Available online at www.sciencedirect.com
ScienceDirect
Journal of the European Ceramic Society 27 (2007) 2303–2310
www.elsevier.com/locate/jeurceramsoc

Elastic behavior of anisotropic terra cotta ceramics determined by kinematic full-field measurements

V. Huon*, B. Wattrisse, M.S. El Youssoufi, A. Chrysochoos

Laboratoire de Mécanique et Génie Civil, Cc 048, Université Montpellier II, Place Eugène Bataillon, 34095 Montpellier Cedex 05, France

Received 21 May 2006; received in revised form 25 July 2006; accepted 7 August 2006
Available online 2 October 2006

Abstract

The anisotropic behavior of terra cotta ceramics is due to the lamellate structure of clay and to the extrusion forming process. In the case of low strains, this behavior is elastic. Digital image correlation was used to give strain field measurements. These measurements allowed to locally characterize transverse isotropic elastic behavior. The consistency of the local characterization procedure is showed by comparing kinematic field measurements on small specimens with fields obtained by 3D finite element computations.

Keywords: Extrusion; Mechanical properties; Traditional ceramics; Structural applications; Terra cotta

1. Introduction

Terra cotta ceramics are often used in residential house building. They are nearly always associated with other civil engineering materials, e.g. terra cotta beams with a core of prestressed concrete are widely used for building floors, terraces or flat roofs. In this kind of composite element, terra cotta serves as a sacrifice formwork, i.e. concrete is considered to be the only material that supports prestressing forces. However, from a mechanical standpoint, terra cotta has remarkable strengths (i.e. often better than those of standard concrete) that are often not effectively utilised. The work presented in this paper is a part of an overall study carried out to characterize the anisotropic thermo-hygro-mechanical behavior of terra cottas used as building material in civil engineering projects. From an industrial standpoint, the goal is to develop numerical computer-aided design tools that can be used to optimize structural elements. This optimization must simultaneously take into account parameters related to thermal comfort and those associated with the mechanical strength of the designed structure.

In the recent past, the classical use of terra cotta bricks did not require in-depth knowledge on their mechanical properties since they were mainly loaded in compression. Now the use of the terra cotta as a composite structural component calls for a more rigorous analysis of its contribution to the overall behavior of the structure. We thus studied the heterogeneous and anisotropic properties of this material using strain field measurements. These measurements were obtained by digital image correlation (DIC) techniques with the aim of checking the degree of heterogeneity of ceramic structures and characterizing the anisotropy of the terra cotta. This technique is now widely used in the field of mechanics of materials and it was, for example, successfully applied to the study of localization phenomena in steel (Luders band propagation, developpement of the diffuse and localised necking).[1]

This paper is structured as follows: first we review the material properties that led us to propose a transverse isotropy model to describe the elasticity of ceramics. Secondly, we show how the elastic parameters were locally derived from tests conducted on elementary structures considered as representative volumes of the material. Finally, to check the influence of the discrepancy noted in the elasticity constants, we compare strain patterns predicted by a 3D FE computation with those obtained by DIC.

2. Material of study: the terra cotta ceramics

The studied material was provided by the industrial partner "Saverdun Terre Cuite". This manufacturer owns several quarries in the south of France. The used samples were derived from the same raw material.

* Corresponding author. Tel.: +33 467 144 737; fax: +33 467 144 792.
E-mail address: huon@lmgc.univ-montp2.fr (V. Huon).

0955-2219/$ – see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jeurceramsoc.2006.08.013

