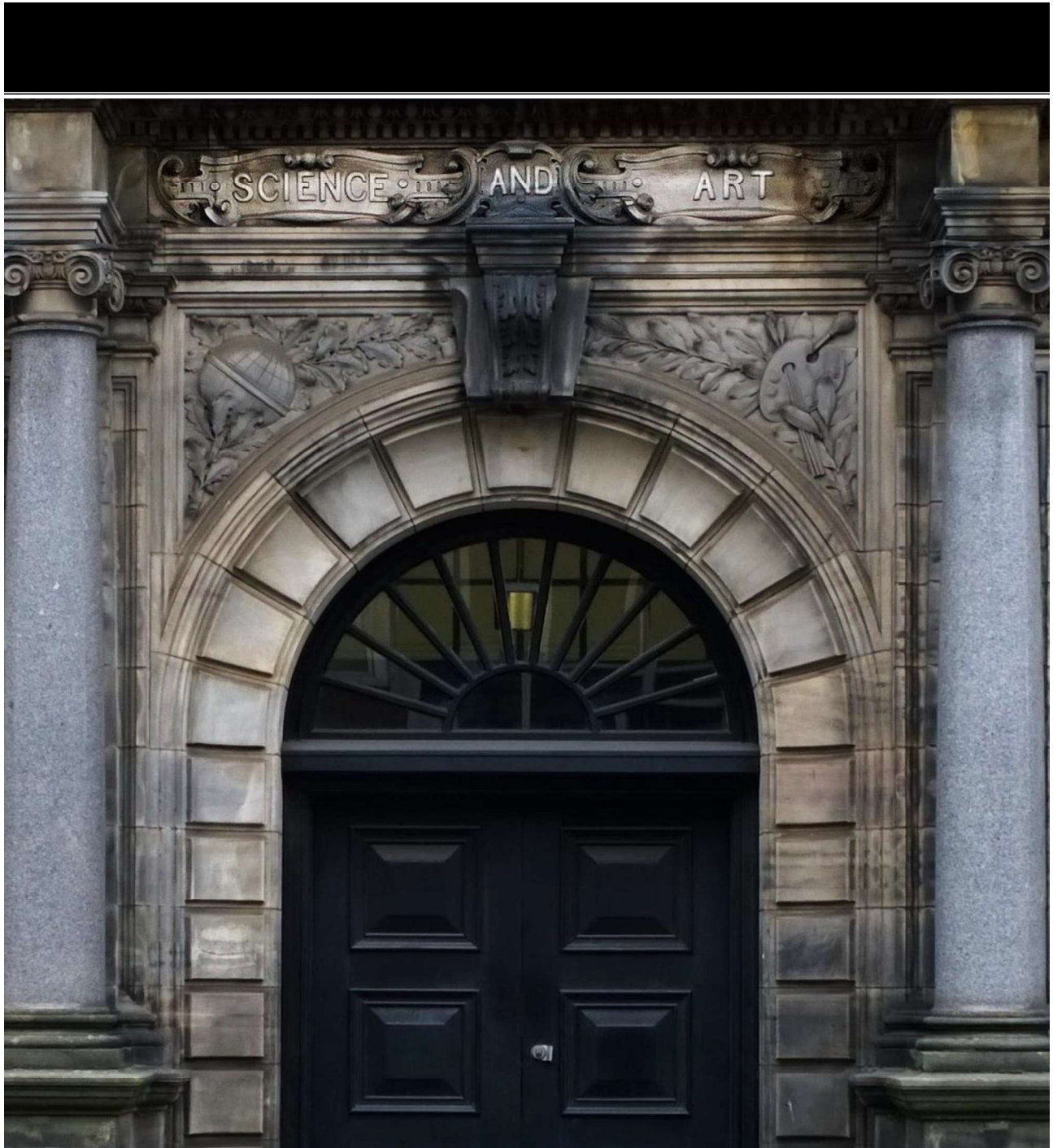
This is an open access article published under a Creative Commons Attribution License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution and reproduction in any medium, provided the author and source are cited.

