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ARCHITECTURE AND CERAMIC MATERIALS, DEVELOPMENT THROUGH TIME: ADOBE AND BRICK

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Abstract. *The fired earth products are from the dawn of time very readily used as a building material in architecture. Regardless of the geographical area, or era, both adobe and bricks have been often used because they are easy and cheap to manufacture.*

The paper provides the review of adobe and brick use, from the earliest times until nowadays. The evolution of their production, forms, physical properties and ways of their usage on the structures are presented.

The goal of the paper is an analysis of development of use of these products which will certainly remain in use for many years to come.

Key words: *ceramic materials, adobe, fired bricks, historical development.*

1. INTRODUCTION

The ceramics in a broader sense comprises the products created by firing clay which is previously treated in a specific way. The ceramic materials industry includes creation of a variety of products which can have different applications in everyday life. From clay and similar raw materials, an entire range of products is obtained depending on the processing method, raw material composition, temperature and number of firing cycles; the obtained products range from the coarsest pieces, such as bricks used in civil engineering, over the pottery which surrounds us in our lives to the finest porcelain.

Clay in its natural conditions, with water added, becomes soft and workable. There are several types of clay, which are mutually different depending on the share of kaolin in the sample, and on other ingredients. Porcelain clay, pottery clay, argil, loam, clay soil, marly clay, as well as brick clay are only some of the varieties. Firing of clay makes the obtained product strong and durable.

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According to their appearance and purpose, ceramic products can be classified as:

- coarse ceramics (intended for industrial usage in construction engineering – roof tiles, masonry blocks, covering panels, floor panels, insulating layers...). Industry of ceramic materials comprises production of most diverse products with a broad spectrum of possible applications in civil engineering;
- fine ceramics (pottery, decorations, object for everyday use, for electric material, for health care use, etc.).

According to a technological production procedure and processing technique, the ceramic products can be classified as: terracotta, majolica, faience, porcelain...

In this part of the paper is presented the historical development of the so called coarse ceramics, i.e. of the ceramic materials used in civil engineering. The paper discusses emergence and historical development of the production technology using adobe, as a precursor to the fired brick, and then fired bricks as one of the most widely used construction materials.

2. BACKGROUND OF THE CERAMIC PRODUCTS USE

History of production and usage of ceramic products goes back to a long time ago, to the paleolith [1]. Making and production of ceramics can be considered one of the oldest industries in the world. When people discovered that clay mixed with water can be easily shaped into a desired form, and that the clay objects become tough after firing, this “industry” was born. It is stands to reason to assume that it was a serendipitous discovery that earth changes after firing. In order to prevent grains from falling out of wicker baskets, people plastered them in mud. When left close to a fire, the clay hardened and turned into a “petrified” mass [2]. This pottery craft was improved in time. Not all societies developed this useful artisanal ceramics. The tribes which had a nomadic way of life did not engage in production of pottery. Life on the move could not satisfy the technical requirements for production of ceramics, and vice-versa, fragile ceramics was not suitable for the nomadic way of life. Most communities in which pottery use was detected are related to the neolith and stationary way of life. Of course, there are exceptions. As early as in the period around 24000 BC were made and then fired first human and animal figurines [3]. For example, on the site of Dolni Vestonice (Czechia) the animal and Venus figurines were dated of having been made in 25000 BC. About ten thousand years later, when the first communities were founded, the first ceramic tiles were created in India and Mesopotamia [3]. It is considered that the pottery products were for the first time functionally used for keeping food and drinks around 10000 – 9000 BC. Agriculture was first developed in the region of Near East. On the Catal Huyuk site in Turkey were found pottery fragments dated back to 6500 BC [4]. Except for the objects for everyday use, fired earth was used as a building material on a massive scale since the ancient times. Earth as a building material is used in several different building techniques, in several kinds of building semi-products and products. The simplest form of earth usage comprises using rammed earth, or grass turfs [5]. It is then followed with adobe and fired brick.

