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LOCAL MATERIALS FOR BUILDING HOUSES: LATERITE VALORIZATION IN AFRICA

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Abstract:

This paper presents the preliminary results of geological and geomechanical studies on the laterite stone exploited at Dano quarry in Burkina Faso. The field work described the geological structure of quarry sites and their environment to determine the rocks alteration and the links between the bedrock and lateritic material. Physic-mechanical properties have been studied for assessing the potentiality of this material for lightweight housing, to be completed with thermal and environmental considerations. Some social and economic evaluations are in progress in order to foster its utilization under local conditions.

Introduction

The use of local materials in the construction is one of the ways to support durable development on the entire planet, because it is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs. The world heritage is very rich in all countries in construction. However, the construction using local materials, in the developed countries, became marginal. These techniques were abandoned because it is not possible to standardize the composition of materials because it varies locally. To resolve the economic and environmental problems, concerning the concrete or cinder block construction in Africa, this material can be again a local resource to traditional housing.

One aim of the project was to build using locally materials, priority laterite materials. This short paper presents some results of physical and geomechanical of laterite stone exploited at Dano quarry in Burkina Faso issued from a field work followed in literature [1]. Many calculations are presented by finite element method and by using assumptions based on Eurocode 6 [2] to examine the loads distribution and the compatibility with the strength.

Description of the city of Dano

General considerations

Dano (total surface 669 km²) is located in the south BF in the IOBA province, near the Ghana, 150 Km from Bobo-Dioulasso and 280 km from Ouagadougou (figure 1). Located in the intertropical zone with high rainfall, the mean annual precipitation has been measured 900 mm. The seasonal variation is very important with two seasons, one very humid and the other dry with hot temperatures. The zone receives a great amount of solar radiation and continuous heat, with important biological consequences such as the development of a dense and widespread vegetal cover. Lateritic structures are visible through the landscape as plateaux slightly tilted to the east. On figure 1, laterites covers bedrock identified as white schist and green altered andesites [3,4]. A geological survey carried out in July 2010 identified outcrops of bedrock and allowed the examination of exposed vertical faces. Moreover, samples for laboratory testing have been collected to investigate the physical and mechanical properties.

Fig. 1 (a) Dano situation in BF (b) laterite plateau and colluvions on slope (c) contact with schists

Building materials and properties

The masonry blocks are obtained from a local quarry, named Dakoré quarry, described in Lawane and al. [1] (figures 2 a and b). The petrographic examination of the rock samples showed that the rock is an assemblage of fragments with a cemented material, iron oxides and hydroxides. The colors hues from dark brown to light yellow (figure 2 c). All the feldspars are weathered in kaolinite. It is known that the strength depends mainly upon its mineral constituents, the porosity, the degree of weathering. Therefore the laboratory study gives a breakthrough to the behavior of the rock in the field or in the building. The average dry density and compressive strength σ_c of laterite were $21,7 \text{ kN/m}^3$ and 2-5 MPa. The strength, the durability and stability are examined in previous study [1].

The effect of moisture content on rock strength is considerable. When the stones are excavated, they are soft, whereas after drying, they become hard and durable. The sensitivity of the strength and deformability of laterite in moisture content and soft rocks has been well demonstrated by many investigators. Reduction of laterite strength up to 50 % on wetting is observed (only few % increases in moisture content is enough to reduce the strength more than 50 % of the dry strength [5, 6].

Fig. 2 : (a – b) Daboré quarry with manual extraction and (c) different blocks (20*30*10 cm) from the top (right) to the base of the quarry (left)

Building modelisation

Assumptions and modelled structure definition

The studied structure represents a small house (plane dimensions $3.58 \text{ m} \times 4.01 \text{ m}$ - high 3.60 m) with three windows ($1 \text{ m} \times 1 \text{ m}$) and a door ($1 \text{ m} \times 2 \text{ m}$). The thickness of the walls is 0.20 m . The plate roof is modeled by a plaque, thick of 0.30 m , in concrete. The wall are considered such as masonry of laterite stones without concrete piles and beams. Figure 3 (a) gives geometrical parameters and the orientation to describe the face. Before the FEM modeling, many calculations of this house, based on [2], have shown the good acceptance to verify $N_{RD} > N_{Ed}$ for houses with three levels ($N_{RD} = A \cdot \phi_s \cdot f_d$ with A: wall section - $N_{RD} = 715 \text{ kN}$).