General rights

Copyright for the publications made accessible via the Queen's University Belfast Research Portal is retained by the author(s) and / or other copyright owners and it is a condition of accessing these publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy

The Research Portal is Queen's institutional repository that provides access to Queen's research output. Every effort has been made to ensure that content in the Research Portal does not infringe any person's rights, or applicable UK laws. If you discover content in the Research Portal that you believe breaches copyright or violates any law, please contact openaccess@qub.ac.uk.



SC16

SCIENCE and ART: A Future for Stone

**Proceedings of the 13th International Congress on the
Deterioration and Conservation of Stone – Volume II**

**Edited by
John Hughes & Torsten Howind**

SCIENCE AND ART: A FUTURE FOR STONE

PROCEEDINGS OF THE 13TH INTERNATIONAL CONGRESS ON THE
DETERIORATION AND CONSERVATION OF STONE

6th to 10th September 2016, Paisley, Scotland

VOLUME II

Edited by
John J. Hughes and Torsten Howind



UNIVERSITY OF THE
WEST of SCOTLAND
UWS

© University of the West of Scotland, Paisley, 2016

Licensed under a Creative Commons Attribution 4.0 International License.



ISBN: 978-1-903978-58-0

ISBN: 978-1-903978-55-9 (eBook)

ISBN: 978-1-903978-59-7 (Set: Volume 1&2)

ISBN: 978-1-903978-56-6 (eBook-Set: Volume 1&2)

Hughes J.J. and Howind T. (Editors), “Science and Art: A Future for Stone. Proceedings of the 13th International Congress on the Deterioration and Conservation of Stone”, University of the West of Scotland, Paisley, September 6th to 10th, 2016.

Cover image: The front door of the Paisley Technical College building, now University of the West of Scotland. T.G. Abercrombie, architect 1898. Photograph and cover design by T. Howind.

RESTORING THE PAST EXPERIENCE OF STONE MASONRY IN BURKINA FASO FOR FOSTERING THE USE OF LOCAL MATERIALS

A. Lawane¹, A. Pantet^{2*}, R. Vinai³ and J.H. Thomassin¹

Abstract

A number of associations, companies, and research institutions are currently working together in Burkina Faso in order to promote the valorisation and the reuse of laterite dimension stones (LDS). In this study, old masonry constructions such as schools and churches built during colonisation period in the city of Dano, situated near the borders of Ivory Coast and Ghana, were examined. This article gives a description of old and often abandoned constructions, where dimension stones are however generally well conserved. At first, a specific classification for laterite masonry able to describe the observed pathologies is presented. Subsequently, possible cultural causes that could explain the current state of these constructions are derived, through a survey carried out among local people. Eventually, a classification for LDS, based on geo-mechanical studies carried out on material from four local quarries of laterite, is proposed. Three quality grades were defined and agreed according to local technicians and professionals. Therefore, based on the traditional experience and on results from geo-mechanical studies, a revamp of the use of local materials for urban and suburban constructions, both for new buildings and for the restoration of ancient construction in West Africa, should be fostered, in line with general principles of sustainability in building construction.

Keywords: laterite, index quality, masonry, vernacular architecture, guidelines, African local houses

¹ A. Lawane and J.H. Thomassin
LEMC, International Institute for Water and Environmental Engineering, Rue de la Science, 01 BP
594 Ouagadougou, Burkina Faso

² A. Pantet*
LOMC, University Le Havre, COREVA Building, 53 Rue de Prony, BP 540, 76058 Le Havre
Cedex, France
anne.pantet@univ-lehavre.fr

³ R. Vinai
School of Planning, Architecture and Civil Engineering, Queen's Univ. Belfast, David Keir
Building, 39 Stranmillis Rd., Belfast BT9 5AG, United Kindom

*corresponding author

1. Introduction

Sub-Saharan Africa is undergoing deep demographic changes. People are moving to the cities and African population will be more urban than rural by 2030. Housing has been recognised as one of the most important and essential need after food and water. Housing construction is a major source of employment and can give an economic propulsion with creation of jobs in Africa, as a significant component of developing countries' economies. Building technology is still extremely labour intensive.

