

## **ARCHITECTURE AND CERAMIC MATERIALS, DEVELOPMENT THROUGH TIME: CERAMIC TILES AND CERAMIC ROOF TILES**

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**Abstract.** *Ceramic tiles and roof covers have been used in construction of architectonic structures from the earliest times. Their relatively simple production, as well as acceptable cost, contributed to the mass usage of these products. The paper presents a review of ceramic tiles and roof tiles, by laying out their development, shapes, physical properties and usage through history in various climates and time periods. The aim of the paper is understanding the importance of use and development of these products in architecture.*

**Key words:** *ceramic materials, ceramic tiles, ceramic roof tiles, ceramo-plastics.*

### 1. INTRODUCTION

Ceramic products appeared very early in the area of civil engineering and architecture. Prior to gaining knowledge about how high temperatures modified clay characteristics, and prior to the beginning of mass usage of fired production in architecture, it was in its unfired form used in civil engineering as adobe. Usage of clay products is almost as old as architecture.

Products obtained by shaping and baking of various types of clay – ceramic products, according to their appearance and purpose, can be classified as coarse and fine ceramics. The coarse ceramics are those intended for industrial use and use in civil engineering. In the first part of the paper, dealing with the development and historical background of usage of ceramic materials in architecture are presented adobe and bricks, as very common building materials in almost all epochs. This part provides a review of the development of tiles some architectonic decorative ceramic elements and of ceramic roof cover.

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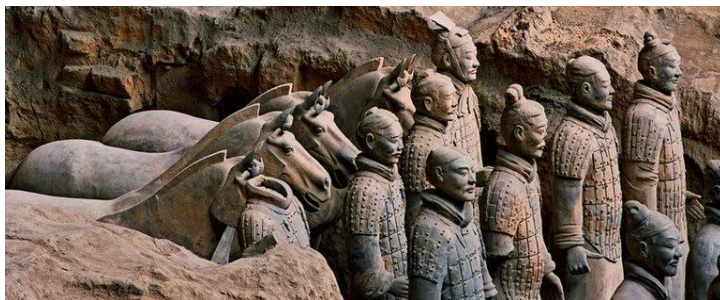
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## 2. TYPES OF CERAMIC PRODUCTS

According to the technological procedure of production and processing techniques, as mentioned in the first part of the paper, ceramic products can be divided into: terra cotta, majolica, faience, porcelain ...

**Terra cotta** (terra-cotta – baked earth) is a sort of unglazed ceramics. It is yellow, orange or dark red in color. Terra cotta is both the name for utensils created in this way and for decorative objects in architectonic formation, which were obtained in this way (ornaments, profiles etc.). Terra cotta was used as early as by the ancient Assyrians. It was used for making sculptures, elements of roof cover... The oldest sculptures were dried in the sun and later fire on an open hearth [1]. In the Etruscans, it occupied an important place in their art. Particularly well known are the Etruscan terra cotta sarcophagi, as well as their sculptural treatment of the exterior and interior of their temples using this material. Even though it was primarily known by its porcelain, China can also boast with its usage of terra cotta. The soldiers and horses of terra cotta, around 8000 of them in full scale, placed inside the royal tomb around 210 BC are widely known, (Fig 1).



**Fig. 1** Soldiers and horses made of terra cotta in full scale – China, source [2]

**Majolica** is a type of ceramics, semi-porcelain made of fine clay. It got its name from the city of Majorca on Balearic islands, where production of Moorish-Spanish glazed ceramics flourished since 9<sup>th</sup> century [1].

In 15<sup>th</sup> century, this type of ceramic products reached Italy, and its use expands to France, Switzerland, Holland and Germany. Majolica is a ceramic product which is glazed. Clay with a lot of limestone is used for it, because of which the end product is very porous. The shaped object is first fired to obtain toughness, and then immersed in viscous mass creating a glossy glaze of metal oxides (for instance tin white glaze – tin oxide). Majolica is a transition from the simple products made of terra cotta, to faience, and element of artisanal art. This is the method for obtaining tiles, but also vases, cookware and other utensils and decorative objects.

