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Ceramics as an important element of design and architecture

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Abstract: Ceramics stands out as one of the most important materials in construction, architecture, industry, and art, and their advantages compared to stone and wood make them exceptionally valuable due to their versatile application and durability. One of the key advantages of ceramics is their resistance to moisture, chemicals, and high temperatures, where stone and wood can be susceptible to damage from moisture or decay. Ceramic materials are exceptionally easy to maintain and can be easily cleaned without the use of strong chemicals. Ceramics offer a wide range of design possibilities and various surface finishes that dictate their application in space. It is possible to create different colors, shapes, and textures, allowing adaptation to different interior and exterior styles. This aesthetic flexibility makes ceramics a popular choice for architects and designers, while stone and wood, although attractive, can be limited in their range and design possibilities. Ceramics are recyclable, and their resources are often readily available, contributing to their growing popularity in modern applications. Their adaptability and durability provide not only functionality but also an aesthetic touch to any space.

Key words: ceramics, production process, binding material, technical properties of ceramics, standards and certificates

Keramika kao bitan element dizajna i arhitekture

Sažetak: Keramika se izdvaja kao jedan od najvažnijih materijala u građevinarstvu, arhitekturi, industriji i umjetnosti, a njene prednosti u usporedbi s kamenom i drvetom čine je izuzetno vrijednom zbog raznovrsne primjene i dugotrajnosti. Jedna od ključnih prednosti keramike je njena otpornost na vlagu, kemikalije i visoke temperature, gdje kamen i drvo mogu biti podložni oštećenjima uslijed vlage ili truljenja. Keramički materijali su izuzetno laki za održavanje i mogu se jednostavno čistiti bez upotrebe jakih kemikalija. Keramika nudi širok spektar dizajnerskih mogućnosti i razne površinske obrade koje i diktiraju njenu primjenu u prostoru. Moguće je kreirati razne boje, oblike i teksture, što omogućava prilagodbu različitim stilovima interijera i eksterijera. Ova estetska fleksibilnost čini keramiku omiljenim izborom za arhitekte i dizajnere, dok kamen i drvo, iako lijepi, mogu biti ograničeni u svojoj paleti i dizajnerskim mogućnostima. Keramika se može reciklirati, a njeni resursi su često lako dostupni što doprinosi njenoj sve većoj popularnosti u suvremenoj primjeni. Njena prilagodljivost i dugotrajnost omogućavaju ne samo funkcionalnost, već i estetski doprinos svakom prostoru.

Ključne riječi: keramika, proizvodni proces, vezivi materijal, tehnička svojstva keramike, standardi i certifikati

1. INTRODUCTION

This professional paper deals with the topic of ceramics as a material, how they are produced and how they are properly used from interior to exterior. The word ceramics comes from the Greek word keramos, which meant clay as a material or products made from baked clay. The basic materials of ceramics include clay, feldspar[1] and quartz sand, which are transformed into strong and durable products by firing. This transformation not only gives ceramics their characteristic strength and wear resistance, but also allows for a variety of shapes and aesthetic finishes. In addition to their functionality, ceramics are often used as a medium for artistic expression, exploring their possibilities through various technical treatments and styles. This combination of tradition and innovation makes ceramics a fascinating subject of study and research, and in this context, ceramics remain a key part of human culture, a symbol of creativity and skill throughout the centuries [1].

In addition to ceramics in the phase of their application in projects, this paper will also cover a brief overview of the binding material and the role of adhesives for ceramics, grouts, silicones, waterproofing, etc. Since EU-produced ceramics also undergo quality checks and controls before being released to the market, the paper will also list the main regulations and certificates that the binding material must have in order to meet the required quality and be an adequate support for ceramics.

1.1. Ceramics through history

Ceramics are one of the oldest human materials, and their development can be traced back through the centuries. The oldest known evidence of the use of ceramics comes from East Asia and dates back approximately 18,000 years to the Late Paleolithic period. Fragments of roughly shaped ceramic vessels were found in the Xianrendong Cave in the Chinese province of Jiangxi, which were probably used for cooking or storing food (Figure 1).

Figure 1. The oldest ceramic fragment found in the Xianrendong Cave

[1] Feldspar is a group of minerals that make up about 60% of the Earth's crust, making them the most common minerals in the crust. They are silicates containing elements such as potassium (K), sodium (Na), calcium (Ca), and aluminum (Al), and are often used in the industries of ceramics, glass, and construction materials. Feldspars are important because they improve the heat resistance of ceramics and influence the color and transparency of glass and ceramic products.

During the Neolithic Age, around 10,000 BC, people began to use ceramics to make pottery for storing food and water, which was essential for the development of agriculture and a stationary lifestyle. These early vessels were often decorated with various motifs, indicating the growth of aesthetic awareness and cultural standards. In antiquity, ceramics became an essential part of everyday life. A special style of pottery known as "red-figure" and "black-figure" pottery, which was decorated with complex images and stories from mythology, was developed in ancient Greece. During the Middle Ages, ceramics continued to develop in different cultures, including China, where fine porcelain pottery was created, which is still considered one of the most valued forms today.

With the Industrial Revolution in the 18th century, ceramic production became more widespread, and new firing and glazing techniques enabled the creation of a variety of shapes and colors. Today, ceramics are used not only in households, but also in industrial applications, technology, and art, making them one of the most important materials in human culture [2].

1.2. Development of ceramic production methods throughout history

Terracotta (Latin *terra* – earth, *cota* – baked, which can ultimately be translated as baked earth) is a traditional material that was historically used for covering walls and floors, and traces of its use can be found today in Croatia, for example in the early Christian basilica in Poreč from the 6th century (Figure 2). Techniques for painting the surface of terracotta developed over time, including additional firing after applying glazes, which enabled the creation of majolica, another well-known method of making ceramics - a type of ceramic tile known for its white glaze with blue floral motifs.

Figure 2. Euphrasian Early Christian Basilica in Poreč

The technological development has led to the emergence of two firing methods: monocottura and bicottura. Monocottura involves the ceramics production process using a single firing, while bicottura requires double firing. The difference between these methods is reflected in the water absorption. In monocottura, the percentage of water absorption ranges from 3% to 6%, while in bicottura this value reaches 10% to 15% and in some cases even more, which reduces the quality and durability of the final product and this method was eventually abandoned. Bicottura was previously used as a form of technological process where the work was divided mainly to save on it. Namely, some factories produced the body of the

tile while others did the surface glazing, which is why there was double firing. Naturally, this process was abandoned since a large percentage of water was retained within the body of the tile, which actually made it lose its quality properties. Microscopically, when observing ceramics made using the bicottura process, shapes resembling porous cheese can be seen, and due to the thin connections between the voids, cracking would occur during the first freezing of the tiles, which was the most obvious indicator that the manufacturing process was not satisfactory. Although at first thought it seems that a tile fired twice should have better technological properties, this is not the case here. Therefore, a tile fired once using the monocottura process was accepted as the best. This process continued to develop over the following years due to the development of technology, or of the kilns, which became longer year by year, and the firing process itself was regulated over time and became better and better.
In the last 50 years or so, gres porcelain appeared. Gres porcelain is an innovation in coating with an exceptionally low level of water absorption below 1%, which over time became the European standard for this type of ceramic coating, and in some modern manufacturers, with additional development of technology, the percentage of water absorption goes below 0.01%. Their emergence on the market sometimes led to a misunderstanding of the product. The misunderstanding was that gres porcelain is a ceramic the composition of which also includes ground granite, which gives it strength and a low level of water absorption. This is certainly not the case, because gres porcelain is a product of the development of ceramics throughout history, which has mostly resulted from the development of production process technology (firing temperature, firing duration, pressing, etc.) [1].