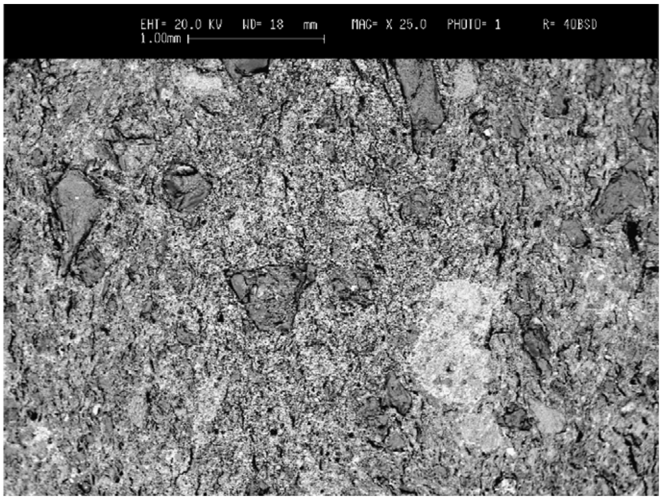

Fig. 1. Illustration of grain size distribution in the material

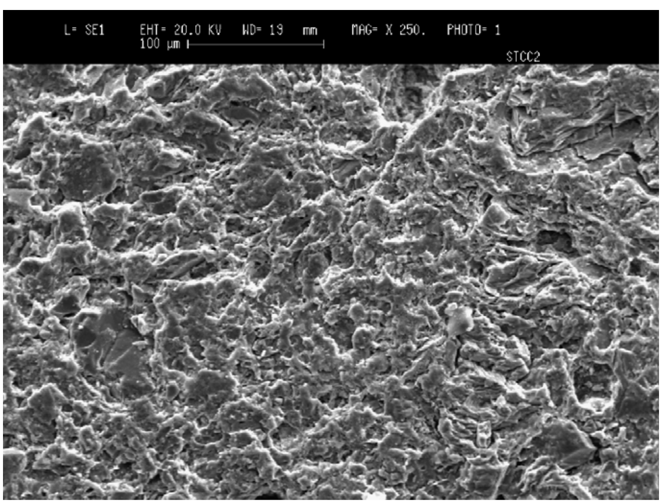

Fig. 2. Illustration of the porosity of the material.

2.1. Chemical composition

An electron probe microanalysis (EPM) was used to determine the grain size and nature. The maximum grain size was 1 mm (Fig. 1), including:

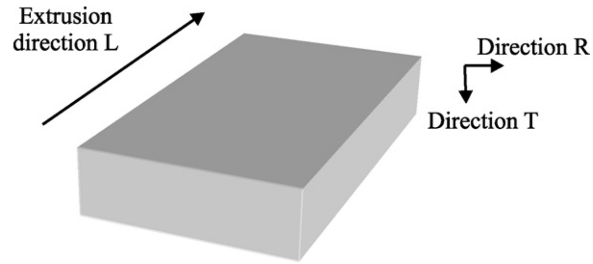

Fig. 4. Directions of transverse isotropy.

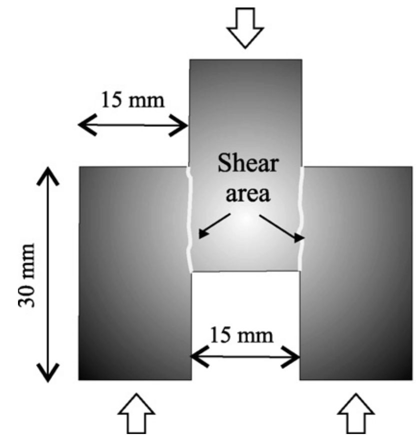

Fig. 5. Y-shaped specimen.

- quartz grains (the most common);
- calcite grains of up to 200 μm in size (the least common);
- a low percentage of small feldspath grains.

The chemical composition of the terra cotta studied in this paper is given in Table 1.

2.2. Manufacturing process

Argillaceous soils are the primary products for manufacturing terra cotta ceramics. In most cases, they are used with additives (sand, limestone, etc.) to enhance the characteristics of structural elements or to modify the functional characteristics or the aspect of the finished products. Clays are hydrated aluminosilicates whose lamellar structure can fix a certain quantity of

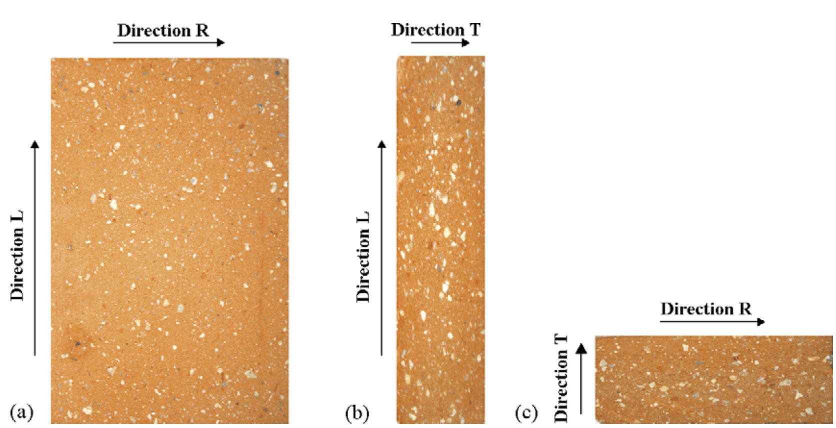

Fig. 3. Illustration of the grain distribution and the grain orientation in the different directions.