Unique, firmest full bricks in Czech Republic

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Abstract. History of ceramic products reach as far as 27000 years back. Discovery of first ceramic products definitely showed ways for first approach in processing plastic materials suitable for production of future ceramic products. When we imagine the method of firing first statuettes, it must have placed the foundations for very first field kilns. Thus if we will push over selves to work harder, fire high-quality bricks and abide technological procedures of production. We will be able to produce unique products which will stay here --with us over centuries.

1. Introduction
First mention of ceramic products are from the lands of the Czech Republic. It is ceramic statuette of naked woman. This creation is made of clay which dates back to early Palaeolithic period between 29 000 – 25 000 years b. c. This figurine was also with others found on 13th July 1925 somewhere in the middle of villages Dolní Věstonice and Pavlov, it was found by archeologist Karel Absolon.

Bricks are universal, ecological, recyclable building material which is known for over 10 000 years. In the world are several unique constructions which are created by bricks and those are pride of worldwide architecture. Such as The big wall (Chinese wall) biggest brick-made construction around the world. Babilonian gardens, Hagia Sofia – one of the most beautiful churches in the world which has been built later on- Medieval castle Malbrok in Poland, which resembles small city, construction Thadz Mahal in India, skyscraper Chrysler Building in New York where was used roughly over 3 826 000 bricks.

Very last brick factory in the region of the Great Prague is brick factory in Štěrboholy, which in 2019 celebrated its 90th anniversary. Interestingness is that until 18th century was in the area of so called „Great Prague“ built more than 200 brick factories. Nowadays the number of active brick producing plants is less than 20 all over the Czech Republic. [1]

The standard states the following:

The manufacturer must declare the average compressive strength of the elements. This strength can be any strength value, but it is recommended to use the compressive strength classes according to the current classification system (see Table 1) In addition, if necessary, the manufacturer must declare the standard compressive strength of the elements. Provisions for the conversion of the compressive strength of a fired masonry element to the standardized compressive strength are contained in standard EN 772-1. The manufacturer must also declare that the individual values of compressive strength of the masonry elements taken from the delivery are not less than 0.8 times the declared compressive strength. In addition, the manufacturer may inform to what extent the declared compressive strength of the elements
is in accordance with the national classification system. In addition, the manufacturer must declare whether the fired masonry belongs to category I or to category II. According to EN 771-1, the requirements for compressive strength do not have to be applied in their entirety to fired masonry elements of special shaped and to additional fired masonry elements. Table 1 Strength classes according to National Annex NA to EN 771-1 If samples of fired masonry elements are taken from the delivery according to EN 772-1 with modification of the pressed surfaces according to 7.2.4 EN 772-1 and conditioned (prepared for testing) according to 7.3.2 of EN 772-1 the average compressive strength of the specified number of fired masonry elements coming from the delivery shall not be less than the declared compressive strength.

Table 1. Levels of firmness according to national appendix Na to EN 771-1

| Strength mark of the bricks | Firmness in pressure MPa | average | individual |
|----------------------------|--------------------------|---------|------------|
| P 2                        |                          | 2       | 1.6        |
| P 4                        |                          | 4       | 3.2        |
| P 6                        |                          | 6       | 4.8        |
| P 8                        |                          | 8       | 6.4        |
| P 10                       |                          | 10      | 8.0        |
| P 15                       |                          | 15      | 12.0       |
| P 20                       |                          | 20      | 16.0       |
| P 25                       |                          | 25      | 20.0       |
| P 30                       |                          | 30      | 24.0       |
| P 35                       |                          | 35      | 28.0       |
| P 40                       |                          | 40      | 32.0       |

Determination of strength: The determination of the strength of masonry unit is carried out in accordance with EN 772-1 Test methods for masonry units – Part 1: Determination of compressive strength. The printed surfaces of the test specimens are treated either by grinding or by double-sided mortar painting. [2]

1.1 Historical evolution of bricks
The brick product is such product which went through a technological process of excavation and processing, drying and burning.

8300-7600 B.C. the bricks were created by hands and were dried in the sun.

7300-6600 B.C. First bricks with dimension 400x150x100 appeared in Jericho

5900-5300 B.C. For the creation of bricks, wooden forms were used even in Egypt.

5000-4500 B.C. Mesopotamia discovered fired brick

2111-2003 B. C. From bricks are being made: temples, palaces, domes for gods, kings and nobility.

604-562 B.C. Architectural gems are being built such as: Hanging Gardens of Babylon.

1400-1600 Establishment of a press machine, which had the main impact on the quality of the pressed products.