The construction of decent housing is a key component of social development and has major impacts on health conditions in urban areas, coupled with access to safe drinking water supplies.

The need for locally manufactured building materials has been emphasized in many countries. Conventional building materials are expensive and have a high environmental impact (Chevalier 2009). In order to address to this situation, attention has been focused on alternative local building materials. In subtropical zone of the Earth, laterites are very common materials. These can be exploited under two forms, as a soft soil or hardened soil respectively. In this latter case, the hardened laterite can be used for masonry purposes. A number of sites exist in the World, like Angkor Temples in Cambodia, the Fortress of Loropéni in Burkina Faso, and the National Monument in Angadipuram in India, which are famous due to the use of laterite. Many quarries have been exploited since long time, initially manually and more recently with mechanical equipment, and laterite dimension stones (LDS) are usually cut for being used as masonry elements (Indian Standard Specification 3620, 1998).

This study focused on the valorisation of this local material. It was carried out with the following objectives:

- To determine the physical and mechanical properties of the material, which can vary in a wide range due to the very complex weathering processes (that have led to the laterite formation or happened in the laterite after deposition) that can vary for each laterite layer. A quality index has been defined, and the best use of LDS was optimised accordingly. Quality control is therefore of primary importance, also considering that today testing procedures are available and easily performed in any civil engineering work.
- To examine the structural behaviour of masonry buildings, taking into account the state of conservation of the materials used for construction. The structural performance of masonry wall structures can only be understood if the history of their construction, their geometry, and the characteristics of the masonry material are known.

This paper provides a relevant case study, demonstrating that laterite stone masonry construction can be developed in Burkina Faso for simple, one-storey housing or, when coupled with concrete frames, for more complex building.

2. Presentation of the site of the study

The investigation focused on a region in the Southwest of Burkina Faso, West Africa. The site, (see Fig. 1), is located in Dano in the IOBA Province, about 230 km southwest of Ouagadougou, on the N12 in Gaoua direction and about 50 km from Loropeni site. In the region, the laterite stone is commonly used for the construction of masonry buildings. Laterite, which has reddish brown colour, is a residual rock, and it is the product of sub-tropical weathering on many rocks. The term laterite is restricted to highly weathered material rich in secondary form of iron, aluminium, poor in organic content. Laterite is usually found as superficial layers such as thick ferricretes, typically observed in the landscape. It is commonly found on top of flat hills or as boulders on slope surfaces. The weathering profiles developing from different parent rocks exhibit the following upward succession of layers: saprolite, mottled clay and ferricrete.

The region has a tropical humid climate characterised by a dry season (November to April) and a rainy season (May to October). Monthly average temperatures ranged from a minimum of 24.7°C in August to maximum values of 31.9°C in May (as measured in 2006). Long term mean annual precipitation is 926 mm. Eighty percent of the annual rainfall was recorded from June to September. Precipitations during this season are characterised by strong and short storms mainly occurring during the evening. The vegetation cover consists of a semi-humid forest and savannah. A hydrographical network developed on the plateau. Vegetable gardening flourished in the flood plain created by an earth dam.

