Investigation of mineralogical composition and technological properties of conventional brick clays

LÁSZLÓ A. GÖMZE • Institute of Ceramics and Polymer Engineering, University of Miskolc • femgomze@uni-miskolc.hu
SERGEI N. KULKOV • Institute of Strength Physics and Materials Science SB RAS, National Research Tomsk State University • kulkov@ms.tsc.ru
EMESE KUROVICS • Institute of Ceramics and Polymer Engineering, University of Miskolc • fememese@uni-miskolc.hu
ALEXANDR Y. BUZIMOV • Institute of Strength Physics and Materials Science SB RAS, National Research Tomsk State University • alesbuyakov@gmail.com
SVETLANA P. BUYAKOVA • Institute of Strength Physics and Materials Science of RAS, Tomsk State University • sbuyakova@ispms.ru
RÓBERT GÉBER • Institute of Ceramics and Polymer Engineering, University of Miskolc • fergabor@uni-miskolc.hu
MHIHAL V. GRIGORIEV • Institute of Strength Physics and Materials Science of RAS, Tomsk Polytechnic University • grv@ispms.ru
ISTVÁN KOCSERHA • Institute of Ceramics and Polymer Engineering, University of Miskolc • istvan.kocsenha@uni-miskolc.hu
ALEKSEY S. KULKOV • Institute of Strength Physics and Materials Science SB RAS, National Research Tomsk State University
TATJANA YU. SABLINA • Institute of Strength Physics and Materials Science of RAS • saborat@ispms.ru
NIKOLAI L. SAVCHENKO • Institute of Ceramics and Polymer Engineering of RAS • savnick@ispms.ru
IRINA N. SEVOSTYANOVA • Institute of Strength Physics and Materials Science of RAS • sevira@ispms.ru
ANDREJA SIMON • Institute of Ceramics and Polymer Engineering, University of Miskolc • femandija@uni-miskolc.hu

Abstract
In this research the layers of a Hungarian conventional brick clay deposit were examined both on material and mineralogical structures and compositions as well as on technological properties. During their examination the authors have found that the volumes of X-ray amorphous submicron and nano particles of the conventional brick clays do not influence on the dry sensitivity of the extruded and formed green products. The authors have found also a strong correlation between the X-ray amorphous nano particles of raw materials and the bending strengths of the sintered ceramics. As more the volumes of submicron and nano particles are in the conventional brick clays as higher are the bending strengths of the produced from them sintered ceramics.

Keywords: bending strength, bricks, clays, drying, minerals, roof tiles, shrinkage, X-ray diffraction

Tatjana Yu. SABLINA, has PhD Education since 1989 at present she is working at the Tomsk State University and Institute of Strength Physics and Materials Science of the Russian Academy of Sciences in Tomsk.

Nikolai L. SAVCHENKO, PhD Education: 1987: Tomsk Polytechnic University engineer,1991-1994: Institute of Strength Physics and Materials Science of the Russian Academy of Sciences in Tomsk - PhD student, 1995: PhD degree from the Institute of Strength Physics and Materials Science of the Russian Academy of Sciences in Tomsk.

Irina N. SEVOSTYANOVA, PhD Education: 1987: Tomsk Polytechnic University engineer,1993-1994: Institute of Strength Physics and Materials Science of the Russian Academy of Sciences in Tomsk - PhD student, 2001: PhD degree from the Institute of Strength Physics and Materials Science of the Russian Academy of Sciences in Tomsk. Field of research: Structure and mechanical property of porous ceramics based zirconia and alumina.

Andrea SIMON, is graduated in the University of Miskolc and has PhD since 2010. At present she is associate professor of the Department of Ceramics and Sinter Engineering (DCSE) in University of Miskolc (Hungary).

LÁSZLÓ A. GÖMZE, is establishment and professor of the Department of Ceramics and Sinter Engineering in the University of Miskolc, Hungary. He is author or co-author of 2 patents, 6 books and more than 300 scientific papers. Recently, he is the chair of the International Organization Board of ic-cmp5 the 5th International Conference on Competitive Materials and Technological Processes (2018).

Sergei N. KULKOV, is professor of the Tomsk State University and head of Department of Ceramics in the Institute of Strength Physics and Materials Science of the Russian Academy of Science since 1989. His research works are represented in 5 books, more than 150 articles, 18 patents and many International Symposiums and Conferences. At present he is head of department, Theory of Strength and Mechanic of Solids”, member of „The American Ceramic Society” of „The APMI - International” and the DYM K Society (France).

Emese KUROVICS, is graduated in the University of Miskolc, Department of Ceramics and Silicate Engineering as a material engineer, where she actually continues her study as PhD student under supervision of Prof. L. A. Gilmaz.

