Ultrasonics 66 (2016) 4–10

Contents lists available at ScienceDirect

Ultrasonics

journal homepage: www.elsevier.com/locate/ultras

Evaluation of correlation between physical properties and ultrasonic pulse velocity of fired clay samples

İlker Özkan *, Zeliha Yayla

Dokuz Eylül University, Torbalı Vocational School, Industrial Glass and Ceramics Department, İzmir, Turkey

ARTICLE INFO

Article history:
Received 4 November 2014
Received in revised form 10 September 2015
Accepted 15 December 2015
Available online 21 December 2015

Keywords:
Brick-making clay
Pottery clay
Physical properties
Ultrasonic pulse velocity
Correlation

ABSTRACT

The aim of this study is to establish a correlation between physical properties and ultrasonic pulse velocity of clay samples fired at elevated temperatures. Brick-making clay and pottery clay were studied for this purpose. The physical properties of clay samples were assessed after firing pressed clay samples separately at temperatures of 850, 900, 950, 1000, 1050 and 1100 °C. A commercial ultrasonic testing instrument (Proceq Pundit Lab) was used to evaluate the ultrasonic pulse velocity measurements for each fired clay sample as a function of temperature. It was observed that there became a relationship between physical properties and ultrasonic pulse velocities of the samples. The results showed that in consequence of increasing densification of the samples, the differences between the ultrasonic pulse velocities were higher with increasing temperature. These findings may facilitate the use of ultrasonic pulse velocity for the estimation of physical properties of fired clay samples.

1. Introduction

Clays have been used for different purposes in many industrial applications for ages [1]. Ceramic industry uses clay minerals as major components. The applications of clay minerals are tightly dependent on their structure, composition and physical properties [2]. It is well-known that industrial clays have a complex mineralogical composition and during firing a series of transformations occur which determine the final properties of the ceramic products [3]. The final properties such as water absorption, linear shrinkage, bulk density and bending strength are determined by using a series of different test procedures [4,5] and are used to assess the quality of ceramic products. As these tests take time, to apply a fast and non-destructive method for evaluating these properties can be useful.

Ultrasonic pulse velocity (UPV) test, a non-destructive and easy method to apply, is increasingly being used [6]. The UPV of a homogeneous solid can be easily related to its physical and mechanical properties [7]. An increasing number of recent studies have demonstrated the convenient use of UPV measurements to assess some properties of materials. Boccaccini et al. have studied to determine the quality control of refractory plates by using UPV measurements [8]. Lafhaj et al. reported correlations between UPV, porosity and permeability of mortar [9]. Another study was conducted on the determination of thermal shock resistance of refractory materials [10]. Sadeghi-Nik and Lotfi-Omran have studied on estimation of compressive strength of fiber-reinforced self-compacted concrete by using UPV [11]. Bentama et al. used ultrasonic waves detect default of porosity of a clay membrane after manufacturing [12]. In another study, some material characteristics of alumina ceramics, e.g., porosity, Young's modulus and Poisson's ratio, have been evaluated using UPV [13]. Also, UPV test was used to assess delamination of ceramic tiles [14].

Studies in the literature point out that UPV test have a large variety of application fields to assess different ceramic materials. Although very limited studies on the potential use of ultrasonic waves to determine the thermal behaviors of the fired clay minerals have been reported in the literature [15], evaluating physical properties of fired clay samples by using UPV has not been studied. The present work was motivated by the fact that no comprehensive research has been previously carried out regarding the possible usage of UPV on evaluating physical properties of fired clay samples. To be able to fill this gap in the literature, the present study was carried out to: (i) determine the characteristics and physical properties of the fired clay samples and (ii) investigate the correlations between the UPV and physical properties of the samples. It is thought that UPV test can be used to predict the evolution of physical and structural behavior of the clay samples.

* Corresponding author. Tel.: +90 232 8531828 145; fax: +90 232 8531606.
E-mail address: ilker.ozkan@deu.edu.tr (İ. Özkan).

http://dx.doi.org/10.1016/j.ultras.2015.12.008

Table 1
Chemical analysis results of the clay samples.

Oxides (wt.%)	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	LOI
BC	57.94	19.12	7.54	3.03	0.73	0.74	3.16	0.88	6.56
PC	60.34	17.31	6.64	0.57	0.42	0.49	1.38	1.00	9.78

2. Materials and methods

The studies were carried out by using two clay samples. Brick-making clay (BC) was obtained from Turgutlu region and pottery clay (PC) was obtained from Karacasu region. The clay samples were characterized by chemical analysis and X-ray diffraction (XRD). The chemical compositions of clay samples were analyzed by ICP-MS at Acme Labs. The phases present in the samples were identified by X-ray diffraction (XRD) using a Rigaku Model diffractometer with monochromatic Cu Kα radiation.

