Data Article

Data on the estimation of thermomechanical damage for fired clay bricks

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\section*{A B S T R A C T}

Fired bricks are on high demand in building constructions because of their cheapness, appearance, robustness, isolation achievement and sustainability. To make fired bricks, Constructions and eco-friendly sector used clay materials. However, the major challenge in their utilization is their thermal and mechanical behavior after exposure. Problems occur mainly when permanently subjected to increased temperature which severely influence its durability, and in this case an overall failure mode calculation is essential. In this work a simple approach based on the Unified Strength Theory (UST) criterion was used to estimate the thermomechanical damage. Results of thermomechanical damage values are shown. © 2021 The Author(s). Published by Elsevier Inc. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/)

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**Specifications Table**

| Subject            | Engineering                                      |
|--------------------|--------------------------------------------------|
| Specific subject area | Materials, Damage mechanics                     |
| Type of data       | Tables, Figures and Process description         |
| How data were acquired | The X-ray diffraction (XRD) were recorded in the range $2^\circ \leq 2\theta \leq 70^\circ$ with a diffractometer Bruker Advance Eco equipped with a Cu Kα1 ($\lambda = 1.5418$ Å) radiation source. The thermogravimetric and thermal differential analysis (TG/DTA) was performed on the Automatic Multiple Sample Thermogravimetric Analyzer TGA-2000. The chemical analysis of major elements (SiO$_2$, Al$_2$O$_3$, TiO$_2$, Fe$_2$O$_3$ total, MnO, MgO, CaO, Na$_2$O, K$_2$O, P$_2$O$_5$, LOI) were assayed using a X-ray fluorescence ARL PERFORM-X 4200 spectrometer. The compressive tests were carried out on a universal testing machine of 2000 kN. |
| Data format        | Raw and Analyzed                                  |
| Parameters for data collection | Data presented are formed by thermomechanical damage values, stress versus strains at various temperatures. |
| Description of data collection | - Nsimalen thermogravimetric and thermal differential analysis (DTA/TGA), - Nsimalen X-Ray Diffraction (XRD) mineralogical analysis, - Nsimalen TM damage values for $b = 3/2$, at different temperatures, - Nsimalen normalized W0 and m for $b = 5/16$ and $b = 7/16$ respectively, - Excel solver was used to carry out numerical calculations. |
| Data source location | Laboratory of Civil Engineering and Mechanics, National Advanced School of Engineering of Yaoundé, University of Yaoundé 1, P.O. BOX 8390 Yaoundé, Cameroon |
| Data accessibility | All the data related are within the article. |
| Related research article | Léon Arnaud Mpoung, Jean Calvin Bidoung, Jean Valdez Sontia Metekong, Jean Raymond Lucien Meva’a, A coupled thermo-mechanical damage model for fired clay bricks based on the unified strength theory, Heliyon 10.1016/j.heliyon.2021e06010 |

**Value of the Data**

- This data can help to improve clay bricks production process through the definition of appropriate firing and operating/use temperatures.
- This data can provide insight for studying the macroscopic response from damage propagation of the clay in the future.
- This data can provide insights to an enhanced understanding of high temperature clay mechanics and provide the basis to improve clay bricks resource durability

**1. Data Description**

This article consists of tables and figures that depict data obtained from various tests among other the thermogravimetric and thermal differential analysis (DTA/TGA) (Fig. 1), the X-Ray Diffraction (XRD) (Fig. 2) for thermal and mineralogical analysis respectively of the clay used. Mineralogical analyses have also been made in order to identify the mineral phases (Table 1). Fig. 3 represents the TM Damage values for the effect of the intermediate principal shear stress, $b = 3/2$, of that clay at different temperatures. Meanwhile, Figs. 4 and 5 present the variation of the two distribution/model parameters with respect to the temperature for two values of the effect of the intermediate principal shear stress, $b = 5/16$ and $b = 7/16$ respectively.

The database is composed of five Excel files that contain raw data (Table 2). It includes data on thermogravimetric and thermal differential analysis (DTA/TGA), X-Ray Diffraction (XRD), thermal and mineralogical analysis, TM Damage values for the effect of the intermediate principal
shear stress, fluctuation of the two distribution/model parameters as regards the temperature for two values of the effect of the intermediate principal shear stress.