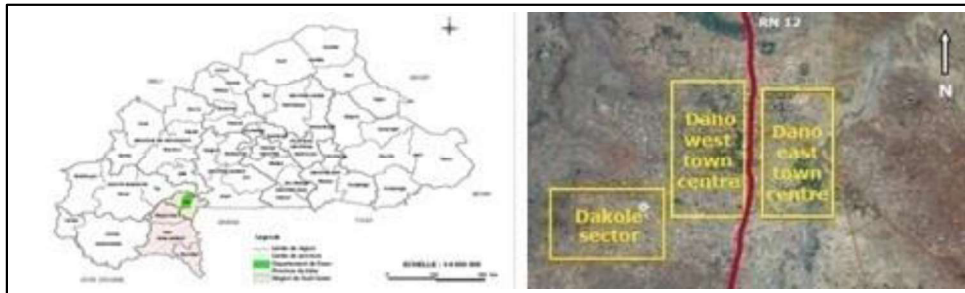


Fig. 1: Site location on Burkina Faso map and Google Earth view of the town of Dano.

The town of Dano was selected for this research due to the existence of several quarries of laterite, either excavated by hand (for local market and simple self-construction housing) or with semi-industrial techniques, for local residential market or for trading.

3. Production of laterite dimension stones (LDS)

Physical properties of LDS vary considerably from place to place (Kasthurba and Santhanam 2005 – Lawane *et al.*, 2014). A careful selection of the laterite stone is necessary in order to ensure its suitability for masonry construction. In order to provide a guidance, many studies indicated minimum requirements in terms of compressive strength. Being soft and porous when freshly extracted, laterite usually hardens if adequate stabilisation is ensured, i.e. under atmospheric conditions but not exposed to rain. The blocks shall be tested for compressive strength, but also for water adsorption, and specific gravity should be measured as well. Stone blocks shall present no cracks, cavities, clay

veins or others imperfections. The shape of the blocks shall be regular and uniform, with straight and rough edges at right angle.

A classification of LDS, with three quality grades, based on geo-mechanical studies carried out on four quarries of laterite and agreed among technicians and professionals was proposed in Tab. 1. The normalised compressive strength is defined by: $fb = Rm \cdot \delta \cdot \chi$ where: Rm , the compressive strength (MPa) - δ , shape factor and χ , curing or drying conditions coefficient, (Eurocode 6, 2013).

During the excavation of laterite stone, a high volume of waste (around 25 to 30 per cent of the total laterite) is generated as scraps. This leads to operational problems, since such material needs to be removed for further excavation. An alternative, added-value option for this waste rock is to use it as aggregate for the manufacture of concrete blocks.

Tab. 1: Quality index for LDS.

f_b (MPa)	> 4	2-4	1-2
compact	Grade 1	Grade 2	Grade 3
granular	Grade 2	Grade 3	Grade 3

4. Survey on housing typology in the Dano town

4.1. Background

The town is developed along a main street, with densely built houses (in the form of buildings with a courtyard), distributed on each side. The spatial structure of the old centre is more or less determined by the related economic life (markets, handicraft, workshops, and bars). The expansion of the centre developed in many peripheral zones such as the administration area (new town hall, school, museum, and hotel), two religious institutions (cathedral and mosque) and many residential areas.

Tab. 2: Summary of results from building survey (for localization see Fig. 1).

Materials	Concrete frame			Masonry	
	LDS	Sand -concrete	Banco	Mix	LDS
Centre	9%	10%	18%	60%	2%
Dakole	34%	18%	17%	9%	23%

Two zones have been investigated to compare construction materials used for the households (or “greater family housing” as defined in Africa). Many households from the extended family (from grandparents to grandchildren) live together in the same courtyard. Two building modes can be identified: masonry, using earth blocks (banco), LDS or mixed techniques, or concrete frame with partition walls in concrete blocks (sand concrete). The distribution and occurrence of each type is reported in Tab. 2. Most houses are built with self-produced materials. Under the influence of modernisation, straw has been replaced by galvanized iron roofing sheets (thatched roofing can still be observed in rural areas),

whereas traditional bricks, produced with a mix of wet earth, dung and straw or vegetable fibres, have been replaced by stabilized earth (soil cement) blocks, and most recently by sand cement blocks.