Variations in linear shrinkage values were measured using a caliper after firing. Archimedes method based on TSE EN ISO 10545-3 was used to determine the water absorption, apparent porosity, bulk density and apparent specific gravity of the fired clay samples. Test involves placing in boiling water for 4 h. After boiling the specimens were immersed in water for a minimum of 12 h

Table 2
Physical properties of the fired BC samples. (Abbreviations; WA: water absorption, AP: apparent porosity, BD: bulk density, ASG: apparent specific gravity, LS: linear shrinkage, BS: bending strength.)

Temperature (°C)	WA (%)	AP (%)	BD (g/cm^3)	ASG	LS (%)	BS (MPa)
850	17.08	30.74	1.80	2.60	−2.30	3.41
900	16.47	29.86	1.81	2.58	−2.73	4.87
950	15.13	27.83	1.84	2.55	−3.19	6.49
1000	14.15	26.28	1.86	2.52	−3.42	9.21
1050	12.00	22.79	1.90	2.46	−3.94	14.56
1100	8.96	17.83	1.99	2.42	−5.36	19.76

Table 3
Physical properties of the fired PC samples.

Temperature (°C)	WA (%)	AP (%)	BD (g/cm^3)	ASG	LS (%)	BS (MPa)
850	17.71	32.40	1.83	2.71	0.58	2.85
900	17.45	32.25	1.85	2.73	0.43	3.79
950	17.15	31.84	1.86	2.72	0.18	6.18
1000	15.46	29.37	1.90	2.69	−0.52	7.82
1050	12.55	24.96	1.99	2.65	−1.56	12.65
1100	12.43	24.84	2.00	2.66	−1.65	17.48

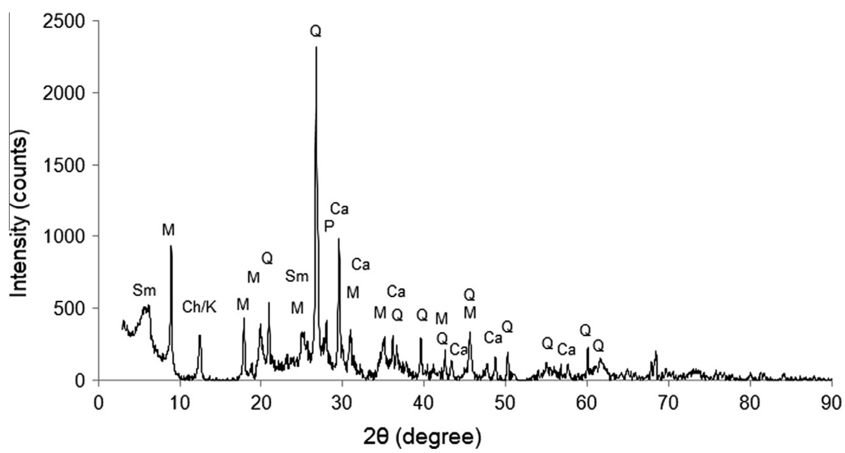

Fig. 1. XRD pattern of the whole rock from BC. (Abbreviations; Q = quartz, M = mica, P = plagioclase, Sm = smectite, Ch = chlorite, K = kaolinite, Ca = calcite.)

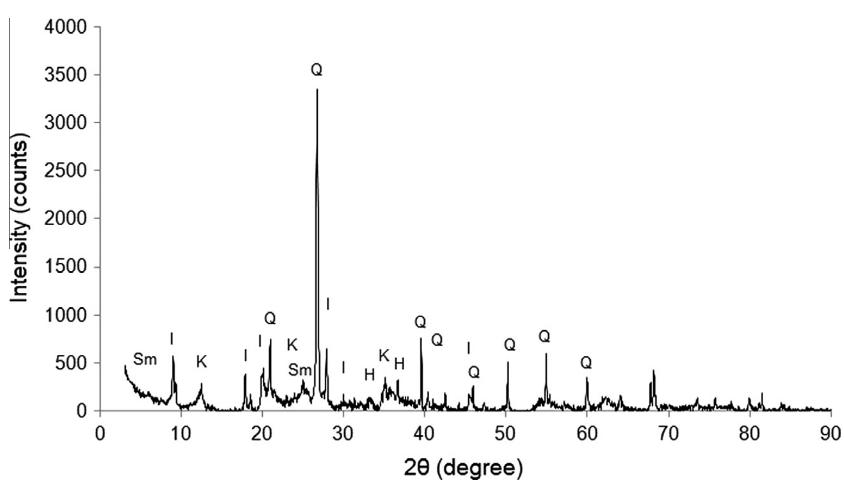

Fig. 2. XRD pattern of the whole rock from PC. (Abbreviations; Q = quartz, Sm = smectite, K = kaolinite, H = hematite, I = illite/mica.)