Ales S. BUYAKOV, is graduated in the National Research Tomsk Polytechnic University, as an engineer and he actually continues his study as PhD student under supervision of Prof. S. N. Kulikov in the Institute of Strength Physics and Materials Science SB RAS.

Svetlana P. BUYAKOVA, is Doctor of Sciences since 2006, full Professor since 2013. She is specialist in material sciences of ceramic and ceramic matrix composites based on oxides and carbides. She is author and co-author of more than 100 papers. Now, she is chief scientist in IS PMS RAS and professor in Tomsk State University and Tomsk Polytechnic University. Her teaching experience: Introduction to materials science, Fundamentals of materials engineering, Materials and their applications.

Alexandr Y. BUZIMOV, is graduated in the National Research Tomsk State University, as an engineer physic and he actually continues his study as PhD student under supervision of Prof. S. N. Kulikov in the Institute of Strength Physics and Materials Science SB RAS.

Róbert GÉBER, is graduated in the University of Miskolc and has PhD since 2013. At present he is lecturer at the Institute of Ceramics and Polymer Engineering in University of Miskolc.

Mihail V. GRIGORIEV, has PhD since 2007. At present time he is a post-doctoral fellow in Institute of Strength Physics and Materials Science of Siberian Branch of the Russian Academy of Science under guidance Prof. Kulkov.

István KOCSERHA, is graduated in the University of Miskolc and has PhD since 2010. At present he is associate professor and chair of the Department of Ceramics and Silicate Engineering (DCSE) in University of Miskolc (Hungary). He is author or co-author of 35 articles and 1 Hungarian patent.

Aleksey S. KULKOV, is physicist and has got PhD scientific degree at Tomsk State University in Russian Federation. At present he is working as research fellow at Institute of Strength Physics and Materials Science of the Russian Academy of Sciences in Tomsk.
1. Introduction

In our days the conventional brick clays are playing very important role in production of ceramic bricks and roof tiles [1-14] but they are wildly used also in different segments of industry [15-17]. Their mineralogical composition, grain size distribution, moisture and specific surface are influencing very strong not only on color and quality of the final products but on the technological properties and parameters also [18-20]. There are several authors underpin that the drying sensitivity of the conventional brick clays depends on their grain sizes and specific surfaces, means as smaller the average grain size and higher the specific surface are as stronger the susceptibility of clays is to the drying sensitivity and drying cracks [21-24]. This option is one of the reasons that it is so important to analyze the mine layers before their exploitation to produce building ceramics like large borehole bricks or roof tiles.

It is obvious that the layers of the conventional brick clay deposits have formed during several thousand years. This circumstance is one of the reasons why they may have very different mineralogical, chemical, morphological and grain size structures depending on their position and location inside of the mined deposits and layers.

The aims of this research work to determine the mineral composition of the layers of a new clay deposit and their influence on the technological properties like extruding, drying and firing as well as shrinkages and bending strengths of the sintered products.

2. Materials and experiments

To determine the material structure, specific surface, mineralogical composition, extruding, drying and sintering properties of clay minerals of a new Hungarian quarry 9 mining holes were drilled in a square mesh structure in 15 m depth of each. The drilled out materials from each mined holes were divided by 5m as 0-5m, 6-10m, 11-15m and were crashed and mixed on a laboratory pan mill with 90rpm through 10 minutes. From each mixture by 100g were taken for the material tests as scanning electron microscopy (SEM and EDAX), Langmuir and BET specific surface determination and X-ray diffraction. All the remaining clays were extruded on a KEMA-PVP 5/S extruder into cylindrical shape rods with diameter of 33 mm. After extrusions each rods were cut on 7 specimens by 150 mm green lengths of each before drying, sintering and bending strength tests. In this research work are shown the results of material tests and examinations made on mixes of the 3 different layers taken from the central (5th) drilling hole.

The typical material structure and chemical composition of clay mixtures investigated with scanning electron microscopy and EDAX are shown in Figure 1 and Figure 2.

3. Results and discussions

The material samples taken from mixtures by 100 g of each were dried in a laboratory chamber-dryer at 85°C during 72 hours. After drying some part of them was used to determine specific surfaces and part of them for determine the mineral and chemical composition through X-ray diffraction. The Langmuir and BET specific surfaces were determined with instrument TriStar 3000 and the results are given in the Table 1.

| Layers Tested mass | Langmuir, m²/g | BET, m²/g |
|--------------------|---------------|-----------|
|                    | single multi  |           |
| 0-5 m 0.3096 g     | 28.7347       | 19.1615   |
| 31.7419            | 20.3931       |
| 6-10 m 0.4781 g    | 29.5417       | 19.6578   |
| 32.1277            | 21.6153       |
| 11-15 m 0.2686 g   | 30.7266       | 20.4658   |
| 33.3207            | 21.7865       |