2. MAIN COMPONENTS OF CERAMICS

Ceramics are obtained as a material by mixing clay, quartz sand and feldspar, or kaolin[2], which are the main ingredients. As such, clay has the function of ensuring the plasticity of the ceramic body, quartz sand provides the skeleton, while carbonates and feldspars help to make the ceramics glassy. The composition of ceramics, solely for the purpose of satisfying their better quality, most often includes a ratio of different clays from different sites, specifically most often a proportion of 50% Ukrainian and 50% German clay, in order to ensure the stability of the quality of the observed ceramics.

Clay, as the basic material for making ceramics, is by definition a hydrated aluminosilicate mixed with quartz sand, limestone and iron oxides. The special characteristics of clay include a high degree of water absorption (up to 80%), high plasticity and stickiness, the ability to retain its shape after firing, and tension while drying. The use of clay has followed the development of the technological process itself and the parallel development of ceramics made of red clay, which was previously used as the main and only material, and today it is increasingly being replaced with white clay, which by its chemical composition is of higher quality and more expensive and ultimately produces better and higher quality products. Clay is a material that is naturally exploited from nature, and as previously stated, different sites also determine its quality. As for European countries, the best-known natural clay deposits are Ukraine, Czechia, Russia, Germany and Türkiye.

When the question arises as to why the quality of clay is important, clay should be primarily considered as a natural material that is imperfect because it does not have the same properties as stone and other natural materials. For example, if clay is excavated at a depth of 10 meters, already at 11 meters it may have deviations in quality that must therefore be tested before being released to production. Better clays are those that have the appropriate degree of purity

[2] Kaolin is a type of mineral clay that consists primarily of the mineral kaolinite, or a hydrated aluminum silicate. This clay is usually white in color, but can have other shades, depending on the presence of various impurities. It is used in the production of porcelain, ceramics, bricks, and tiles due to its white color and ability to withstand high temperatures.

achieved by controlling the particle size and moisture content necessary for further processing. Good quality of clay is important for the technological process because clay shrinks by 5% to 6% already during the first pressing. In the composition of ceramics, sand is a shrinkage regulator, while feldspars can shrink by up to 50% [2].

3. PRODUCTION PROCESS OF CERAMICS

In the production of ceramic tiles, the three most common clay shaping techniques are pressing, extrusion, and casting. Pressing is the most commonly used method where the material is formed with a die on both sides and processed at a given pressure. The moisture content in this process is from 5% to 6%. Extrusion, an advanced technique, uses a ribbon-shaped clay that is cut into fragments with a moisture content between 15% and 20%. Casting, which is considered an inferior process because it generates products of varying thickness and size, is characterized by a moisture content between 30% and 35% and as such results in a variable mass due to the nature of the casting [3].

3.1. Clay treatment process

The entire clay treatment process begins with the dosing of raw materials that are transported by bulldozers into hoppers where the clay is mixed with water at a given ratio. The material is mixed and ground in several chambers to make the particles finer in size through a series of screens of a finer mesh. In this way, the granules are selected by size, up to the desired grain size, and an important item is their maintenance to prevent clogging of the pores. The same is the case with scales, because they need to be regularly calibrated and replaced so that their deviations do not interfere with the production process and disrupt the exact proportions of the materials. During the crushing in the first chamber, the granules are the largest in size and, in the presence of liquid and a sieve, fall into the second chamber, where the larger granules are again separated from the smaller ones. The smaller granules then pass into the third chamber, where they take on a more rounded shape similar to ping-pong balls (Figure 3). In order to avoid later anomalies on the surface of the final products, aluminum silicate, and iron are separated from the material during the grinding process through the chambers.

Figure 3. Ground granules from the third chamber

3.2. Pressure and temperature treatment to create granules

After the grinding process through the sieves, the mixture takes on a mushy form and is placed in pools (Figure 4), where it is further mixed to ensure that each of the ingredients is properly combined. Each mixture contains a different combination of materials, depending on what is planned for production. After that, part of the mixture is transferred to silos, or hoppers, where burners are located. There, temperatures reach up to 550 °C while the pressure is between 15 and 20 bars. Liquid is injected into the raw material, and the combination of pressure and temperature in this process creates granules of a spherical shape and moisture content of 5% to 6%, making them easier to shape later. During pressing, if the material does not contain enough moisture, it cannot be compacted - otherwise, only powder particles are compacted. The granules thus formed are stored in silos from where they proceed into the pressing process.

Figure 4. View of a pool with a combined mixture

3.3. Pressing process

In the pressing process (Figure 5), the granules are compressed into a compact mixture in the form of a plate, before the process of decoration. Today, there are two pressing methods, dry and semi-dry pressing, and the difference between them is in the pressure. During pressing, not only is the composition compressed, but the particles are also deformed, which leads to their fragmentation within the total volume. The pressing process is divided into two phases. The first phase is the preliminary compaction of the mixture, where the pressure is reduced to remove the air forced out from the mixture. The second phase completes the process and creates a cake that retains its shape. The process is carried out using a mold, the back of which can be in the form of lines, honeycombs, nets, etc., while the face is adjusted depending on whether a smooth or some other structure is desired. The pressing force has also developed over time, and today it averages around 8600 t/m². In better factories, the force of the presses stands at about 8600 t/m², and often reaches up to 26,000 t/m². Pressing is followed by the process of dehydration, during which the pressed plate travels to a chamber with spirals, where the temperature of the chamber medium is 120 °C, in order to extract moisture from it. This process is exceptionally important because it is necessary to remove moisture in a percentage of 5% to 6%, which was necessary for the pressing process. If moisture remained in the subsequent firing process, it would result in the tile cracking.

Figure 5. Pressing process

3.4. Decoration process

Technologies for the decoration process have also changed throughout history, and the first of them was screen printing. This is a screen with apertures, onto which the paint was applied by moving a blade left and right, leaving an impression on the surface of the tile. With the development of technology, screen printing was replaced by rollers (e.g. Rotocolor roller), which were 90 to 350 cm in length, and in one production process between 5 and even 15 of them were used. The difference between the rollers was in the "quantity of design" - during the decoration process, the first roller left the first layer of design, then the second, third, etc., with each roller applying its own layer. As for the repetition of patterns, similar parts would appear only after every 124th repetition of the design. The ink was poured directly into the roller, allowing precise dosing of the ink during application. The difference between screen printing and the Rotocolor roller (Figure 6) was that screen printing had a visible mesh, while with the Rotocolor roller this was only the case if a magnifying glass was used.

