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Research paper

Traditional brick productions in Madagascar: From raw material processing to firing technology

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ABSTRACT

Bricks are the most common building materials of Madagascar due to the large availability of clayey raw material, the simple technology of production and the ease of use. The brick production is mainly organised in local workshops close to supplying site of clayey deposit where sediments are extracted, moulded in bricks, dried and then fired in open-air furnaces. Fuel varies from peat soils to wood depending on the local availability. Correspondingly, firing time varies from few days in wood furnaces to some weeks in peat fired furnaces. Samples of bricks and raw materials as well as peat fuel, from four workshops located in central and southwestern Madagascar were collected and analysed to infer the technological skills of the Malagasy traditional brick manufacture. Central Highlands Madagascar workshops use clayey lateritic soils formed from in situ weathering of basement rocks. The main plastic component of these deposits is kaolinite. Also the clayey sediments from southwestern Madagascar have kaolinite along with low-ordered clay minerals and carbonates such as calcite and minor Sr-rich dolomite.

As far as fired bricks are concerned, experimental data evidenced quite low firing temperatures (below 600 °C) in the two different furnaces, regardless the type of fuel. As far as peat fuel is concerned, its low calorific value along with a large amount of furnace energy dispersion does not allow to achieve the temperatures required to produce good quality bricks, notwithstanding long firing time (some weeks). On the other hand, firewood powdered furnaces, although providing much higher energy and a consequent much shorter firing process (few days), also suffer of diffuse heat dispersions which concur to the bad quality of the final product.

The specific energy input calculated for type 1 furnace (peat fuel) ranges between 0.09 MJ/kg and 0.18 MJ/kg of clayey material thus confirming a rather inadequate firing process for the production of good quality bricks, and a rough estimate indicates that volume ratios between peat and clayey material as low as 1:1 should be used in order to reach "modern" specific energy inputs.

1. Introduction

The most used building material in Madagascar is brick, representing the framework of the typical two-floors Malagasy buildings along with rock blocks at the base and brick walls coated by dried mud mixed to wood (Fig. 1). Rarely the entire walls are made up of bricks, proving that, in spite of the rough and old-fashioned production, bricks represent a valuable construction material. Neverthless, the artisanal process produces poor-quality bricks, which need to be replaced within few years.

Bricks are relatively recent in Madagascar. The kiln to bake bricks was introduced by British missionaries in the 1830s (Atolagbe and Fadamiro, 2014; Gade and Perkins-Belgram, 1986), and traditional building materials such as earth, timber, wood are still largely used in inland smaller villages. These autochthonous materials, largely implemented before European colonisation of Madagascar and African

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Fig. 1. Examples of traditional Malagasy buildings.

countries, fully respect and support the basic principle and factors of sustainable housing and environmental development (Atolagbe and Fadamiro, 2014).

On the other hand, Malagasy brick production suffers from several drawbacks in terms of circular economy, as evidenced by Atolagbe and Fadamiro (2014): 1) bricks are not recycled; 2) the supplying of raw materials, the firing procedures and the transportation determine a cost that is unaffordable for low-income economies; 3) the massive exploitation of clayey deposits is an additional factor compromising the environment and the weak hydrogeological system (Ramasiarinoro et al., 2012).

As in other African countries, Malagasy brick production is strongly promoted by the large availability of different types of clayey sediments. Lateritic soils formed by weathering of igneous or metamorphic parental rocks in humid-tropical climate conditions are predominant, along with subordinate marine and alluvial clayey deposits.

Brick production is scattered all over the country although mainly develops in areas close to the largest villages or towns, and not far from clay deposits supplying sites. In the same place, skilled workers mould the clayey raw material in wooden dies, then dry and fire the bricks.

Firing takes place in open-air furnaces stoked with peat or wood; the type of fuel depends on the local availability. According to the type of fuel, firing time varies from few hours up to few weeks. Actually, wood requires shorter firing times whereas peat fires in much longer times. Interestingly, the large trenches left by clayey sediment exploitation are often reused for rice cultivation. Worth to note is that the same production cycle along with the firing process is reported in an excerpt of a Natural history dictionary dating back to 1831 (Batelli, 1831), in which the author carefully described a ceramic production in Holland carried out by using peat fuel.

The present research aims at a first recognition of the traditional technological process of Malagasy brick-manufacture by characterising unfired and fired bricks and in this first part of the investigation, the peat fuel.

Materials from four active workshops from the Central Highlands and from the southern coast of Madagascar have been collected during two field trips in 2011 and 2014. The whole production process was investigated including:

a) types of exploited deposits,
b) evaluation of the firing temperatures by evidencing mineralogical and textural modifications induced by the firing process (Cultrone et al., 2001; De Bonis et al., 2017; De Bonis et al., 2014; Germinario et al., 2016; Grifa et al., 2009),
c) types of furnace and heat transfer by comparing mineralogy of fired samples from different portion of furnace,
d) evaluation of the energies involved during the production cycle as a function of the estimated firing temperatures and calorific values of peat fuel.

2. Brief geological remarks

The island of Madagascar covers an area of ca. 587,041 km^2 (Fig. 2a). Archean and Proterozoic rocks crop out in the eastern two-thirds of Madagascar (most of which were involved in Pan-African orogenic events). The western third of the island is covered by Late Palaeozoic to Cenozoic sedimentary rocks (detrital continental sequences, marine-shelf carbonates and marine-fluvial siliciclastic rocks) deposited during and after the separation of Madagascar from the African continent (Piqué et al., 1999).

Madagascar also experienced two significant magmatic episodes during Cretaceous and Cenozoic. The first occurred during the Late Cretaceous (Turonian-Santonian; 92–84 My; Cucciniello et al., 2013, 2010; Storey et al., 1995) and is characterised by a flood basalt sequence, dyke swarms and intrusions localised along the rifted margin of the eastern coast, in western Madagascar and directly above the Precambrian basement (e.g., Cucciniello et al., 2013 and references therein).

Cenozoic magmatic episodes occur scattered throughout the island (Cucciniello et al., 2017; Cucciniello et al., 2016, 2011; Melluso et al., 2016, 2011, 2007, 2007; Melluso and Morra, 2000) and consist of lavas, pyroclastic rocks, dykes, and plugs, and widely range in composition from subalkaline to strongly alkaline rocks.

Due to the many different climate conditions, from tropical rain forest to oceanic climate but dominated by a tropical savannah climate (type Aw; Kottek et al., 2006), the Malagasy rocks are intensely prone to weathering that forms thick lateritic soils (up to tens of meters). The upper portion of laterite and saprolite sequences on steep slopes during monsoonal seasons can form typical erosional forms locally known as *lavakas* (Cox et al., 2009).

3. Studied materials and sampling strategy

Considering the limited volume of the investigated furnaces, a total