Czech format of full brick (Figure 1). Order on 14th April 1883 with coming of the metrological reform. It is format of 290x140x65. This format is specific only for the Czech Republic and Slovakia. In Austria and Poland are formats of full bricks 250x120x65. In Germany the format is 240x 115x 71 [2].
2. Brick raw materials

Brick raw materials are ceramic raw materials which are sorted into (Table 2, 3):

a) Shapeable, plastic materials, which after mixing with water create plastic dough useful for shaping which is followed by drying and firing in brick kilns where it gets needed firmness. Nowadays are used 3 types of firing. One historical method of firing cannot be omitted and that is firing in outdoor bonfire or charcoal kilns (bricks were placed vertically on one another, wood was placed around and set on fire. Subsequent fire created required heat for the firing. Second method is used even today. So called „Circular kilns“ or „round kilns“. These were built in circles or ovals, divided into sections which had individual firing.

Into every section were placed openings which were then walled up and here were placed bricks for the firing. After wall up fire was made inside and fuel was added through the top of the chimney. The used fuel was from coal or its fine-grained fractions up to coal dust. Today, the use of a tunnel kiln is considered as the standard. It is in a shape of a tunnel, where is heated in the middle section by natural gas. Front part is heated and the end part transfers the residual heat from the cooling process to the dryers. This method is the most environmentally friendly and it reduces the amount of CO2 emitted by up to 40% compared to older circular kiln technology.

Table 2. Shapable raw materials are divided according to the content of typical clay minerals and according to the method of weathering at the sediment deposition site

| Granulometry of clay soils | 1. clays | 2. dusts | 3. sands |
|----------------------------|----------|----------|----------|
| d< $2 \cdot 10^{-6}$ m     | $d \in (2 ; 50) \cdot 10^{-6}$ m | $d \in (0,05 ; 2) \cdot 10^{-3}$ m |
| Clay                       | ($\geq 50\%$ clays)               |                      |          |
| dirt                       | ($20\%$ - $50\%$ clays + $50\%$ - $80\%$ dusts) |                      |          |
| dust                       | ($< 20\%$ clays + $> 30\%$ dusts)  |                      |          |
| sand                       | ($< 20\%$ clays + $> 50\%$ sands)  |                      |          |
If necessary, it is also possible to divide different ratios of fractions appearing in the raw material according to the ratio (d-grain).

**Table 3. Clay soil**

| Clay soil                  | Kaolinic and illitic | Not strenghtened | Kaolins, clays, anorganic pigments |
|----------------------------|----------------------|-------------------|-----------------------------------|
|                            |                      | strenghtened      | Clay, lupes, clay slates          |
| montmorillithic            |                      | bents             |                                    |
| illitic, chloritic, montmorillithic, kaolinic | Non-strenghtened | dirts, lime clays, marls |
|                            |                      | strengthened      | Dirt, Clay                        |

b) Non-formable materials, which alter the behaviour of other materials during their creation process, drying and firing. These affect characteristic of the product up to micro space of fired product. Among these materials is counted several types of sediments up to industrial waste such as fly ash, slags, dregs and different types of sawdust.

We divide these amorphous raw materials into:

Slags: which affect the ductility, drying and firing behaviour (deformation, sintering and shrinkage). Lightening agents: which reduce the bulk density of the fired shard, either directly after firing, thus the number of pores is increased, or indirectly by the composition of various types of raw materials. Fluxes: which are substances which form a given melt at a temperature which is lower than the firing temperature. This is achieved by adding easily fusible substances, such as feldspar, trachytes, pegmatites, various glasses. Optionally various oxides: CaO, MgO, FeO, K2O, Na2O.

Today’s manufacturers in the Czech Republic achieve a maximum strength of P25 (min 25N/ mm²) Higher or high strengths are required for some vertical structures. [3]

Even today we can find great amount of use for bricks with high firmness on vertical structures. These are load-bearing pillars for raised balconies, load-bearing walls for storing high-stress ceiling structures, elevator shafts and similar. As can be seen, the standard does not provide for such products, but products with extreme strengths do exist. I am thinking of products that achieve a compressive strength around P100 (min 100N/ mm²). Products offered by the last Prague brick factory of Štěrboholy, which thanks to a unique raw material (illitic slate), a well-chosen technological process and a method of processing, is the only manufacturer that produces such products.

3. Conclusions
Brick materials are an integral part of everyday life. In the time of innovation and modernization in the building industry, bricks were irreplaceable. Many centuries, bricks resisted weather conditions and made the aesthetic value. They are exchangeable, non-toxic, fire-resistant, after their life they are recyclable, and will be used throughout the next millennia.

References:
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