**Faience** is semi-porcelain made of fine clay baked at lower temperatures, which has an opaque with glaze suitable for painting on it [1]. The faience technique has a Moorish-Spanish origin, even though this production technique was somewhat known as early as in the times of ancient Egypt, Babylon and Assyria [1]. It was taken to Europe from Arabia in 14<sup>th</sup> century. It was named after the city in Italy, Faenza, near bologna which became famous for the ceramic products in 18<sup>th</sup> century. Under the term of faience is nowadays considered the white color pottery which was later painted (Fig 2). Decorative, hand painted ceramic tiles are widely used.



**Fig. 2** Palazzi di Firenze Faience Cupola source [3]

**Porcelain** is the white semi-transparent ceramics made of fine kaolin clay baked at temperature ranging from 1200 to 1400°C [1]. It is mostly painted. It is used for production of various decorative objects and cookware. Probably the most famous porcelain is the Chinese one.

The ceramics can be decorated in several ways. One of them is **carving or imprinting of decorations** (carving, impression of seals and marks...). By using the **engobe application** technique a layer of white or colored clay mixture is applied as a base layer for painting or carving of images. Engobe application is the process in which, by mixing the solution of clay and melt-resistant oxides, are obtained colored coatings on ceramic materials. Engobe covered surfaces have no gloss. Decoration is performed using also relief, glazing and in the recent period, numerous other mechanical procedures. **Glazing** is the glassy layer which prevents absorption of liquids and serves as a decoration. Glazing is made from the quartz sand and easily meltable materials – lead, tin, potassium, borax etc. [1]. Glazing can be transparent or opaque (white or painted, made of tin). Painting of glazing are almost performed using metal oxides resistant to high temperatures. According to the method and temperature of firing, the oxides change the quality and shade of colors. The most durable ceramic paints, which can endure firing at high temperatures beneath the glazing are cobalt paints (various shades of blue), manganese (brown to violet), ferric (red to brown and yellow), copper (red to green and turquoise), antimony (yellow), chrome (grey-green and yellow-green), tin (white) [1]. For the painting are also used gold, silver, iridium and titanium (gray and black). Such paints are applied on the baked glazing and fired for the third time, at lower temperatures in special ovens.

### 3. CERAMIC TILES

Ceramic tiles include tiles of various dimensions, made of fired clay, with a finish layer which can be treated in various ways. They are mostly quadrilateral, but they can be found in other forms as well. They can be glazed, non-glazed, white or colored, with various patterns and motifs. In civil engineering, both in the past and nowadays, their main function is covering of floor or wall surfaces.

Regarding the vast range of colors which can be used to paint them, glazed, and then to be laid in most different forms and patterns, they were readily used in architecture of both housing and monumental buildings. Tiles can be arranged in an infinite number of patterns and motifs. They can be used for tiling entire walls but also for border trimming, for friezes, murals, floor and wall mosaics...

They can have different forms. The quadrilateral, trilateral and hexalateral tiles were most frequently used for architectonic structures. By combining all the forms at the same time, it is possible to create several different patterns. It is a so called Archimedean technique, semi-regular arranging of tiles used in Islamic architecture, Italian medieval architecture, and on contemporary structures [4].

The emerge very early, in history. There are remains of this ceramic product found in the period 4000 years ago, in the dynastic period of ancient Egypt [5]. Also, in Mesopotamia, in addition to the brick production, a sophisticated technique of painted decorative ceramics was also developed. There are remains in the ancient Babylon [6]. In Persia, they reach a considerable degree of decorative treatment, and along with glazed bricks they were extensively used for covering and decorating of wall surfaces... The Etruscans used them in a somewhat unusual way. Due to the shortage of stone, they clad wooden pillars and beams in ceramic tiles, to imitate the Greek Doric style [7].

In Rome was used the opus Alexindrinum, a technique in which small regular tiles in combination with the pieces of marble stone and glass are arranged around large marble circles [4]. This technique was revived later, in 12<sup>th</sup> century, owing to the Cosmati family, after whom it was then named.

Ceramic tiles were changing through epochs, from lavish facades and interior decorations of Spain [8] and Portugal, through the ceramics of renaissance Italy to the blue drawings on white tiles in England and Holland [1].

In the western countries, since 12<sup>th</sup> century, ceramic tiles have been used as floor covers in churches. At first, for these covers were used non-glazed tiles, red, brown and yellowish color with imprinted or engraved ornaments.

Encaustic tiles are tiles made of clays of various colors, which are used to achieve a certain pattern, just as with the glazed ones. They are made by compacting the clay in profiled moulds, so as to obtain depressions which will later be inlaid with a different type of clay which creates a pattern on the tile which is baked afterwards (Fig 3). This technique was observed on the structures from 13<sup>th</sup> century [4]. They were later used in the Victorian age [9].