Ceramic products were from the ancient times used as a building material. Usage of these materials for construction purposes is related to the very distant past. They were used all around the globe. A large number of magnificent structures from the ancient past

which are preserved even today prove that the ceramics is a tough, durable and gladly used material. Their production was historically improved with the technological advancement. A large number of significant buildings are even nowadays built of ceramic materials, primarily of bricks. The reason for this is in its numerous positive physico-mechanical properties, simple way of production, low cost.

3. ADOBE

Regarding that in the concept of ceramics are comprised clay product which are fired, i.e. after forming exposed to high temperatures, one of the first building materials, adobe, could not be completely classified within this group of materials. Adobe comprises a formed and dried, but unfired brick. The clay mixture, as a form of micro-reinforcement, was added straw, animal hair or some other available material in order to prevent onset of cracks during drying.

In the history of architecture it became famous very early. Adobe survived in Jericho, in the territory of present day Israel, and it is dated in the 9th millennium BC. It was shaped as a loaf of bread, because it was made without moulds, in the same way bread was kneaded [5]. In Mesopotamia, around 2800-2300 BC was used a rough form of adobe, with a flat base and a rounded top [5]. Rectangular, regularly shaped adobe appeared at a later date, because for making it, it was necessary to make moulds, which required a considerable degree of carpentry skills. The tool used for making adobe was, therefore, the mould, which represents the first technical innovation in the brick production industry.

The oldest images attesting usage of the mold in production were discovered in the tomb of Rekh mi Re in Thebes, in ancient Egypt [6]. In the mentioned picture, one can see the entire production procedure: the workers are taking the water out of the pool, mixing the water with earth and straw and then placing it in the moulds arranged on the ground. After that, a piece of wood is being used to remove excess mass from the mould, the mould is being taken out and placed on the ground so that the procedure can be repeated. In this way, it was possible for one craftsman to make several hundred regular adobe bricks. Fresh adobe bricks formed in this way were left to dry on the hot Egyptian sun. (Fig 1).

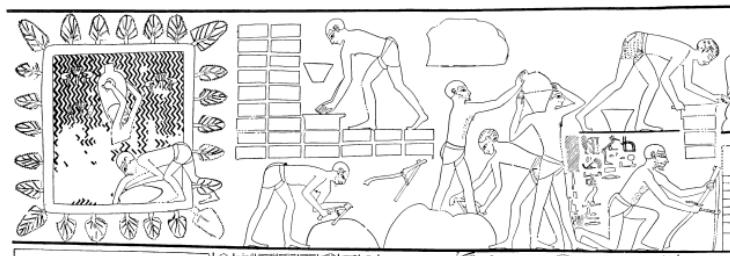


Fig. 1 Adobe mould and the picture from the tomb of Rekh mi Re in Thebes where the procedure of adobe making can be seen [7].

According to some authors, the daily norm of the workers making adobe was at first 1000 pieces, and after a period of practice, it would reach in time as much as 1800 pieces [8]. Adobe was used in Egypt for construction of housing buildings, but also for construction of religious edifices of lower importance. Mud mortar was used as binder during adobe bricklaying [9], but woven straw was installed in the walls, and it had the function of a bedding course. Adobe was used for making terraces on which buildings were built, but also the auxiliary ramps for lifting of loads to higher elevations. Different dimensions of adobe were used for various buildings in Egypt. Starting from the period of the Middle Empire, the adobe used for the temple walls had the pharaoh seals imprinted in them, which is most welcome when determining construction time of the buildings.

It is assumed that it was not the Egyptians who used these wooden moulds for adobe production, but that rather they adopted them from Mesopotamia, where they had been used as early as in the Ubaid period (5900-5300), long before people started using metal. [10]. In Catal Huyuk, in the south of Turkey earthen slabs formed using moulds and dated back to 5700 BC were found; they were so large it took two men to lift them [5].