Figure 6. Rotocolor roller for decoration

The latest decoration process that is most commonly used today is the Inkjet printer. This device uses a design created in graphic programs, allowing the printing of any desired pattern. It is also a cheaper and more environmentally friendly option due to the simpler process of preparing the design of new collections. The Inkjet printer consists of a large head in which the ink is in a liquid state and is dosed by the computer, according to a predefined design. Before the introduction of Inkjet technology, and in some factories even today, the method of applying glazes to the surface layer of ceramics was used in the production process. The glaze was a mixture with absorbent salts that penetrated deep into the tile and were later polished to give the tile a so-called full-body effect. Today, a large number of factories have given up this method because unglazed tiles are of considerably higher quality. Factories that still use glazes often apply a layer of glass (or finely ground glass) to the surface of the tile after decorating by printing before firing. This layer provides a shiny finish, but has a purely aesthetic function. If such a tile is placed in a high-traffic area (e.g. an atrium), the surface layer of glass will wear out or be damaged over time. Damage can also occur if the tile comes into contact with a quartz pebble in a shoe – quartz stone has a value of 8 or 9 on the Mohs hardness scale, while the hardness of glass is much lower, which causes it to peel and break.

3.5. Firing process

After the tile has been prepared in terms of the ratio of materials, pressing and decoration, the most important process that determines its quality follows, which is the firing process. Another important factor is the duration of the firing process through which the tile goes. In general, the longer the process, the higher the quality of the tile. The first modern kilns for ceramics were 90 to 100 meters long, but with the development of technology this segment has been improved, so that today the average length of the kiln is 120 meters, while in better factories they reach 150 meters. When firing large-format tiles, the length of the kiln must be even greater due to their surface area, and in these cases the kilns can reach up to 250 meters. Inside the kiln are rollers that guide the tile through the entire process, and they are made of

white aluminates that can withstand exceptionally high temperatures. Since they are continuously exposed to heat to maintain the quality of the process, they need to be replaced regularly in order not to disrupt the production process. The temperature through which the tile passes starts from zero and gradually increases as it moves through the kiln. At temperatures up to 200°C, residual moisture evaporates, and at 300 to 400°C, organic substances such as organic carbon and humus burn out. At 500°C, kaolinite and other natural minerals present in the clay burn, while at 700 to 800°C all remaining coke burns out. Above 800°C, the clay components decompose into oxides while forming silicon and alumina. The distance between the tiles entering the kiln must be at least 1 cm because, when they reach the highest temperature, the tiles and rollers become glowing hot and act as a single body. Burners are installed in the central part of the kiln, placed above and below, where the highest temperature of 1250°C is reached. The tile remains at this temperature for a certain time. After that, the temperature begins to fall and, just as it gradually increased, it must gradually decrease. It is very important to regulate the conditions of the production process in which ceramics are fired, because atmospheric conditions, such as humidity and room temperature, can significantly affect the firing process and thereby the quality of the final product.
Sometimes a temperature difference (Figure 7) of only 1 °C can significantly affect the tone and caliber of the tile, so it is crucial to monitor these parameters precisely. The tile exits the kiln at a temperature of 120 °C and gradually cools down to atmospheric temperature so that it can proceed with further treatment processes.

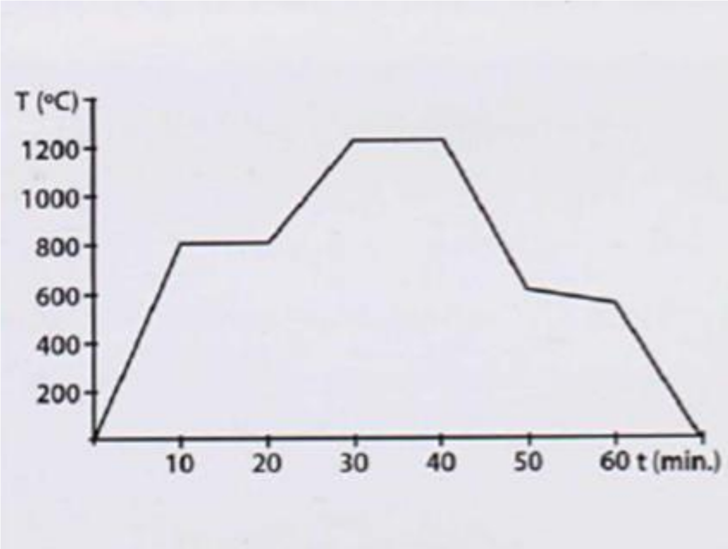

Figure 7. Temperature curve during the firing process

It is particularly important to note that when cooling, until the temperature drops to 560°C, the process must be gradual and must not proceed too quickly. If the temperature were to drop suddenly, the tile could crack or bend. Kilns inside factories are never turned off and operate continuously, 24 hours a day. The only exception is during the facility maintenance and the introduction of new technologies, but even this is carefully controlled, since stopping the firing process (Figure 8) is very expensive. The energy source used is natural gas, and the firing duration is also very important for the quality of ceramics. It largely depends on the thickness of the tile - for example, a 10 mm thick tile requires a minimum of about 50 minutes of firing, a 14 mm tile 90 minutes, while for a 20 mm tile the firing process takes as long as 4 hours.

Figure 8. The kiln in which the firing process takes place

3.6. The process of checking the strength of the fired tile

After the tile has completed the firing process and reached room, atmospheric temperature, it goes through another checking process before further processing for the final surface treatment. This is the strength checking process, in which the tile is treated with a hammer weighing 160 kg. This check is conducted only in the case that an air molecule accidentally remains in the tile during firing, because it cannot be removed any more after firing. The hammer is made of hard plastic, and during the check it is tightened and hits the surface of the tile. If the tile does not have any remaining air molecules, it passes the test and goes into the further treatment process, and if it breaks, that part is separated into a special container and later recycled in production. This check is exceptionally important in order to prevent production errors and to ensure that the quality of the tile is unquestionable.

3.7. Rectification

If the tile has passed the strength test, it goes through a rectification process, which gives it the correct caliber and refines its edges, which later facilitates its application during installation. Rectification (Figure 9) used to be an expensive process, but today, with the development of technology, this segment has been simplified and is an essential part of production.

Figure 9. The tile rectification process

The rectification process takes place so that the tile, after being checked, over the line enters the rectification area where there are three disk zones. The first disk removes the excess on the edges caused by pressing and firing the tile, the second disk shapes the tile edge, and the third disk smooths the surface, after which two angle grinders create a slight bevel on the edge so that the rectified tile is not too sharp, which can be a problem during application (cutting and handling). There is often a misconception that tiles in this process are laser-cut to the desired dimension, but this is not true because the laser cannot cut or rectify the tile. Its role is to dictate the cutting direction, while the rest of the work is performed by diamond cutters, which are part of the disks in the rectification process. At the end of the rectification, a sensor checks and specifies the caliber.

Manual control is also introduced for additional verification, where every 500th piece is checked to see if the rectification was performed correctly and whether the tile caliber is appropriate. In addition to checking the caliber, the orthogonality of the corners is always checked, whether they are correct or whether the tile has been warped during the production process.