2. Experimental Design, Materials and Methods

Clay from Nsimalen, a locality around Yaoundé (Cameroon), was selected because of its matter of development implementations [2].

The thermogravimetric and thermal differential analysis (TGA/DTA) and the XRD have been undertaken to pinpoint its thermal behavior and mineralogical composition.

Approximately 1 g of material is collected and dried in the oven at 40 °C for at least 24 h. The sample is crushed manually with agate mortar and sieved dry to 250 μm until full passage. An aliquot is placed door by simple pressure in order to limit any preferential orientation of the mineral according to the method of Moore and Reynolds (1997). The resulting difractogram allows the identification of all reflections.

Table 1
Identified mineral phases.

| Identified Phases | d-spacing (Å) |
|-------------------|---------------|
| Kaolinite         | 7.13 ; 4.45 ; 3.57 ; 2.56 ; 2.49 ; 2.34 ; 1.97 ; 1.49 |
| Quartz            | 3.34 ; 4.25 ; 2.45 ; 2.28 ; 2.23 ; 2.12 ; 1.97 ; 1.81 ; 1.67 ; 1.45 ; 1.41 ; 1.38 ; 1.37 |
Fig. 3. TM Damage values for the effect of the intermediate principal shear stress $b = 3/2$ at different temperatures namely 29, 95, 200, 550, 700 and 950 °C with $\theta$, the stress angle corresponding to the twin-shear parameter of shear stress $0 \leq \theta \leq \theta_b$.

Fig. 4. Normalized W0 with temperature for $b = 5/16$ with $\theta$, the stress angle corresponding to the twin-shear parameter of shear stress such that a) $0 \leq \theta \leq \theta_b$, b) $\theta_b \leq \theta \leq 60^\circ$.

Fig. 5. Normalized m with temperature for $b = 7/16$ with $\theta$, the stress angle corresponding to the twin-shear parameter of shear stress such that a) $0 \leq \theta \leq \theta_b$, b) $\theta_b \leq \theta \leq 60^\circ$. 
Table 2
Contents of the database.

| File name                | Variable name | Contents                                      |
|--------------------------|---------------|-----------------------------------------------|
| ATG-ATD_Nsimalen.xls     | Temperature   | ATG-ATD of Nsimalen clay                      |
|                          | Mass          |                                               |
|                          | Loss mass     |                                               |
|                          | Calculated derivative |                           |
| TM damage value.xls      | TM damage     | Damage of Nsimalen clay                       |
|                          | Strain        |                                               |
|                          | Temperature   |                                               |
| DRX_Nsimalen.xls         | Theta (θ)     | DRX of Nsimalen clay                          |
|                          | Intensity     |                                               |
| Normalized m             | Temperature   | Progression of normalized m in relation to temperature |
|                          | Normalized values of m |                |
|                          | Experimental value |                              |
| Normalized W0            | Temperature   | Trend of normalized W0 in terms of temperature |
|                          | Normalized values of W0 |                                      |
|                          | Experimental value |                                      |

The peculiarity X-ray diffraction (XRD) high points were registered in the progression $2^\circ \leq 2\theta \leq 70^\circ$ with a diffractometer Bruker Advance Eco outfitted with a Cu Kα1 ($\lambda = 1.5418$ Å) irradiation generator. The ray generator was exploited at ambient temperature with tension and current setting as 40 kV and 30 mA respectively.

The thermogravimetric and thermal differential analysis (TG/DTA) was conducted on the Automatic Multiple Sample Thermogravimetric Analyzer TGA-2000 of AGES in an intense airing environment at a warm-up speed of 5 °C/min for 25–1000 °C ± 1 °C temperature on Nsimalen samples (0.1–1.5 g).