In the area of Mesopotamia, the most frequently used building materials were adobe and fired brick of various dimensions and formats. Often used was the insufficiently dried adobe, which in the wall under the own weight compressed into a mass resembling rammed earth [11]. For that reason, the Mesopotamian building technique is based on the massive load bearing walls. As soon as around 3000 BC, quadrilateral – parallelepiped adobe made in moulds was widespread across the entire Near East. In Mesopotamia, this material was abundantly used, in almost all types of structures, starting from the plateau terraces on which buildings were erected to the fortification walls... Adobe was used for construction in Mesopotamia using mud mortar, often with courses of reed at specific intervals. The ziggurat cores were built using adobe, and the external cladding was constructed using fired bricks and bituminous binder. This method improved waterproofing of structures to a great extent.

In Persia, several types of materials were used, including adobe. Walls were constructed using adobe, and then they were clad using fired bricks, glazed bricks, stone and sometimes adorned using metal elements. Adobe was used for building structures on Crete and Mycenae, mostly for housing architecture. Even the walls of royal palaces were built of adobe, whereby for the palaces the stone in very large blocks was also used.

In construction of buildings in the ancient Greece, different kinds of material were used. Adobe was also used, in the earliest phases of development of Greek architecture, both for housing buildings and for city walls.

During other, later phases and historical epoch, in other civilizations, adobe was likewise used. Adobe was used in construction of the following large structures: Great Mosque of Djenné (Fig 2), famous building made from banco, a type of adobe, San Miguel Mission in Santa Fe, New Mexico, Poeh Museum tower, the tallest adobe structure in New Mexico, USA, Church at San Pedro de Atacama, Chile, Cliff dwellings of poured or puddled adobe (cob) at Cuarenta Casas in Mexico. The world's largest adobe structure is probably Bam citadel, or the Arg-é Bam, in Kerman Province, Iran, dating to at least 500 BC.



Fig. 2 Great Mosque of Djenné, source [12]

In the Near East countries, then Africa, the Danube river delta in Europe, even nowadays this material is often used. It is used for structures of vernacular architecture in almost all the world where clay is readily available material. Portugal, for instance, has a large number of buildings made of this material [13] [14], followed by Cyprus [15], Chile, Iran, New Mexico, Spain, France, Romania, Serbia... In Serbia, vernacular architecture structures were, until a several tens of years ago built using adobe (Fig 3). In the area of Vojvodina, the dominant type of popular houses are those made of rammed earth and adobe.

Lately, construction using ecological materials is insisted upon, so adobe is often encountered as well.



Fig. 3 Adobe on the buildings of vernacular architecture in Serbia.
Photo A. Momčilović Petronijević.

4. FIRED BRICK

The fired brick is one of the dominant construction materials. It has the same origin as adobe, it is made of the same raw material, so it appears in the same area where there adobe emerged prior to it, in the areas of Mesopotamia, Egypt [16], China... It is probable that the fired brick was created when people found out that after the fires that broke out, the buildings made of adobe became hardened, while all wooden elements were burnt. Fired bricks developed in China in the similar fashion, where it has been existing since 16th century BC.[5].

The earliest data on the fired ceramic date back to the period 7000-6000 BC. The idea that the same technique, firing, can be used for building materials was for the first time put into practice in old Mesopotamia, around 5000-4500 BC, in Madhur, for construction of drainage [10]. Yet, usage of fired bricks remained rare to around 3000 BC. Usage of adobe was simple and cheap, and no qualified labor was needed to use it. The fired brick was different. In order for the clay to obtain the proper strength, it has to be fired at the temperature of 950-1150 degrees. Lower temperature results in brittle bricks, and higher would melt the clay. It is also necessary to select the proper clay, since experimenting is expensive, regarding that the fuel – wood for brick firing is scarce. Firing made the bricks thirty times more expensive [10]. Even in the time of Babylon, when the industry of firing bricks was already well advanced, fired bricks were still two to five times more expensive than the unfired ones. Regarding the shortage of wood required for brick firing, it was used scarcely, in combination with adobe, by using the fired bricks for external or decorated surfaces and on places where loading is higher and there where damp was prone to create problems [5].

There were different forms and dimensions of the bricks. It was possible to see the bricks on the construction plans surviving on the clay tablets. From them, one can conclude that bricks played a significant role in the building engineering of the period, and it was a unit of measure in all construction works [10].