The EU standard for caliber deviation is 5% in relation to the tile format. Thus, for example, a caliber deviation of 1.5 mm is allowed for a tile of 30 cm × 30 cm format. In production, a monocaliber is always aimed for, i.e. efforts are made so that all tiles are of the same caliber. For example, for a tile of 60 cm × 60 cm format, its mold is actually 72 cm, because during the production process (dehydration, drying, firing, etc.) water is lost, and thereby volume is also lost, which causes the tile to shrink in size. It is estimated that the tile shrinks by 10 cm only in the stages before rectification, while the remaining 2 cm are reserved for the rectification process. The rectification process is very important for the application of the tile, especially when determining the joint. For non-rectified tiles, the joint must be 3 mm, while for rectified tiles it must be 2 mm. The joint is responsible for correcting the system and potentially avoiding problems. Today, a leveling system has been developed with spacers, wedges and accessories, which helps with the installation of ceramics. Even more important is that the joint allows expansion. Expansion joints in the screed must follow the expansion joints of the tiles, because if the systems do not match, cracking may occur. As a base, the screed has the ability to expand and contract in different weather conditions, while ceramics do not have this adaptability, which is why joints are of key importance. It is precisely because the screed has the ability to contract and expand that expansion joints are made every 4 m × 4 m in indoor spaces, or 3 m × 5 m in outdoor spaces.

3.8. Polishing

Polishing is primarily the surface treatment of the tile, and today in technologies we distinguish between classic polishing and semi-polishing. Classic polishing is carried out with two large discs with diamond grinders, which remove 0.5 mm of the tile surface, after which 40 heads give the final shine (each consists of 6 grinders that polish the tile, and the grading itself goes from coarse 140 to the finest 4000). Today, some factories use 30 heads in the initial polishing for the purpose of savings in the production process, and they supplement the process by using glass to smooth out micropores. Such production is considered cheaper, and the product may be easier to maintain due to the glassy surface structure, but it is still not the same quality product as the one without glass. Namely, with greater use of glass and in contact with harder substances (on the Mohs scale), the surface is more easily damaged. The semi-polishing process is performed with 5 to 20 heads, not using diamond grinders but metal ones in combination with sponges, which give a softened surface with a slight shine (without high shine). Today, polishing technologies range from *lapatto* – roughly polished tile, where the process is performed with hard disks. If the tile has a surface groove, only the top is polished, while the small holes remain and give it a rougher structure. Such tiles are more difficult to maintain, but are used only in outdoor areas because of their anti-slip properties. The softest tile treatment in today's technological process is *satinato*, where softer sponges and brushes are used. Unlike *lapatto* treatment, the entire surface layer is polished (regardless of whether it has grooves or not), which achieves a uniform finish, soft to the touch, which makes it suitable for interiors where it is important to ensure easier maintenance.

Figure 10. Lines of the polishing facility

The polishing process previously shown in Figure 10 is related to PEI markings, which refer to glazed tiles and determine how many revolutions per minute are required for their surface treatment. The following markings are distinguished here:

- PEI 0 – 150 revolutions per minute
- PEI 5 – as much as 18,000 revolutions per minute

Unglazed tiles, which have better wear resistance properties (with up to 30-year guarantee of use), are always technologically and qualitatively better than glazed tiles, and the print itself penetrates deeper into the tile during the decoration process. It is important to note that the polishing process creates fine micropores, which must be cleaned of residual grout and dust when installing the tile. This procedure should be carried out within 24 to 48 hours after installing the tile, because if the micropores are not cleaned, it may result in the formation of scale, which will change the appearance of the tile in terms of darkening over time, depending on the use and atmospheric conditions. Today's ceramic cleaning products contain hydrochloric acid, which on the one hand helps because it destroys and dissolves residual scale, but on the other hand can damage the grout. Therefore, when washing for the first time, it is very important to rinse the surface thoroughly with clean water to avoid damaging the grout. Today, in order to close the fine micropores in the production process, some manufacturers use ground glass of fine grading, which additionally closes the micropores. After the polishing process, large-format tiles undergo additional reinforcement by implementing a fine mesh on the tile body, thus improving its properties for use on facades and in areas with greater use (floors, kitchen countertops, etc.). The final stage includes the application of surface antibacterial protection - today it is Microban technology, which is based on silver ions and has the main function of preventing the reproduction of bacteria on the surface, which facilitates application and maintenance.

3.9. Packaging

After the production process has been completed, the tile has gone through all the previously described stages and checks, the following is the packaging process, where the tiles are placed first in cardboard boxes, and then on pallets ready for further transport. Before packaging, each tile is assigned its own technical sheet, which is an attestation of the collection in which it was produced, but also a manifestation of the conditions in which it was produced. The technical sheet is responsible for the quality of the tile and is an important segment of the specification for projects, but also for complaints if there is one. Each tile package, as well as the technical sheet, must contain the most important information about the tile, but also about the results of the production process. The aforementioned information includes the name of the tile, tone, caliber, class, tile code, person responsible for quality control, date and time of production, etc. After packaging, the tiles are placed on a pallet, the pallet is plasticized for additional protection and taken to the warehouse, where each tile has its own pallet place, from where it is later taken for transport [4]. Figure 11 shows an example of a package with all product information.

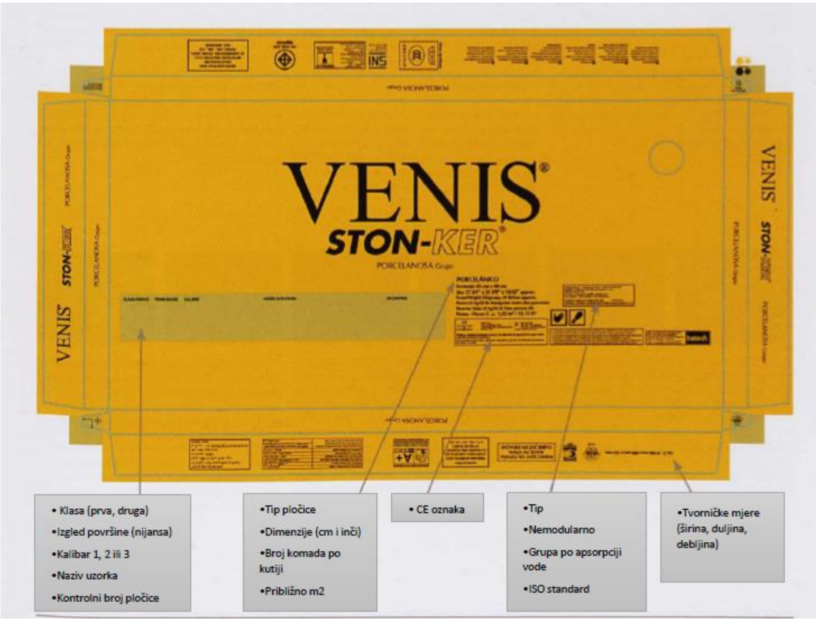

Figure 11. An example of a package with all the information about the product

4. TECHNICAL DIFFERENCES BETWEEN CERAMICS AND GRES PORCELAIN

This part of the paper will present some of the technical characteristics that distinguish ceramics and gres porcelain, as well as the fundamental technical differences between them.