Table 1. The specific surfaces of the clay mineral mixtures taken from the 3 different layers of drilling 5

The XRD diagrams of the layers are given in Figure 3 and the mineralogical and oxide compositions of the layers are given in Table 2 and Table 3.
Analyzing the mineralogical composition determined by X-ray diffraction we can see that total volumes of clay minerals are more than 25 m% which means that this mined raw material is applicable to produce good quality ceramic bricks and roof tiles using plastic forming technology like extrusion. At the same time the ratios of the X-ray amorphous particles are higher than 15 m% in each case. Because of the large volume of the X-ray amorphous submicron and nano particles after the sintering will be formed a nano size porous structure that will make the produced bricks and tiles frost resistant [25].

After the extrusion the 21 pieces of cylindrical rods with green lengths of 150 mm were dried in open air at room temperature of about 25-30°C and their diameters, lengths and weights were measured by 1 hour in the first 3 hours and after by 2 hours. The results of mass and volume losses are presented in Bourry diagrams in Figure 4.
cracks because of the too fine grain structure. During the drying we did not find any cracks or microcracks on the surfaces and nor in the cross-section of the extruded ceramic rods in spite that the studied brick clays have 19-25 m% of particles with nano sizes. This means that increment of fine particles in the conventional brick clays does not increase the drying sensitivity of the extruded and plastic formed ceramic items. So the appearances of cracks during drying must be explained with incorrect forming pressures and residual stresses inside of the body after extrusion and pressing and not with the fine grain size structures.

After drying the 21 pieces of the cylindrical rod specimens were sintered in an electrical chamber kiln with heating rate of 60°C/hour up to 950°C and kept at this temperature during 2 hours and after the heating system was switched off. The volumetric and mass losses of drying and firing together are shown in Fig. 5 and Table 4.

The 3 point bending strength test gave relatively high values which means that the conventional clay minerals from this new mine can be perfectly used for production ceramic roof tiles with high quality. Analyzing the reasons of this relatively good mechanical bending strength the authors could not find a convincing correlation between the bending strength and quartz content but a very good correlation have been found between the bending strength and volumes of XRD amorphous fine particles in the conventional brick clay raw material (Figure 6). So it can be stated that using conventional brick clays the bending strength of the sintered products will as higher as more X-ray amorphous nano particles are in the minerals.

4. Conclusion

The most important conclusion of the present research work is that the examined clay deposit is applicable for production building ceramic items like wall bricks and roof tiles. At the same time submicron and nano particles of the conventional clays are not reason of the micro and macro cracks on surface and in body during drying the extruded and pressed from them products. The strong correlation was founded between the bending strength of the sintered cylindrical ceramic rods and the volume of the X-ray amorphous submicron and nano particles. As more the volumes of submicron and nano particles are in the conventional brick clays as higher are the bending strengths of the produced from them sintered ceramics.

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Table 4. The volumetric and mass losses of drying and total after firing and the 3 point bending strength (Table 4).

| Layer (depth), m | Volumetric shrinkage, % | Weight loss, % | 3 point bending strength, MPa |
|------------------|-------------------------|----------------|-----------------------------|
| 0-5              | 13.07                   | 15.32          | 7.80                        |
|                  | 20.11                   | 15.87          |
| 6-10             | 14.54                   | 17.85          | 9.90                        |
|                  | 21.10                   | 12.05          |
| 11-15            | 15.51                   | 18.45          | 10.79                       |
|                  | 21.92                   | 12.07          |

Fig. 5. The volumetric and mass losses of drying and total after firing

Fig. 6. Bending strength [MPa], quartz and X-ray amorphous nano particles ratio [m%] of specimens made and sintered from the clays of the different layers
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Hagyományos téglaagagok és téglaagagok összetételének és technológiai tulajdonságainak vizsgálata

Jelen kutatás során egy nagyüzemelyes, magyarországi gyár agyagbányában rafet rejtéget vizsgált a technológiai tulajdonságokat, valamint az anyag, és azt a szerkezetet alapján. A szerzők megállapították, hogy a téglaagagok a téglaagagok és nanomérzetű részecskéjeinek mennyisége nincs hatással az extrudált nyers anyagok réztelenítésére. A szerzők erős kapcsolatot találtak a nyersanyag keményítésére, és a szintetizált kerámia hajlószilárdsága között. Minél nagyobb arányban tartalmaz a nyers anyag és nanomérzetű részecskéket, annál magasabb lesz a belőle készült, égetett kerámia termék hajlószilárdsága.

Kulcsszavak: agyag, asványok, cserép, hajlószilárdság, száradás, tégla, XRD, zsugorodás

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