Glazed bricks constitute a major discovery in the production of fired bricks. Parts of the palace in Babylon were artistically decorated using the glazed bricks. Bricks were shaped, and as still fresh, they were dried and then baked and glazed. Small elements were used to compose large desired images, in order to avoid fracturing due to shrinkage of large parts. The dye glazing was applied on them as an emulsion prior to baking, so it became glazed after baking. Unfortunately, there are no surviving detailed data of their technology (Fig 4). The Sumerians plastered, painted their buildings and used mosaics of clay cones inserted in the wall surface to improve durability and esthetics of their buildings [17]. In the Column temple in Uruk, there surviving cones made of terra cotta mosaics, arrange across a plastered area to form a specific pattern.

Glazed bricks were used in Susa, in a similar way as in Babylon [18] (Fig 4). Here, the bricks are tapered towards their back side, so that pointing joints on the wall face would be minimized. Each brick was marked, showing its position in the wall. The brick was laid prior to baking for trial, and in the kilns were produced the elements of a giant puzzle which had to be laid in a certain order [10].

On Crete, there is evidence about using the fired bricks for construction, while it was almost not used at all in Mycenae. In almost all ancient civilizations, fired brick became a very important building material. Yet, the greatest leap in producing and using fired

bricks occurred in the period of the Roman Empire. Roman legions took the brick firing technique into all corners of the empire.



Fig. 4 Glazed bricks on the Ishtar Gate, Babylon.

Source [19], photo by Jan van der Crabben

The fired brick was profusely used in Rome, and until 2nd century AD, it became sophisticated and industrial. Digging up clay, its processing and placing in moulds was performed by slaves in the Roman empire. In the surrounding areas, it was the Roman military that was charged for the production of fired bricks. The earliest fired bricks made in Rome were of poor quality. Only later, in order to avoid the negative effects of clay shrinking during drying and baking, sand was added to mitigate this problem. Fired brick became the most used building material in 3rd and 4th centuries AD.

In Rome, the dimensions of bricks were standardized, but rarely uniform. Bricks were modeled by inserting the prepared mixture of clay into the open moulds. Usually, the roman brick had a square form, even though there could be other shapes (rectangular, triangular if needed, or any other shape for special purposes). Vitruvius [20] tells about three types of adobe, „Lydian“, *pentadoron* and *tetradoron*. The latter two types of brick have Greek origins. The standard Roman brick has a side of one foot¹, and thickness of around 4,5 centimeters. There were bricks of larger dimensions, square, having sides of 1,5 foot and larger having 2 feet which were rarely used. Rectangular bricks were rare. During production, some bricks had a seal imprinted on the top sides. In the earlier period, the seal was simple, and had nothing but the initials. Later, the data in the seal were extended, including the name of the land owner, manager of the brick baking facility, datum. These data are contained within circular or rectangular frames.

Bricks were used for bricklaying of walls, for lining of walls, for construction of arches and vaults, for floor tiling (Fig 5).

Walls could be constructed of brick only, which was a rare case, or they were concrete, with a cast core, lined with bricks, as a more common variant. The thickness of the joints could be different, and varied from only 0,5 millimeters, up to several centimeters, when it suited the thickness of the brick. There are multiple versions of bonds, depending on the way the brickwork was laid. The Romans called the building techniques – the *opus*. This term survived to this day, and refers to the construction method in the ancient Rome, regarding

¹ The Roman foot is long 29,57 cm

building walls, floors or other types of building works [21]. Wall lining with bricks was elevated to a higher level, with formation of different ornamental styles. Therefore, bricklaying styles featured *Opus latericium*, *Opus testaceum* or *opus doliare*, *Opus spicatum*, *Opus mixtum*...



Fig. 5 Usage of bricks for floor tiles and wall construction at an early Byzantine site, Iustiniana Prima (6th century) in Serbia.
Photo A.Momčilović Petronijević and Ć. Vasić

Bricks were used for bedding courses of the cast walls. Bricks were used for construction of arches [22]. In addition to the arches, vaults were massively built, used for spanning large areas, as well as domes.