The majority of housing in the urban centre is composed by buildings partially realised in earth bricks or adobe with possible addition of straw, connected with mortar made of clay and sand. The basement and the lower layer of masonry elements are generally built with LDS. Coating is applied and smoothed to produce a smooth wall surface, which is treated with plaster (mixture: clay- cement or clay – lime) to achieve some weather protection.

The Dakole sector, more residential, is an area where houses are built in LDS masonry or with frame structure in concrete, whereas the partition walls are realised with LDS. The complex of the Drayer Foundationed, a German charity working for children, has been built in LDS. No coating was applied, because the aesthetic effects and the waterproof qualities of the laterite were considered satisfactory.

4.2. Construction techniques with laterite dimension stones (LDS)

The construction system with LDS usually follows horizontal and parallel shelves where medium and large blocks are mainly used. The mortar used to connect the block is either clay or lime based. Only for the outer walls, the earth is removed on many centimeters and replaced by cement mortar, to avoid erosion (water or wind) actions (see detailed photo in Fig. 2). Inner walls are plastered and painted. In the case of building with concrete frame structure, a floor slab is casted and supported by columns, isolating the roof space. Ventilation holes are created in the upper layer of the walls.



Fig. 2: Typical houses in LDS, either load bearing masonry or with frame concrete.

5. Diagnosis survey of laterite constructions

5.1. Description of the state of a colonial building

The oldest building realised in LDS that can be found in Dano is a school, built in the 1930's by the religious Fathers during the last years of colonial period. The building was left without any maintenance during the post-independence era, leading to severe deterioration. The building shows a rectangular plan section sized about 40.5×10.5 m, with a maximum height of 6.25 m. Two corridors, along the northern and southern load-bearing walls, give access to the aligned classrooms.

The construction (see Fig. 3) is composed by thick masonry walls (double walls) built with adobe with lime mortar and coated with plaster (clay and cement), whereas the top layers, which are exposed to rain and wind, are made with LDS. The load-bearing walls are made with a mixed masonry of adobe and stone blocks locally quarried. Stone units are connected together by means of a weak lime and sand mortar. The cohesion between the mortar and the stone is weak. All different types of masonry in the structure can be defined as solid masonry.



Fig. 3: Views of the school and CAD representation.

A layer of lime plaster and one of lime wash paint were applied to create smooth surface. Masonry blocks have small to medium size (L: 20 cm, h: 15 cm, w: 10 cm) with rough surface, rectangular or square shape. Some of them show a flattened surface. Blocks were used according to their strength, being the weaker used for filling or for coating, whereas the stronger were used for structural purposes. A virtual reconstruction view has been obtained with a CAD application as shown above left in Fig. 3.

A continuous vaulted gallery ran along the two long sides (north and south walls) of the building. Pupils accessed the gallery from the courtyard. The arches were built with ashlar, with a stiff structure made up of well carved headers forming a single arch line. The opening between columns is about 2 m. A wood formwork was presumably used during the construction. The eastern and western sides show gables, made up of small headers and long stones on the corners, without openings. The horizontal elements of the flat roof are made of a mixed construction system with steel profiles for the classrooms and with wood beams for the corridors. The whole structure was covered with galvanized iron sheets.

On site visual inspection revealed severe damages. The roof structure of the school was dismantled and partly destroyed. As a result, the vault of the north wall collapsed, and the building was no longer in an operational state. Bricks from demolition were reused for foundations, but also as aggregates in concrete. However, the integrity of the existing arches appears still satisfactory and not affected by the general conditions. No deformation and collapse of gable walls was observed, although these were built as a single layer. There is no evidence that the building collapsed because under dimensioned, or because of insufficient bearing capacity of the construction material or due to any overload on the structure.