**Fig. 3** Encaustic tiles, source [10]

Glazed and faience tiles are also used. In the renaissance age, the floors in French courts were covered with faience tiles of bright colors [11]. The painted tiles produced in Europe left the mark on production of tiles in the entire world. The produced tiles in the medieval times often had religious motifs of extreme complexity painted on them.

The tiles with the motifs from the Old Testament, scenes from the life of Jesus Christ and other biblical scenes are not rare during the medieval times. The Chertsey type of tiles from the 13<sup>th</sup> century, which are laid in one monastery, display Richard the Lion heart fighting Saladin, (Fig 4) [12].



**Fig. 4** Richard the Lion heart fighting Saladin, display on ceramic tiles [12]

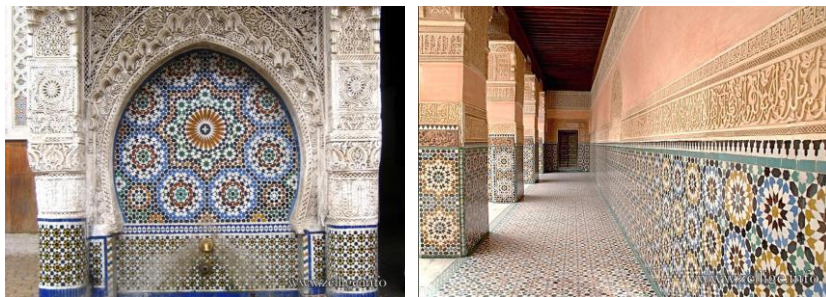
In 13<sup>th</sup> century are used ceramic tiles with a pressed relief and colored arabesques. With the emergence of faience in Italy in 15<sup>th</sup> century, the ceramic tile glazing technique was improved. This technique was taken over to the countries of northern Europe, and in 17<sup>th</sup> and 18<sup>th</sup> century it reaches a high level of perfection in the Dutch city of Delft, where a special type of glazed ceramics was developed [1]. This type of tiles was named “Delftware”). The base color of the tile was white, and on it was drawn a drawing mostly in various shades of blue, but also of other colors. The colors cover only a small surface of the tiles. Delftware type of tiles was extremely popular in Holland, and these tiles were exported through northern tip Europe, starting from 16<sup>th</sup> century onwards.

The royal courts in that period could have the so called porcelain rooms which were almost completely covered in such tiles.

There are several types of traditional tiles which have been produced in Morocco even nowadays. This type of tiles has small mosaics and brightly colored “Zellige” tiles.

Zellige is mosaic tilework made from individually chiseled geometric tiles set into a plaster base. This form of Islamic art is one of the main characteristics of Moroccan architecture. It consists of geometrically patterned mosaics, used to ornament walls, ceilings, fountains, floors, pools and tables (Fig 5).





**Fig. 5** Zellige Morocco [13]

In Europe, there was tradition to set the tiles of terra cotta on the walls of post-and-pan structures, so as to form a certain pattern by their combination and overlapping. In England was developed the so called “mathematical tile” for cladding walls, so that from the outside it would appear they were made of bricks [4].

With the advancement in the production of tiles during XIX century, a breakthrough was made in the domain of production of terracotta for cladding of walls. Arts and crafts (the full name is the Arts and Crafts Exhibitions Society) is a style which developed in the years between 1880 and 1900. This movement was affected by the development of artisanal crafts in Europe, and it became one of precursors to Secession and Bauhaus. The trail to a new art was blazed by England, where the society of Arts and crafts was founded under the leadership of William Morris and John Ruskin who tried to revive crafts and arts. The motifs on the tiles designed by Morris were sailboats, birds, fish, plants.... The production of designed tiles saw its revival and popularity in the Victorian times. Arts and crafts encouraged the manual production of terra cotta tiles. A good example of usage of these tiles is the Natural history museum in London (1880). In the USA, the tiles made of terra cotta were intensively used, mostly the glazed ones. Louis Sullivan clad all full elements on his buildings with modular tiles, using his original system of ornamenting [4] (Fig 6). It is interesting that the tiles from the Victorian times became the standard for arrangement of kitchens, bathrooms and public spaces in the modern age.