Lining of internal walls of *thermae* was performed using special elements made of fired clay, a kind of tiles with flanges, which were pressed into the wall in a way that there is a spacing between the wall surface and the tile, where hot air would flow. Also, for this purpose were used hollow rectangular cross-section bricks. Bricks were used for construction of aqueducts, and fired clay was used for water distribution pipes, water cisterns... the waste water drainage system was once built from bricks, as well as hypocausts... glazed bricks were used in the eastern parts of Empire.

The best example for brick usage can be seen in the remains of the Trajan's market (Fig 6), and in Ostia, where almost every structure was built of brick.



Fig. 6 Remains of Trajan's market, Rome.
Source A. Momčilović-Petronijević

The Romans spread the technology of production and bricklaying across entire empire. Thus usage of bricks took root in almost all parts of Europe. After the decline of the Roman Empire, bricks lose some of their popularity, but come back into mass usage during the medieval period. During 12th century, the production technique of fired bricks was transferred from the north of Italy into the north of Germany, where a particular gothic style was established, based on bricklaying construction, the Backstein gothic. Gothic buildings of this kind are found in the area of Denmark, Germany, Poland... [1] In England in the first half of the 16th century, the brick baking is at its heyday during the reign of Henry VIII. Large parts of his Hampton court (near London, 1520.god) were built from fired bricks [5].

In the period of Renaissance and Baroque, fired bricks could be rarely seen on the facades, it was most often covered with plaster. In 18th century bricks continued to be rarely used on the facades in northern Europe. At the beginning of 19th century, some Georgian architects used bricks for construction of family houses. The brick is back in style by the mid 19th century during the Neogothic period. In the long history of its existence, bricks alternately came in and out of architectonic style.

In the 19th century, with industrial revolution, bricks became more available and its transport cheaper. The form and quality of new, machine produced bricks became more regular, and its usage more cost effective. In 19th century, the fired brick was especially extensively used in England, but also in its colonies in South Africa, Australia, New Zealand... [5]

With the increase of labor cost, in 20th century, more and more only the wall faces were clad in bricks, to reduce the cost, without losing the esthetics of these buildings. Bricks proved to be not the right choice of materials, concerning construction of multi-storey buildings which saw expansion by the end of 19th century in the USA, because of the considerable thickness of the walls necessary for resisting the loads of the upper floors. Apart from the technical problems, it was the emergence of modernism by the turn of the 20th century which gradually reduced usage of bricks in construction, basing it on concrete, steel, glass... Yet, some of the architect of early 20th century did not completely abandon bricks: Walter Gropius, Adolf Mayer, Mies van der Rohe, Le Corbusier have in their creative opus some structures made of brick. Brick was often used by Frank Lloyd Wright, who used it on almost every building he designed. The Finnish architect Alvar Aalto played an important role in reintroduction of brick into contemporary architectonic buildings. The Aalto's modernism with regional characteristics inspired by the tradition of the brick architecture of northern Europe is what makes this architect stand apart from the international style (Fig 7). Willem Dudok is a Dutch architect who also very readily employed bricks in his designs.

In the period after the WW2, many great names at the architectonic stage recurrently used bricks – Philip Johnson, Robert Venturi, Aldo Rossi, Mario Botta...

In addition to Europe and America, which were mentioned, the brick is considerably used in the Islamic world, Sin which on the occasion of construction of building it is combined with glazed tiles, producing impressive results [23]. The Near East Architecture reached may its highest level in the Iranian city of Isfahan in which almost all buildings are made of the brick. Two large mosques, Royal or Imam's or somewhat smaller sheik Lotfollah's mosque are true pearls of Islamic sacral architecture. It is assumed that in the Royal mosque, more than 18.000.000 bricks were installed; the height of the portals

supporting the minarets is 48m, and the height of the central cupola is 52m [5]. This mosque represents a very important creation made of bricks, built in 17th century. Yet, the visual effect was not achieved with bricks but with glazed tiles, covering the mosque both on the outside and on the inside.