The first of these is density, which is defined as the ratio of mass to volume of a body. Thicker formats do not and need not always have higher densities, as examples can often be found where a visibly thinner tile (e.g. 5 mm) is heavier than a thicker one (e.g. 1 cm or more), and this is of course related to the pressing process. That is why, when we talk about density, it is related to the manufacturing method and is therefore not the same for ceramic tiles and porcelain tiles. The density level of gres porcelain tiles is significantly higher, and thereby the level of their application in projects is wider (as floor and wall coverings for interiors and exteriors). The density level of ceramic tiles is lower, and therefore their application is more limited (as wall coverings for interiors), but unlike gres porcelain tiles, we can create various applications such as various reliefs, structures, shapes, etc.

In addition to density, one of the main characteristics is strength, which is represented by three parameters, namely bending strength, impact strength and hardness. The bending strength parameter differs for ceramic and gres porcelain tiles because the coefficient for ceramics is around 25 MPa, while for gres porcelain tiles it ranges from 40 MPa to 49 MPa. The impact strength parameter does not have a numerical value, but due to the density parameter during production, gres porcelain tiles have better impact strength than ceramic tiles, which is why they are often used for floors. The hardness parameter is measured on the Mohs scale of minerals from 1 to 10, where ceramics have a hardness of 4 to 6, while gres porcelain tiles have a hardness of 7, like quartz.

Wear (abrasion) resistance PEI[3] is divided by classes and application based on load as follows

- PEI 0 – minimum durability (wall cladding),
- PEI 1 – application for walls or possibly floors where the frequency is low,
- PEI 2 – covering of floors or walls of residential rooms,
- PEI 3 – cladding that is resistant to wear (for rooms that have access to the street or high-frequency zones, such as offices, etc.),
- PEI 4 – application in residential and commercial conditions (hotels, restaurants, shops, etc.),
- PEI 5 – application for public areas with a high degree of frequency (airports, shopping centers).

Frost resistance is the ability of the material to withstand multiple temperature changes from minus to plus, especially important for exterior cladding in the exterior. Tests are carried out for temperatures from -20 to +20°C through cycles. Ceramic tiles can withstand 25 to even 125 cycles of temperature changes from -20 to +20°C, while gres porcelain tiles can withstand even 300 such cycles.

Porosity is represented as a ratio of the amount of water that the tile can contain based on its composition. It is tested by placing the produced tile in water for 24 hours. Porosity is marked with the symbol E, where there are the following types of tiles depending on the percentage of porosity:

- 0.5% - these are gres porcelain tiles that do not absorb water, are frost-resistant (the water absorption property is closely related to this), have smaller pores (water cannot spread throughout the body of the tile to a greater extent, which is an advantage in adverse conditions such as ice, snow, etc. because they do not lead to cracking),
- 0.5 - 3% - these are ceramic tiles that absorb slightly - monocottura
- 3% - 10% and more - these are ceramic tiles that absorb water - monoporosa.

Furthermore, anti-slip is the property of the tile surface to provide a secure grip under feet or shoes, reducing the risk of slipping. This property is especially important in areas where floors are frequently wet or prone to becoming dirty, such as bathrooms, kitchens, terraces, swimming pools or industrial areas. The choice of tiles with the appropriate level of slip resistance depends on the specific needs of the space and safety standards. The standard for public buildings in the EU for slip resistance is R10. Slip resistance is determined with the German slope test (ramp test), where the floor covering is coated with oil or soapy water and is determined by two tests:

- shoe test (where the surface is coated with oil), where there is a classification into groups based on the angle of inclination of the slope, namely:
  - 3-10° - R9,
  - 10-19° - R10,
  - 19-27° - R11,
  - 27-35° - R12,
  - over 35° - R13,

[3] PEI - Porcelain Enamel Institute

• barefoot test (where the surface is coated with soapy water) in which there are three classification groups according to the effect of slipping. During the test, a person moves across the surface forward and backward while the floor covering is inclined more and more until the person slips while walking in small steps, and this resulting angle of inclination is actually a measure of slip resistance properties that give the classification group as follows:
  - A – smallest inclination with an angle of up to 12° - use of ceramics with this marking for areas exposed to moisture (showers), wet corridors, pool bottoms, etc.,
  - B – larger inclination with an angle of up to 18° - use of ceramics with this marking for areas exposed to moisture (showers), wet corridors, pool bottoms, etc.,
  - C – largest inclination with an angle of up to 24° - use of ceramics with this marking is for very slippery floor coverings such as steps for entering pools, etc.

Anti-slip properties are inversely proportional to cleaning and maintenance, so the higher the anti-slip rating of a tile, the more difficult it is to maintain, and therefore the first wash after installation is important (due to micropores) [3].

5. CERTIFICATES AND ECO LABELS FOR CERAMICS

The certificates that ceramic tiles should have depend on their purpose, the legislation of a particular country and quality standards. However, there are some universal certificates and standards that are key to ensuring safety, quality and sustainability, the most important of which are:

- ISO 10545 - international standard for testing ceramic tiles that includes characteristics such as wear resistance, water absorption, chemical resistance and resistance to breaking and bending.
- CE marking - a mandatory marking for products sold on the European market. This marking confirms that the tiles meet the basic safety requirements of the EU directives.
- LEED - a certificate that evaluates the product's contribution to sustainable development and construction. LEED-certified tiles show low emissions of harmful substances and use recycled materials.
- Ecolabel - EU label for products that meet high ecological standards, such as low CO_2 emissions and minimal environmental impact.
- GREENGUARD - certificate that the tiles do not emit harmful volatile organic compounds (VOC), which ensures better indoor air quality.
- NSF - certificate for tiles intended for food and medical areas, ensuring easy cleaning and resistance to bacteria.
- Carbon footprint – label for emissions of carbon products, in the first place emissions of greenhouse gases during the tile production process.
- ISO 14021 – marking of products obtained from recycled material (clay or other ingredients required for the production of tiles or tiles that have not passed the quality control check).
- ISO 50001 – marking of a standard for reducing energy consumption and greenhouse gas emissions.
- ISO 9001 – a marking for aesthetic and technical characteristics through quality control systems and for design, distribution, etc.
- EPD – environmental product declaration (a standard for the construction sector that explains a new sustainable model for reducing environmental impact).

When choosing tiles, it is important to check whether they have the relevant certificates for safety, quality and environmental friendliness, especially if they will be used in specific conditions (such as wet or outdoor areas). Tiles that meet these standards ensure not only durability but also additional safety and sustainability [4].

6. INSTALLATION OF CERAMICS

Installation of ceramics is a common and important construction procedure that is used in almost all types of spaces – from residential to commercial and public buildings. In addition to providing aesthetic value, tiles are also practical due to their resistance to moisture, wear and tear and easy maintenance. In order for the final result to be of high quality and long-lasting, it is important to properly follow all the steps of the ceramic installation process. Therefore, some of the main recommendations and conditions that must be met in order for the tile installation (Figure 12) to be successful, and the installation system itself to be made with high quality are presented in the continuation of this paper.