**Fig. 6** a) Guaranty Building, Buffalo, N.Y., Dankmar Adler and Louis Sullivan, 1894–95;  
b) National Farmers' Bank, designed by Louis Sullivan, 1908, Owatonna, Minn,  
source [14]

At the turn of 20<sup>th</sup> century, Antoni Gaudi (1852-1926) to a great extent used the ceramic tiles on the facades of his buildings [15]. Yet, Gaudi most often used a kind of mosaic from the shards of ceramic tiles, as a sort of an art form, for which he remained remembered. Such details feature on the Guell pavilion (the riding hall), chimneys and vent ducts of the Guell Palace, as well as interiors of almost all his designs. Certainly the most impressive mosaic made of ceramic shards is in the Park Guell, with famous curvy benches (Fig 7) and the dragon – guardian of the park done in the same technique [15].



**Fig. 7** Usage of the ceramic shards, The Park Guell Barcelona, photo A.M.Petronijević

Azulejo are faience, multicolor-painted (most often blue, green and yellow) glazed tiles for cladding of walls and floors. The art of making of these tiles was brought to Spain by the Moors in 13<sup>th</sup> century, and the main center of production was Seville. The Azulejo were often used in the baroque interiors of Spain and Holland [9]. In Portugal, the tradition of Azulejo tiles was continued, and they are used even nowadays to decorate buildings, ships and even stones and rock used for interior arrangement. Tiles with various motifs are nowadays mass produced in factories, meaning that their cost is lower than before.

Oskar Niemeyer is one of the architects who used the ceramic tiles successfully on the facades of some of his buildings (St. Francis Church in Belo Horizonte). Eduardo Nery also readily used ceramic material and its shards in his designs. He used these irregular ceramic shards when designing the mosaics on the Municipia Square in Lisbon, and on the retaining wall in the Infante Santo Avenue (Avenida Infante Santo) in Lisbon [16] (Fig 8).

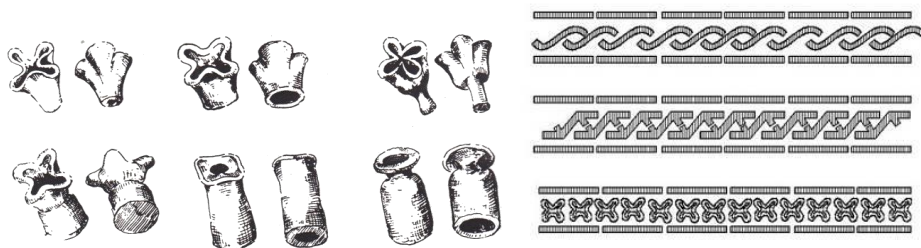


**Fig. 8** Eduardo Nery: a) Town Hall Square Lisbon Portugal [17]; b) The Avenida Infanta Santoin Lisbon [18]; c) Underpass system [18]

Islamic architecture, especially the sacral one abounds in usage of ceramic glazed tiles. These structures are unmatched in terms of decoration level regarding the use of ceramics. In Persia, in 9<sup>th</sup> century, the old tradition of production of glazed tiles was revived. The previously mentioned Imam's mosque in Isfahan, built in 17<sup>th</sup> century was clad with 472000 of glazed tiles of vibrant colors. The sheik Lotfollah's mosque situated on the same square attracts attention by the exterior cladding of the cupola made of glazed tiles in various colors, with floral motifs, while the interior enthalls with the prevalent blue color of the glazed tiles. The cupola is on the outside clad with copper glazed tiles in combination with blue patterns, while the dominant color on the wall under it is blue. The segments painted in various coloration ranges and proportions of floral motifs on the separate architectonic elements – cupola, arches differ from one another [4], [19].

#### 4. CERAMO-PLASTICS

The ceramic elements of specific forms which are used as decorations on the facades can be classified in the special group of these products. In the group of Serbian medieval monuments build in Byzantine style, the ceramo-plastic elements are used as decorative elements. These decorative elements are classified in two groups: cups and tiles. Both types are inlaid in mortar in a wall recess between two courses of bricks, so their front surface remains visible in the facade [20] [21]. The mostly have a quatrefoil or circular form on the front side. Neither the cups nor decorative tiles are glazed (Fig 9).