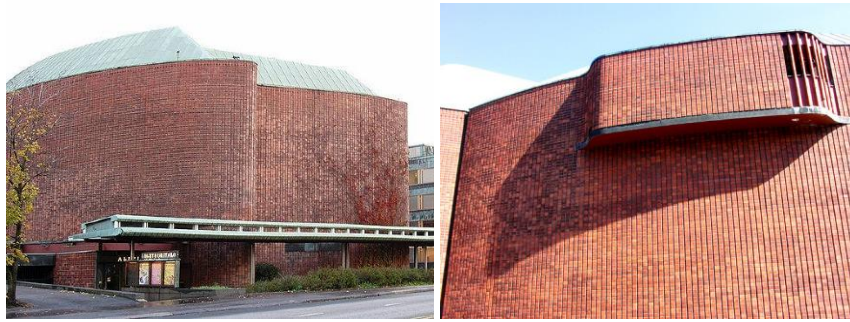


Fig. 7 Alvar Aalto. House of Culture.

Source [24]

4.1. Production of bricks

Prior to 19th century, bricks were made manually, by compacting the clay first in wooden and later in metal moulds, after which it was baked.

The brick firing procedure can vary, and it evolved in time. The simplest way of baking is the following: raw bricks are stacked, with the fire burning in the middle. There are kilns with two chambers, where the firing chamber is in the bottom part, while the bricks are on the top. The deficiency of these kilns is that those bricks which are in the lower rows, closer to the fire chamber, are exposed to higher temperatures and get over-baked, and clinker bricks are produced, while those bricks further away from the fire remain under-baked and brittle [5].

The Roman kilns could have been different in form, but they all worked using the same principle. The lower level accommodated the fire chamber where fire was fed through the side opening (Fig 8). The most common fuel was wood, while there are examples that the baking temperature was achieved using coal. Above the fire chamber was a perforated ceiling, which was the floor of an upper level, on which bricks and roof tiles were stacked. Hot air reached the upper level through perforations, and in this way fired the stuff. The walls around this space were thick, to prevent cooling. The layouts of these kilns were rectangular or circular [10]. The making and baking technique of firing bricks was so perfected, that it could not be surpassed in quality even by the makers of many later epochs.

The other type of dual chamber kilns, which emerged later comprises an elongated kiln design, so the fire burns at one end of the kiln, and chimney is on the other. In this way, the hot air does not flow directly upwards, but flows around the bricks, providing a more constant temperature and contributing to the more regular quality of bricks.

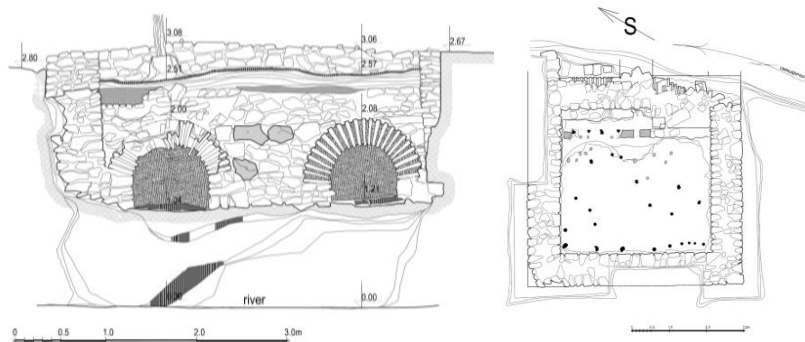


Fig. 8 Brick kiln, Caričin Grad.

Drawing A. Momčilović Petronijević according to the documents of the Institute for protection of cultural monuments of Niš [25]

A traditional kilns type are so-called Scove kilns. Those are temporary structures. Scove kiln is a kiln in which green bricks are stacked, enclosed with burned bricks that are then daubed with clay to reduce the loss of heat, and burned. A brick clamp is a traditional method of baking bricks, done by stacking the unbaked bricks with fuel under or among them and then setting the fuel on fire. The clamp is considered a type of kiln. If the clamp is insulated by packing earth or mud around it, it becomes a scove kiln. [26]

The permanent kilns are called continuous permanent kilns. The bricks from these kilns are of good quality, but the initial investment is slightly higher. The Hoffmann kiln and the bulls trench belong to this group of kilns.