1. The installation of ceramic tiles should be carried out by qualified personnel with proven experience and appropriate tools and equipment such as notched trowels, spacers and tile wedges, rubber mallets and vacuum cups for installation, as well as rubber trowels, sponges and containers for grouting, etc.
2. It is necessary to check whether the underlay and base to be covered are stable and suitable for laying ceramic tiles. It is recommended that all wet areas be waterproofed.
3. The surfaces to be covered must be completely cleaned of dust or any other substances that could affect the adhesion of the tiles.
4. The work area must be sufficiently illuminated for the installation to be successful, especially the edges between the tiles. The electrical lighting of the construction site recommended for illumination should project a light that is brighter than normal.
5. The type of adhesive should be chosen depending on the conditions and the tiles that are used. The choice of tiles and adhesive is crucial for the subsequent execution of the entire installation process. Factors that should taken into account are the type of ceramic material, the format of the tiles, the underlay and the final purpose (any traffic to which it will be subjected, safety requirements in terms of falls, etc.).
6. The only recommended fixing system is the attachment on a thin layer using a notched trowel. The double-binding technique (adhesive is applied to both the base and the back of the ceramic tiles) is recommended for tiles with a format larger than 1000 cm^2. It is important to remove any traces of binding material that may remain on the surface of the tile before installation, making sure that the joint remains clean to make grouting easier. It is not recommended for cleaning to use metal tools or blunt objects, which could damage the surface of the tiles.
7. During handling, special care must be taken to avoid scratching, breaking or cracking the tiles, especially the rectified ones. Before installation, it is always necessary to make sure once again that the tiles are free of any defects.
8. The joints for grouting should be at least 1.5 mm for interior floors and 3 mm for exterior paving. For installations with offset joints, the tiles should be arranged in a 3/4 system. It is also recommended to use self-leveling tile spacers. Before use, for the system of de-leveling transitions, it is necessary to carry out a preliminary test with the tiles to be installed and check the separators during the breaking process, as the tile is damaged. This is especially common with embossed or rectified tiles.
9. It is necessary to follow the manufacturer's recommendations regarding the preparation and use of the adhesive. Adhesive in a greater thickness is not recommended and it should not be applied more than specified in the technical sheet of the product. It is also necessary to check the wetting capacity of the adhesive on the ceramic tile by moving it from side to side. The adhesive under the tiles is evenly distributed, as different thicknesses can cause defects at the edges caused by different shrinkage of the binding material. When installing near previously installed tiles, it is necessary to assess whether shrinkage is possible, which then needs to be compensated.

10. Edge joints that appear at corners, changes in tiling level and other material changes should be covered with a tile trim or the tile itself and sealed with a flexible sealant. The minimum joint width in this case should be 8 mm.

11. Care should be taken of structural joints as expansion joints should be installed according to instructions.

12. During installation and at the end of the day, or before the binding material hardens, it is necessary to check the quality of the work performed. Any defects are corrected using vacuum cups and rubber mallets.

13. Before grouting, it is necessary to check whether the binding material has hardened, after which the spacers and wedges are removed, the joint space is cleaned in length, width and depth, and a check is made to confirm that the joint is not accidentally wet.

14. The joints should be performed when the tiles are fully fixed to the surface as far as tiling is concerned, where it is necessary to follow the recommendations of the adhesive manufacturer to ensure sufficient time before installing the floor that will be walked on or that will be subjected to a certain load. In this way, movement and/or breakage will be avoided.

15. The material and selected tools must not damage the surface of the tiles and the grout should be applied using a rubber trowel.

16. After grouting, it is necessary to wait for the grout to dry, and then it is necessary to clean it with a sponge moistened with clean water. The grout mixture must not be allowed to harden on the tile, especially on textured tiles, nor must the grout be soaked with excess water.

17. It is also important to protect the tiling from early loading, other construction, bad weather, scratches, abrasion, impacts, etc.

18. For cleaning, always use products compatible with the chemical resistance of the tiles. It is not recommended to use strong detergents containing abrasives or cleaning agents containing hydrofluoric acid (HF). This acid corrodes the glaze and as such can cause irreparable damage to the tiles [3].

Figure 12. Tile installation process

7. FUNCTION OF BINDING MATERIALS

Binding materials are of great importance in the ceramic, construction, architectural and similar industries because they ensure permanent binding, protection and aesthetic finish of ceramic products. Depending on the type of product and their application, some of the key binding materials such as ceramic adhesives, grouts, waterproofing, silicones and other commonly used binding materials will be described below.

Ceramic adhesives are used to bind ceramic tiles and other ceramic elements to different surfaces, such as concrete, plaster or wood. Their main functions include:

- strong adhesion - they ensure a firm adhesion between the ceramic and the base, which increases resistance to mechanical loads and vibrations,
- flexibility - many products are formulated with a flexible composition that allows them to withstand movement and stress without cracking,
- resistance to moisture and freezing - quality adhesives are resistant to moisture and temperatures, which makes them suitable for use in wet rooms, such as bathrooms, kitchens or outdoor areas.

Grouts are binding materials used to fill gaps between ceramic tiles after installation. Their functions include:

- aesthetics - grouts give a final look to ceramic floors and walls, and are available in different colors and textures,
- protection against water penetration - high-quality grouts prevent the penetration of water and moisture, thus reducing the risk of damage to the underlay and formation of mold,
- stress reduction - the joints allow a small movement between the tiles, which reduces the risk of ceramic cracking due to stress, e.g. earthquakes.

Waterproofing is the process of protecting construction elements from water penetration. In ceramics, waterproofing materials are important for:

- protecting underlay - they prevent water from penetrating the underlay, which can lead to structural damage and reduced durability,
- keeping the interior dry - in bathrooms, kitchens, etc., waterproofing helps to keep the interior dry, thus preventing the occurrence of moisture and mold,
- increasing durability - the use of waterproofing materials extends the life of ceramic tiles and underlays.

Silicones are flexible materials used to seal or protect joints in ceramic structures. Their key functions are:

- sealing[4] - silicones prevent the penetration of water and moisture into joints between ceramic elements and other materials,
- flexibility - due to their elasticity, silicones can withstand movement and vibration without cracking, which makes them ideal for use in damp rooms,
- chemical resistance - silicones are resistant to many chemicals and temperatures, which makes them suitable for use in different environments.

In addition to those already mentioned, there are also other binding materials used in ceramics, and these are:

- cement mixtures - used for binding heavier ceramic tiles, as well as in construction work, thus providing high strength and pressure resistance,
- epoxy adhesives - these adhesives are exceptionally strong and resistant to chemicals, which makes them suitable for industrial applications and underlays exposed to harsh conditions, and are often used, for example, in swimming pools due to constant contact with the water medium.

The role of binding materials in ceramics is multifaceted and crucial for achieving durability, functionality and aesthetics of ceramic products. From adhesives and grouts to waterproofing and silicones, each material helps to improve the performance and durability of ceramic installations. Understanding these materials enables better planning and execution of ceramic works, which ultimately leads to higher quality and longer-lasting solutions. The regulations and certificates that binding materials must have to satisfy their own quality, but also the quality of the products with which they are used, will be discussed below. All regulations are prescribed by European standards, and are important for specifications in projects, especially in those within the European Union.

[4] Sealing means the process of closing joints, cracks or openings to prevent the passage of liquids, gases, dust or other particles. In various industries and applications, special sealing materials and methods are used to ensure protection, resistance and durability of systems, devices or construction elements.