The clay was crushed in a grinder and sieved at 800 μm. Then, the test brick slip were formed as conventional cube-shaped of $4 \times 4 \times 4$ cm operating with combined clay and suitable amount of water (approximately 20% on dry basis) to fulfill right usability. The realized cubes were first desiccated at atmospheric environment for 72 h and positioned in an oven at 105 °C for 24 h for an entire elimination of hydrating water, before being fired in a smoother boiler up to 1050 °C. Five temperatures, to which the samples laid in the furnace are warmed up, were selected: 95, 200, 550, 700 and 950 °C. The compressive tests were accomplished on a universal testing machine of 2000 kN according to ASTM C67–80a standard. The tests were undertaken at a steady rate of motion of 5 mm/min to obtain the absolute stress – strain curves. An equally dispersed and continuously growing charge was required up to specimen breakdown, on cross-sectional sides portrayed by the width and the depth of the brick ($4 \times 4 \times 4$ cm).

A coupled thermo-mechanical (TM) damage evolution model [1–7] was proposed built on a prefered rock Unified Strength Theory (UST) [8,9] failure criterion. The model approval [1] was implemented through compressive stress-strain data which were fitted by Eq. (1) obtained using a minimization of the square of the error technique.

$$
\sigma_{ij} = \mu E_T \left( \varepsilon_{ij} - \varepsilon^{th} \right) \left( 1 - \xi + \xi \exp \left[ - \left( \frac{W}{W_0} \right)^{\theta} \right] \right)
$$

(1)

With
- $\sigma_{ij}$ is the stress component,
- $\varepsilon_{ij}$ is the strain component,
- $\varepsilon^{th}$ is the thermal strain component,
- $\xi$ is the adjustment factor
- $\mu$ is the ratio due to the behavior of clay at elevated temperatures
- $E_T$ is the modulus of elasticity at temperature T
- $W$ is a Weibull parameter that specifies the constraint level of the submicroscopic constituent,
- $W_0$ (the scope ratio corresponding to the submicroscopic constraint component part) and $m$ (the scope ratio determining the amount of regularity) are the statistical parameter used in the Weibull distribution.

Graphs were produced using Excel after testing functions that could fitted the data obtained. The functions that fitted the data are given by Eqs. (2) and (3) for normalized $W$ and normalized $m$ respectively.

\[
\begin{align*}
\frac{W(T)}{W(29^\circ C)} &= \frac{29.7424}{1 + \exp(-(72.171T - 42.2266))} : R^2 = 0.942; \ 0 \leq \theta \leq \theta_b \\
\frac{W(T)}{W(29^\circ C)} &= \frac{29.7676}{1 + \exp(-(67.2894T - 44.81))} : R^2 = 0.9872; \ \theta_b \leq \theta \leq 60^\circ \\
\frac{m(T)}{m(29^\circ C)} &= -0.06461 \tan\left(-2.68\left(\frac{T}{1000}\right) + 1.7125\right) : R^2 = 0.9044; \ 0 \leq \theta \leq \theta_b \\
\frac{m(T)}{m(29^\circ C)} &= -0.0012 \tan\left(-0.056\left(\frac{T}{1000}\right) + 1.573\right) : R^2 = 0.883; \ \theta_b \leq \theta \leq 60^\circ
\end{align*}
\]

CRediT Author Statement

Meva‘a Jean Raymond Lucien: Project administration, Conceptualization, Methodology, writing – original draft, validation; Bidoung Jean Calvin: Conceptualization, Methodology, Formal analysis, data analysis and interpretation the data, writing – original draft; Sontia Metekong Jean Valdez: Resources, Investigation, writing – original draft; Suila Yilaren: Writing – Original draft; Basil: Reviewing & Editing; Mpoung Léon Arnaud: Investigation, Formal analysis, Conceptualization, Methodology, Analysis tool or data, wrote the paper.

Declaration of Competing Interest

The authors sincerely thank the Local Materials Promotion Authority (MIPROMALO) in Cameroon for its collaboration in making available the samples used for this study. They equally express their gratitude to the National Civil Engineering Laboratory (LABOGENIE) in Cameroon and the Laboratoire de l’Unité de Recherche Argiles, Géochimie et Environnements sédimentaires (AGEs) de l’Université de Liège where all the tests were carried out.

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Supplementary Materials

Supplementary material associated with this article can be found in the online version at doi: 10.1016/j.dib.2021.106997.
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