**Fig. 9** a) Fired earth decorations on the church facades [20]; b) usage of bricks in decorative purposes [21]

Regarding that during religious service churches were a place of chanting, the acoustics of the churches was improved by the usage of earthen pots which were built in the walls at specific points, and worked as resonators. These ceramic pots have various forms and can have various sizes. There are pots which are medieval beakers, adapted to serve as resonating boxes, by having their handles and bottoms removed. There are pots which were made with a purpose to be used as resonators. [21]

Ceramic elements of most various forms are even today readily used on the building facades (Fig 10).





**Fig. 10** Usage of ceramic elements in façade decoration, Subotica, foto A.M.Petronijević

## 5. ROOF COVERING

Roof covering made of fired earth probably goes as far back as the fired brick. The old method of making of the first elements for covering made of clay is similar to making fired bricks. A wood mould is laid on a flat surface and filled with clay mixture. The upper surface of the mould is leveled and the mould is removed. After a period of drying the roof tiles are fired. Curved roof tiles after being removed from the mould are placed on the new mould of a desired profile, and then fired.

Terra cotta was in ancient Greece used for decorations, and it was also used as a roof cover. In Lerna, nearby Argos on Peloponnesus were found roof tiles made of terra cotta dated back to the period of 2600-2000 BC. The Greeks used three types of cover tiles, called the Laconian, Sicilian and Corinthian [22]. The terra cotta roof tiles were considerably more expensive than straw as a roof cover, but they were readily used because of their considerably higher resistance to fire.

The ancient Greek cover tiles – *tegulae*, are laid one next to another, with the upper rows overlapping the lower rows of tiles, which had raised lateral borders edges. The joints between the tiles were covered with narrow elements called – *imbrices*. The ends of tegulae obtained decorations – acroteria [7]. Acroteria decorations can be observed on the roof ridge, as well (Fig 11).

The Etruscans used the high quality clay both for adobe and for fired ceramic products. In this way large ceramic tiles for closing of tombs were made, then roof covering tiles, decorative elements for decorations of temple cornices... The Etruscan roof covering was tile, like imbrex and tegula in Greece, with special elements covering their joints. In Rome as well, the roof covering was mostly made of ceramic products. The fired clay covering is like imbrex and tegula in Greek architecture.

There are various specific types of tiles with specially shaped profiles, for ventilation, corners, ridges... The rounded tiles have a mildly conical shape and they are placed in



**Fig. 11** Imbrex and tegula, source [23]

two rows like the S-tiles. The curved tile which was used in Holland known as the Flemish tile has a cross-section of an asymmetrical letter S. [4]

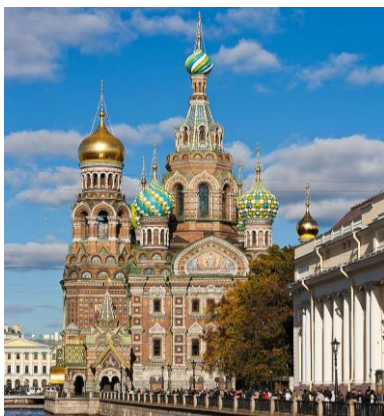
After the emergence of the press of tile production, the potential for production of the tiles of most varied forms and dimensions was created. The machine-produced extruded tile with a single groove was invented by the brothers Joseph and Xavier Gilardoni of Alsace in the 40's of the 19<sup>th</sup> century. This tile was patented in Great Britain in 1855 after which several variants were developed in France after that. [4]. Sometimes this tile was placed on a rectangular grid on the roof, and sometimes it was laid in staggered rows. Often these tiles were called the "French tiles", the Marseille tiles being exported all around the globe. The tile was connected to the roof structures with wires passed through the hole in the lower side of tiles

The Marseille tile is a French roof covering which belongs to the broader category of Gilardoni tiles which the Gilardoni brothers started to produce in 19<sup>th</sup> century, using a new press for tile production. Those are rectangular tiles with a central web as a reinforcement, and with a groove on the lateral longer side so that it would be more resistant to weather conditions, and with a rounded shorter side which is in contact with the face of the next tile. This tile was one of the top export articles of France in this period. (Fig 12). [4].