8. EUROPEAN REGULATIONS FOR BINDING MATERIALS

Manufacturers of high-quality construction materials, including binding materials for ceramics and stone, must meet strict European regulations to ensure that their products are safe, reliable and suitable for the European Union market. These regulations cover technical, health and environmental requirements that ensure that the materials comply with the prescribed standards. Below is an overview of the key European standards and certificates that binding materials must have, which are:

- Regulation CPR 305/2011 is a regulation that is mandatory for certain types of construction materials, and especially for products and systems for the repair and renovation of concrete structures and for screeds and mortars, which include the binding materials for laying ceramics on floors and walls. These construction materials must have the CE marking on their packaging so that they could be sold in the European Union. In order for the packaging to have the CE marking, the manufacturer must have a declaration of conformity with the reference standards and must prove that it has met these standards through specific tests. Raw materials, production processes and products in question must also be controlled according to the periodic testing plan defined by law. Therefore, compliance with regulation CPR 305/2011 ensures the quality of the products and their suitability for the purposes stated by the manufacturer.
- Regulation EN 12004:2017 is a regulation that establishes the criteria and test methods for the classification of adhesives for floor and wall ceramics and related materials. According to this regulation, adhesives are divided into 3 categories, which are indicated by letters of the alphabet as follows:
    - C = cementitious - cement-based powder adhesives that are mixed with water or other suitable liquids at the time of use on the construction site.
    - D = dispersive - paste adhesives based on synthetic polymers in water dispersion. These adhesives are ready to use.
    - R = reactive - adhesives consisting of two or more compounds that must be mixed at the time of use on the construction site.

  For each category, there are separate classifications based on the results of resistance tests, where class 1 represents a normal adhesive that reaches the minimum required resistance levels in all tests, while class 2 represents a super strength adhesive with a higher resistance than that required. The regulations also specify additional characteristics that class 1 and 2 adhesives have (Figure 13), and they are:
    - E = extended opening time,
    - T = slip resistance,
    - F = fast hardening.

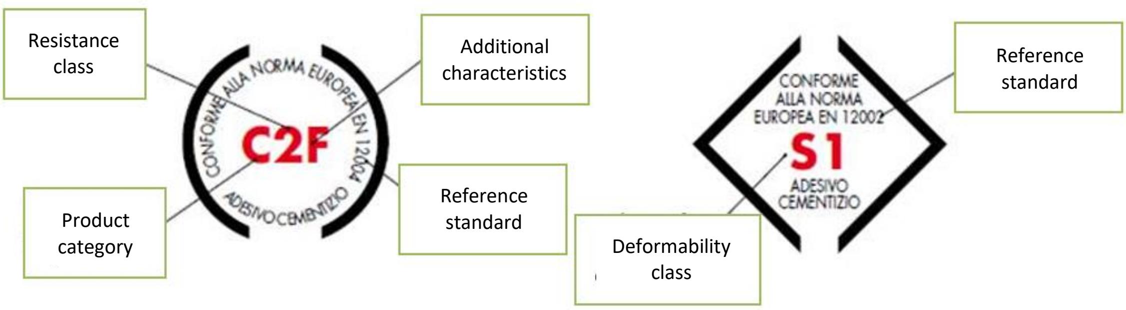

Figure 13. Example of regulation EN 12004:2017

This regulation, among other things, establishes testing criteria and methods for the classification of adhesives for floor and wall coverings in ceramics and similar materials based on their deformability. Thus, adhesives are divided into two groups as follows:

- S1 = deformable adhesives - adhesives that reach a deformability of ≥ 2.5 mm in specific tests,
- S2 = highly deformable adhesives - adhesives that reach a deformability of ≥ 5 mm in specific tests.

- Regulation CPR 305/2011 is a regulation that establishes that adhesives for flooring and coverings meet the minimum testing requirements in accordance with EN 12004 and that raw materials, production processes and finished products are subject to a control plan, including specific tests and periodicity. Some of the additional characteristics of adhesives prescribed under this regulation are:
    - quick-drying versions,
    - white, super white or grey adhesives,
    - sand-free adhesives (for mosaics),
    - adhesives with limited dust,
    - adhesive versions in two consistencies,
    - single-layer and double-layer adhesives,
    - fiber-reinforced adhesives,
    - lightweight adhesives,
    - adhesives with the addition of Microban as a technology that prevents the growth and development of bacteria on certain surfaces.

Figure 14 shows a table of the correct selection of adhesives according to their application.

	EN 12004	C2 TE S1	C2 TE S2	C2F TE S2	C2 TE S1	C2 TE S1	C2 TE S1	C2 TE S1	C2F T S1	C2F S1	C2 TE	C2 TE	C2 TE	C2F
	Glavne karakteristike													
PRIMJENE ILI SPECIFIČNE NAMJENE	Maks. debljina (mm)	15	20	30	20	20	20	15	15	20	15	10	10	15
	Veliki format	√	√	√	√	√	√							
	Intenzivan promet	√	√	√	√	√	√							
VANJSKI PROSTOR	Vodonepropusni bazen	120	120	90	90	90	60	90	90	90	30	30	NE	30
	Beton	120	120	120	120	120	120	120	120	120	60	60	60	60
	Sredstvo za postizanje vodonepropusnosti	120	120	120	120	120	120	120	120	120	30	30	NE	30
	Estrih i žbuka	120	120	120	120	120	120	120	120	120	90	90	60	90
	Stari pod	90	90	90	90	90*	90*	90*	90*	90*	30*	30*	NE	30*
INTERIJER	Beton	360	360	360	360	120	120	120	120	120	120	120	90	120
	Sredstvo za postizanje vodonepropusnosti	360	360	360	360	360	360	360	360	360	120	90	60	90
	Grijana podloga	120	120	120	120	120	120	120	120	120	120**	90**	60**	90**
	Estrih i žbuka	360	360	360	360	360	360	360	360	360	120	120	90	120
	Tekući estrih	120	120	120	120	120	120	120	120	120	90	90	60	90
	Suhe ploče	120	120	120	120	120	120	120	120	120	90	60	30	60
	Stari pod	360	360	360	360	120	120	120	120	120	90*	90*	60*	90*

Figure 14. Table of the correct selection of adhesives according to their application

- EN 13888 is a regulation that establishes test criteria and methods for the classification of grouts (Figure 15) for ceramic tiles and similar materials.

According to this regulation, grouts are divided into two categories with the following designations:

- CG = cementitious - cement-based powder grouts that are mixed with water or a suitable liquid at the time of use on the construction site. There are two separate classifications for products in this category based on test results, and these are class 1 and class 2. Class 1 denotes a normal grout that reaches the minimum required levels in all tests, while class 2 indicates a grout with reduced water absorption and high abrasion resistance.
- RG = reactive - grouts consisting of two or more compounds that must be mixed at the time of use on the construction site.

Figure 15 shows the classification of grouts according to this standard.