5.2. Deterioration processes observed in LDS structures

Masonry defects can be associated with several reasons, from a wrong choice of materials to an insufficient quality of the workmanship (Bromblet and Association MEDISTONE, 2010). The local climatic impact can also have a role. Main categories of defects and related causes were defined by direct observations on the surveyed LDS building (the old school and the houses) in Fig. 4:

- Deterioration of the structure of LDS, by atmospheric agents, such as sandy wind and rain, affecting surface stone (a). The block can also be damaged by the cracking associated with the action of water and temperature variation, which facilitates rock degradation and failure (b),
- Disintegration of lime and sand mortar joints, due to the moisture transfer or water runoff action and also because the excessive mortar width between the layers and loss adherence (c),
- Organic deterioration from musk and other plants growth on the lowermost layer of masonry elements, due lack of drained or ventilated space in the basements (d),
- Cracks due to uneven distribution of the loads.



Fig. 4: Views of the most usual defects observed in LDS structures.

Some of the above mentioned defects can be avoided by controlling the block production. Good ashlar with rough, parallel surfaces are to be preferred, since these features improve the joint strength, contribute to an even distribution of the loads and reduce the potential accumulation of organic material on joints. The quality of the laying of the block is also an important factor for preventing structure failures. The width of the joints should be kept at a minimum, and in some cases the laying should be carried out even without joint. The quality of the LDS is another key point. Top quality LDS seem to be subject to hardening upon exposure to alternate wetting and drying, but poor to medium quality are not, since granular morphologies are disintegrated by drying and wetting cycles. Masons must be careful when choosing the blocks during construction, trying to use them according to their quality in different places of the structure.

6. Conclusions

This study aimed at understanding the potentiality of the utilisation of LDS as building material. The geological study of laterite quarries showed large variability in quality. Such variability influences the stone availability, and, consequently, has an impact on the economic viability and safety of the exploitations. All the material extracted from the quarries (LDS and waste) need to be valorised to their maximum potential.

The fostering of a return of stone masonry constructions poses important challenges because of the variability of the properties of traditional materials. The assessment of the structural conditions of old masonry structures, with the definition of damages or defects categories that can be listed through visual inspections, contribute to indicate the actual potential of the use of LDS in building, provided that a proper choice of the material is carried out and proper construction best practises are followed. The quality grade of LDS must be considered during the construction phase, since higher or lower quality blocks can be used for different purposes, also depending on the typology of building structure (load bearing masonry or concrete frame). When both climatic exposure and thermal properties of the lateritic material are properly considered, masonry structures can provide the required thermal comfort to dwellers in a sustainable and energy efficient way, provided that iron sheet roofing is avoided.

Some requirements for improving design guidelines have been proposed. It is however of utmost importance to increase the knowledge on the building material through laboratory tests on samples cored on site (for each quarry) and loading tests on buildings at realistic scale. Systematic analysis of building defects should also be considered as part of a design approach aimed at overcoming these challenges.

References

- P. Bromblet et Association MEDISTONE, 2010 : Guide "Techniques de conservation de la pierre". Association MEDISTONE.
- Chevalier, J, 2009, Analyse du cycle de vie: Utilisation dans le secteur de la construction, Techniques de l'ingénieur. Environnement, 1 (G5880).
- Eurocode 6, 2013, Calcul des ouvrages en maçonnerie - Partie 1-1 : règles générales pour ouvrages en maçonnerie armée et non armée, NF EN 1996-1-1+A1 Mars 2013.
- Indian Standard Specification 3620, 1998, Indian Standard Specification for Laterite Stone Block for masonry, Bureau of Indian Standards, New Delhi, India, 86, 1-8.
- Kasthurba, A. K., and Santhanam, M., 2005, A re-look into the code specifications for the strength evaluation of laterite stone blocks for masonry purposes, Journal of The Institution of Engineers (India), 86, 1-6.
- Lawane, A., Vinai, R., Pantet, A., Thomassin, J. H., and Messan, A., 2014, Hygrothermal Features of Laterite Dimension Stones for Sub-Saharan Residential Building Construction, Journal of Materials in Civil Engineering, 26 (7).