The modelisation is made with Robot Structural Analysis Professionnal 2011 from Autodesk. The masonry is a composite material with block-stone and vertical and horizontal mortar joints. Two different approaches could be adopted to model : the 'micromodel', or 'two-material approach', and

the macromodel, or ‘equivalent-material approach’ [7]. We choose the standard FEM modelling, based on the concepts of homogenized material. Figure 3 (b) shows the mesh and defines the boundaries conditions. The input parameters are decided, basing on many experimental studies, basically in rock mechanics. In this formulation of macromodels, characteristics values are considered with high safety factors, to assess the average mechanical properties of masonry. The strength is determined from $f_d = \frac{f_k}{\gamma_M} = 1,3 \text{ MPa}$ with f_k , characteristic value of the compression strength (carefully, 2 MPa is the taken value) and $\gamma_M = 1,5$ to consider the incertitudes. The shear modulus is obtained with the formulae: $G = \frac{E}{2(1+\nu)}$ with $\nu = 0.3$. Nowadays, the incomplete characterization of the material, due to the lack of reliable experimental data, renders uncertain the calibrations of others numerical models, more sophisticated (non linear behavior, elasto-plastic with softening rules....) and limits the FEM modeling at simple approach, which complete the basic and practice approach with Eurocode 6.

Fig. 3 : (a) plan of the house and orientation (b) mesh of the building and limit conditions

Results - Loads applied (gravity and exploitation) and wind effect on the west face

The calculation take into account load charges (gravity G and exploitation Q) and wind effect W, with ELU considerations, i.e majoration of the actions defined with the following combinaison $1,35 G + 1,5 Q + 1,5 \times \Psi_{0,i} W$. The chose of west face for the wind direction is because there is no openture (no windows and door). The wind pression is à 1 kN/m^2 [2].

Fig.4 : Global displacements under the own self weight without and with lateral wind on the west wall
On figure 4, we observe the two cases, (1) only the loads (G and Q) and (2) the loads and the wind effect. In (1), the global displacements are higher (2 mm) in the upper part of the walls, more around the openings. For (2), the global displacements increase with a maximum of 3 mm, in the middle of the west face and in the upper part of the walls, in particularly the east face. All the house slants in the direction wind.

Concerning the case (2), the lateral stresses are negligible with max values (0,1 MPa) at the walls base. The vertical stresses increase around the open ($\approx 0,25-0,30$ MPa), et un bulbe de contrainte au dessus et en dessous. The base of the east face is submitted to the higher stresses ($\approx 0,3$ MPa). Knowing the calculation strength (1,3 MPa), with the consideration of the natural variations (humidity, porosity...) , the safety factor is 10.

Conclusions

To resolve the economic and environmental problems of housing, local resource to traditional housing is a real possibility exploited at Dano quarry in Burkina Faso. The objective is to develop construction housing, sufficiently able to resist to limited loads and to give thermal comfort inside. This paper presents the preliminary results of modelling a traditional housing structure under various actions. To build with laterite blocks can offer sufficiently security. Of course the approach is at macroscale with a homogenised material but considered with large uncertainty because the results obtained with the geomechanical study and the dependence with the moisture, which can range in this tropical climate. The actual ultimate strength in monotonic loading can be predicted with good approximation. This good agreement with the experimental results seems to be encouraging. At future, a better physical representation by incorporating interface elements/contact should be investigated but inevitably requires the experimental data on the properties of these interfaces. In spite of the specific limitations of this model, the global behaviour is correctly represented, thus proving that laterite bricks could be effectively used in the study of masonry structural elements. Some social and economic evaluations are in progress in order to valorise such material and to foster its utilization under local conditions.

Acknowledgements

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