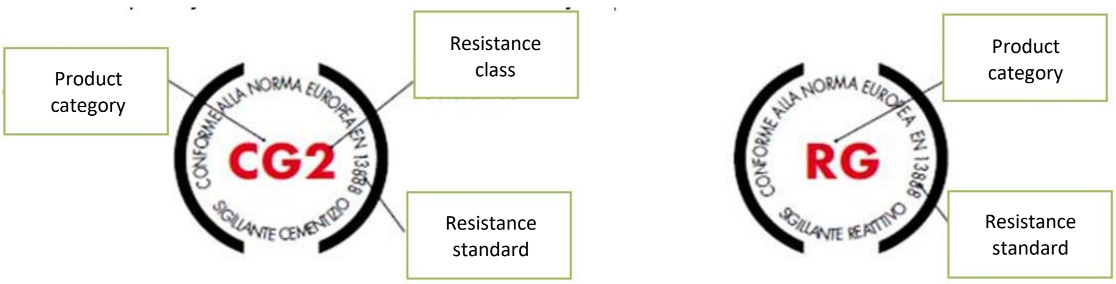

Figure 15. Classification of grouts

- Regulation EN 14891:2017 is a regulation that establishes criteria, test methods and requirements for conformity evaluation, classification and marking of liquid-applied water impermeable products for use beneath ceramic tiling bonded with adhesives. According to this regulation, products are classified into three types:
  - CM - cementitious liquid-applied water impermeable products,
  - DM - dispersion liquid-applied water impermeable products,
  - RM - reaction resin liquid-applied water impermeable product.

In order for the product to comply with the standard, it must have, among other things, an adhesion strength ≥ 0.5 N/mm² in all tests, a bridge resistance ≥ 0.75 mm and must not allow water penetration. The following additional characteristics are provided for each type:

- O - products with bridge resistance ≥ 0.75 mm at low temperatures (-5 °C),
- P - products that have a minimum adhesion resistance ≥ 0.5 N/mm², even after testing with chlorinated water.

- Regulation UNI 11493:2017 is a regulation that serves as a guide for the production of a professional floor or covering that can ensure long-term application. It consists of two parts:
  - Part 1. "Instructions for design, installation and maintenance", defines the quality and performance of ceramic tiles, provides rules and instructions for material selection, design, installation, use and maintenance and specific typical solutions in accordance with standards, in order to ensure and maintain the required levels of quality and performance over time. It applies to all types of ceramic tiles. Some basic requirements that are found within it include: ceramic tile characteristics and requirements: regularity, durability, sustainability, safety,

  - requirements related to underlays: aging, conditions, compact state, resistance, dimensional regularity, surface finish and moisture,
  - selection and specification of tiles, adhesives, grout materials and installation techniques related to project data,
  - requirements related to installation layout such as minimum joint width,
  - requirements related to connections,
  - design solutions for some important solutions: heated floors, swimming pools, terraces, facades, installation of large format tiles,
  - installation: verifications, checks and procedures,
  - instructions for proper maintenance.
  - Part 2. "Knowledge, skills and competences for ceramic floor and wall tile installers", defines the role of the installer, highlighting the basic requirements along with a body of knowledge, skills and competences.
- EN 13813 is a regulation that establishes test criteria and methods (Figure 16) for the classification of ready-mixed mortars[5] for screeds as follows:
  - CT = ready-mixed cementitious screed mortars - cement-based powder mortar that is mixed with water at the time of use on the construction site,
  - C = compressive strength after 28 days (N/mm²),
  - F = flexural strength after 28 days (N/mm²),
  - A1 fl = flame resistance.

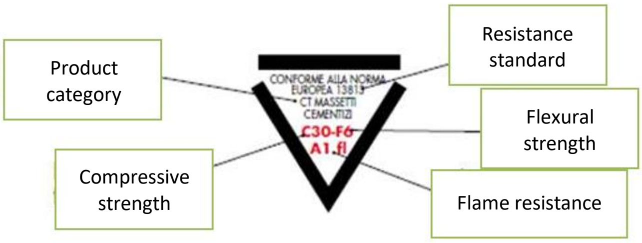

Figure 16. Classification of mortars

- Regulations EN 1504 and CPR 305/2011 establish the criteria and requirements for the evaluation of conformity, classification and description of products for the protection and renovation of concrete structures. It consists of 10 parts, and some of the most important ones are summarized below:
  - Part 2 - specifies the requirements for the identification, performance (including durability aspects), safety and conformity evaluation of products and systems used for the protection of concrete surfaces, in order to increase the durability of concrete structures and reinforced concrete, as well as for new concrete and for maintenance and renovation works,
  - Part 3 - the products are classified as structured and unstructured products and are divided into classes as follows Class R4 / Class R3 | Class R2 / Class R1. To be classified as class R4 and R3, products must have higher resistance in all prescribed tests compared to class R2 and R1 products, must have a higher elastic modulus than the limits set by the standard and must pass the carbonation resistance test,
  - Part 5 - defines and specifies requirements for products and systems which, when injected into a concrete element, restore the integrity and durability of the structure, being used for filling cracks, voids and interstices in concrete

[5] Construction mortar is a mixture used to bind building elements, such as brick, stone or ceramic tiles. It consists of binding material (cement, lime), aggregate (sand) and water.

for the transfer of forces (Category F), for ductile filling of cracks, voids and interstices in concrete (Category D) and for expansive filling of cracks, voids and interstices in concrete (Category S),

- Part 7 - the standard specifies requirements for the identification and performance (including durability) of products and systems used for active coatings or barrier coatings to protect existing uncoated and buried reinforcing steel in concrete structures being renovated [5].

9. CONCLUSION

Architecture is much more than shaping the space and erecting buildings. It shapes the way we perceive the world around us and influences our daily lives, from how we move through space to how we feel within it. Materials play a key role in architecture because the choice of materials defines the character and atmosphere of a space. The same space, designed with different materials, can completely change the atmosphere and user experience. Carefully considered selection allows architects and designers to express unique ideas, creating spaces that are not only functional but also aesthetically appealing. Their availability allows the creation of sustainable spaces that meet today's needs and use resources responsibly.

Ceramics are a particularly interesting example of a material that has undergone a major development. Once used almost exclusively as wall or floor coverings, ceramics are now one of the most important materials in modern architecture and design. Thanks to technological innovations, ceramics are today also used for facade systems, decorative panels, and even furniture. The ability of ceramics to imitate other materials - such as stone, wood, or metal - allows designers to achieve different aesthetic effects without compromising quality or durability. In addition, ceramics are environmentally sustainable, fire, water and weather resistant, which makes them a perfect choice for modern buildings that require durability and low maintenance. With all these possibilities, architecture today is in a position to become even more responsible and innovative than before. The quality of materials, their sustainability and aesthetic values play a key role in designing the spaces of the future. Architects, who today have access to a rich spectrum of materials, are no longer limited by traditional techniques and styles, but can explore new possibilities and create innovative, sustainable spaces. Ultimately, architecture and material design will continue to develop, enriching our spaces, both interior and exterior, and creating an environment that reflects the values of modern society – responsibility, innovation and aesthetics.

REFERENCES

1. Filetin, T., Kramer, I.: Tehnička keramika, 2. izdanje. Fakultet strojarstva i brodogradnje, Zagreb, 2005.
2. Ćurković, L.: Keramika, beton i drvo – skripta, Zagreb, 2011.
3. URL 1: https://www.porcelanosa.com/en/ (Accessed: 22.5.2025)
4. URL 2: https://www.panaria.net/ (Accessed: 22.5.2025)
5. URL 3: https://www.laticrete.com/ (Accessed: 22.5.2025)