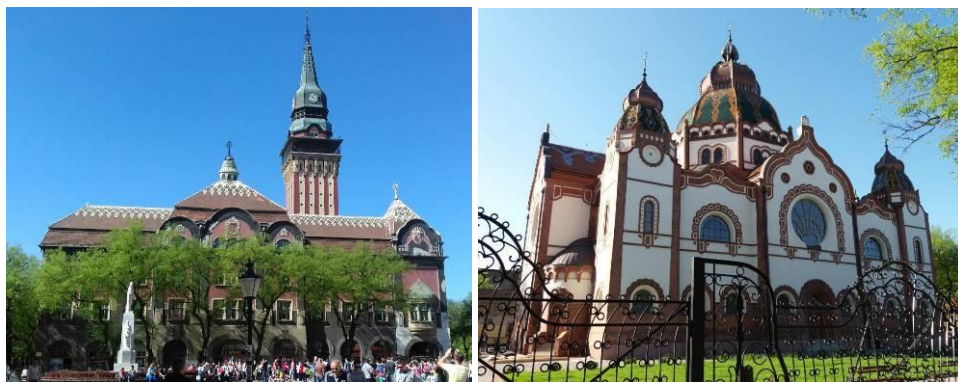
**Fig. 12** "French tile or Marseille tile" by the French Gilardoni Brothers in 1850. Source [24]

Nowadays a wide range of tiles of most varied shapes, dimensions and colors are available. Often used are polychromic tiles, which perhaps are most characteristic of roofs in Russia.



**Fig. 13** The Church of the Resurrection of Christ in St. Petersburg, Russia [25]

The Church of the Resurrection of Christ is an example of colorful clay tiles used to make roof mosaics (Fig. 13). As well as a number of other countries, Czechia also has roofs constructed in multiple colors. The use of variously-colored tiles in Serbia, on buildings in Subotica, is shown in figure 14.



**Fig. 14** Usage of tiles of various colors, Subotica, photo A.M.Petronijević

## 6. CONCLUSION

The beginnings of ceramic products go back to distant past. The peoples of Mesopotamia, as a cradle of civilization, of the Near East, and of ancient Egypt used the ceramic tiles since the earliest time. As early as in the age of pharaohs, around 4000 BC, in Egypt were made decorative clay tiles. We can encounter them in the architectonic edifices of Assyrians, Babylonians... Tiles were used for tiling the access to temples, palace courtyards... The later historical civilizations also produced and used the ceramic tiles: Persians, Greeks, Romans... The ceramics is in use in the countries of the Far East, India and especially China which remained remembered primarily for the use of porcelain and glazed ceramics. Throughout centuries, ceramic tiles passed through various phases, most varied motifs, treatment and laying techniques were used...

Even today the ceramic tiles occupy an important position both in the interior and the exterior. Development of the ceramic envelopes of buildings is dealt with scientist all around the world.

Remains of the earliest tiles of fired earth found on Peloponnesus, in the area of Corinth, where the tiles were produced using firing technique replaced the reed roofs. After emergence of roof tiles as a new construction product, it abruptly spread to continental Greece, to the west coast of Asia Minor, south and central Italy...

By covering buildings with roof tile, the fire resistance of buildings was increased, so roof tile, even though considerably more expensive than the reed and straw, was readily used. Mass production of roof tiles started in Holland in 14<sup>th</sup> century.

Roof tile has advantage over other types of roof coverings. With its properties: durability, shaping potential and large range of colors, it allows the architects all around the world to make their ideas come true in architectonic works of art.

It is concluded that the ceramic is one of the oldest materials in the civil engineering and architectonic construction throughout history, which occupied and still occupies a significant place as a bearing element of the structure, as a cover (roof tile), as a lining in the interior (tiles) and exterior (facades, paths, squares). By its continuous improvement of ceramic products properties, it remains competitive with other contemporary building materials.

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## **ARHITEKTURA I KERAMIČKI MATERIJALI, RAZVOJ KROZ VREME: KERAMIČKE PLOČICE I KERAMIČKI KROVNI POKRIVAČI**

*Keramičke pločice i krovni pokrivači se od davnina koriste u građenju arhitektonskih objekata. Njihova relativno jednostavna proizvodnja, kao i prihvatljiva cena koštanja doprineli su masovnoj upotrebi ovih proizvoda. U radu je dat pregled keramičkih pločica i crepova, kroz prikaz njihovog razvoja, oblika, fizičkih osobina i primene kroz istoriju u različitim podnebljima i vremenskim epohama. Cilj rada je sagledavanje značaja upotrebe i razvoja ovih proizvoda u arhitekturi.*

*Ključne reči: keramički materijali, keramičke pločice, krovni pokrivač, keramoplastika*