In 1857 an Austrian inventor, F.E. Hoffmann invented a brick kiln for continuous baking consisting of an arched tunnel around a central chimney, so that the heat passes by the chambers filled with bricks, by heating up the chambers, one by one, so that the fire never needs to be extinguished [5] [27] (Fig 9)

Bull's Trench is the brick firing kiln conceived in England in 1876. The fire burns in a trench dug in the ground, which takes considerably less investment for kiln construction, while the number of produced bricks is large. It has usually a rectangular, circular or elongated layout. Such kiln type is used nowadays in India, Pakistan, Bangladesh... [5] In 1927 was designed (by a German, Habla) a highly automatized tunnel brick kiln. It facilitated serious savings of human labor, and it was very popular in Germany, England and USA before WW2. Simultaneously with the industrial production of bricks, it was still made manually, particularly those bricks of specific format and shape, and decorations of fired clay – terra cotta which were used for the facades of buildings in 19th century in addition to various brickwork bond combinations. [5].

Production of hollow bricks began in France, in 1843, and the following year, 1844 in England, too [5]. This was an important milestone in its construction. A lighter bricks were made, for whose production was used less material, and which has better thermal characteristics. It could also have various forms, from parallelepiped, to square, cylindrical, hexagonal, triangular and other specific forms.



Fig. 9. Hoffmann ring oven in Mildenberg museum.
Source [28]

Nowadays, the brick production process is advanced, and it mostly consists of the following phases: the initial step in production of the brick is crushing and grinding of raw material in a separator and a jaw crusher. Next, the blend of ingredients desired for each particular batch is selected and filtered before being sent on to one of three brick shaping processes - extrusion, molding, or pressing, the first of which is the most adaptable and thus the most common. Once the bricks are formed and any subsequent procedures performed, they are dried to remove excess moisture that might otherwise cause cracking during the ensuing firing process. Next, they are fired in ovens and then cooled. (Fig 10) Finally, they are destacked - automatically stacked, wrapped with steel bands, and padded with plastic corner protectors [29].



Fig. 10 Bricks production – some phases.
Source [30].

5. CONCLUSION

Adobe at first, and then the brick was used for construction of a large number of most diverse types of buildings. Be it housing architecture, fortification system architecture or magnificent sacred structures, the brick was very often and readily used in almost all historical epochs. In some epochs, it was more popular, in some less, but it was never abandoned. It was used as a building material, as a cladding or in combination with other materials. Most different types of bricks in terms of forms, physical and mechanical characteristics... A number of good characteristics as a building material made the brick

and its varieties almost omnipresent in all types of buildings since the beginning of architectonic creation until today.

The brick as a building material is very durable. It has a number of good characteristics it is very user and maintenance friendly, creating energy efficient buildings, but also performing various functions [31]. The brick advantages are numerous – it has high strength to compression, frost, it is not flammable, it can be reused and recycled, it is available in many shapes, colors and textures...

Some other reasons for using readily the brick are as follows: for its making is used raw material, the production processes are environmentally acceptable, life cycle of structures are long, without intensive maintenance, durability, recyclability and esthetics [31], cost [32]....

The brick and brick products will undoubtedly, for a long time be an integral part of the architectonic trade.

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ARHITEKTURA I KERAMIČKI MATERIJALI, RAZVOJ KROZ VREME: ĆERPIČ I OPEKA

Proizvodi od pečene zemlje se od najdavnijih vremena veoma rado koriste kao građevinski materijal u arhitekturi. Bez obzira na geografski prostor, ili epohu, ćerpič i opeka, su jako često u upotrebi zbog pogodnog načina proizvodnje i pristupačne cene.

U radu je dat pregled upotrebe ćerpiča i opeke, počev od najdavnijih vremena pa do danas. Prikazana je evolucija njihove proizvodnje, oblika, fizičkih osobina i načina primene na objektima.

Cilj rada je sagledavanje razvoja upotrebe ovih proizvoda, koji će zasigurno još dugi niz godina biti u primeni.

Ključne reči: keramički materijali, ćerpič, opeka, istorijski razvoj