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RESEARCH ARTICLE
Ceramic

3D Sgraffito on Ceramic Surfaces

Seramik Yüzeylerde 3B Sgraffito

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ABSTRACT

This study explores the application of computer-aided designs (CAD) to clay surfaces using the Sgraffito engraving technique. The project aimed to modernize traditional Sgraffito techniques by employing computer-controlled engraving machines, allowing for enhanced precision and repeatability. Various types of clay bodies—plastic, leather-hard, and dry—were tested to identify the optimal hardness level for machine engraving. The results indicated that leather-hard clay provided the best outcomes, minimizing issues such as chipping and dust formation that were observed in softer and drier clay bodies. The initial phase involved developing a 3D ceramic printer. The mechanical components were assembled, and software such as Carbide Create and Candle were used to generate engraving codes and control the printing process. The study further examined the impact of different end mill types and engraving depths, finding that flat-surfaced mills provided more consistent results at various depths. To enhance the contrast of the engraved designs, a black engobe mixture (70% clay, 20% feldspar, and 10% black stains) was applied in two coats to the ceramic surfaces before engraving. Following the engraving, the tiles were dried, biscuit-fired, and glazed using a spraying technique, resulting in a smooth, uniform surface. This research demonstrates that combining traditional Sgraffito methods with modern CAD tools and 3D printing technology enables the creation of high-quality ceramic tiles with greater precision and efficiency. The successful adaptation of these techniques can pave the way for further innovations in ceramic art, preserving traditional aesthetics while embracing contemporary digital methods.

Keywords: Ceramic, Sgraffito, CAD, Design, 3D Printing

ÖZET

Bu çalışma, bilgisayar destekli tasarımların (BDT) Sgraffito kazıma tekniği kullanılarak kil yüzeylere uygulanmasını incelemektedir. Projede, geleneksel Sgraffito tekniklerini modernize etmeyi amaçlayarak, bilgisayar kontrollü kazıma makineleri kullanılmış ve bu sayede daha yüksek hassasiyet ve tekrarlanabilirlik sağlanmıştır. Makine kazıması için en uygun sertlik seviyesini belirlemek amacıyla plastik, deri sertliği ve kuru olmak üzere çeşitli kil türleri test edilmiştir. Sonuçlar, deri sertliğinde olan kilin, daha yumuşak ve kuru kil türlerinde gözlemlenen kırılma ve toz oluşumu gibi sorunları en aza indirerek en iyi sonuçları verdiğini göstermiştir. İlk aşamada bir 3B seramik yazıcı geliştirilmiştir. Mekanik bileşenler bir araya getirilmiş, kazıma kodlarını oluşturmak ve baskı sürecini kontrol etmek için Carbide Create ve Candle gibi yazılımlar kullanılmıştır. Çalışmada ayrıca farklı uç freze türleri ve kazıma derinliklerinin etkisini incelenmiş ve düz yüzeyli frezelerin çeşitli derinliklerde daha tutarlı sonuçlar sağladığı tespit edilmiştir. Kazınmış desenlerin kontrastını artırmak için kazıma öncesinde seramik yüzeylere iki kat halinde siyah engob karışımı (yüzde 70 kil, yüzde 20 feldispat ve yüzde 10 siyah boyalar) uygulanmıştır. Kazıma işleminden sonra karolar kurutulmuş, bisküvi pişirimi yapılmış ve püskürtme tekniği kullanılarak sır uygulanmıştır. Bu araştırma, geleneksel Sgraffito yöntemlerini modern BDT araçları ve 3B baskı teknolojisi ile birleştirmenin, daha yüksek hassasiyet ve verimlilikle yüksek kaliteli seramik karolar oluşturulmasını mümkün kıldığını göstermektedir. Bu tekniklerin başarılı bir biçimde uygulanması seramik sanatında yeni ifade biçimlerinin ortaya çıkamasını sağlayabilir.

Anahtar Kelimeler: Seramik, Sgraffito, BDT, Tasarım, 3B Baskı

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INTRODUCTION

Sgraffito is a decorative technique derived from the Italian word "graffiare," which means "to scratch." The technique involves carving through a layer of colored slip or paint applied to the surface of ceramics to reveal the contrasting layer beneath, creating intricate patterns and designs. In Italian, it is referred to as "sgraffia" or "sgraffituna." From the 17th century onward, the term "sgraffito" was adopted in French to denote engraving and gradually became the standard term used in international ceramic literature. It is also known as "krantputz" in German, "graffiato" in Spanish, and "kakiotoshi" in Japanese, demonstrating its widespread adoption across different linguistic and cultural contexts (Yardımcı & İrdelp, 2013).

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The history of sgraffito is deeply intertwined with the development of ceramic art and has been used as a decorative technique since ancient times. It was first employed in the early ceramic works of Ancient Greece, Rome, the Far East, Europe, and Islamic civilizations, where it evolved into distinct styles and forms. During the Roman Empire, ceramics were often coated with a fine-grained red slip and adorned using the sgraffito method, followed by firing in an oxidizing atmosphere. Between the 11th and 17th centuries, the Byzantines frequently utilized this technique, producing sgraffito decorations using lead glazes in shades of green, yellow, and turquoise, reflecting the cultural and social dynamics of the period (Bozkurt, Bayındır, & Çukurcalıoğlu, 2014; Lamb, 1999).

In contemporary ceramic art, sgraffito continues to be a prominent decorative method, adapting to modern advancements in ceramic technology. Today, colored ceramic slips have largely replaced traditional slips, expanding the color palette available for sgraffito works and enhancing its visual appeal. This technique is commonly implemented using three main approaches: underglaze, inglaze, and overglaze, each producing unique aesthetic effects depending on the properties of the ceramic body and the artist's stylistic intent (Yardımcı & İrdelp, 2013).

In education, the integration of sgraffito into art curriculums has been shown to foster critical skills such as patience, precision, and attention to detail among students. This technique also plays a crucial role in preserving traditional craftsmanship by connecting younger generations with cultural heritage. Studies suggest that incorporating sgraffito into art education programs, particularly in regions like Kütahya, where this craft is historically significant, would not only contribute to the conservation of this unique art form but also enhance aesthetic competencies among students (Bozkurt, Bayındır, & Çukurcalıoğlu, 2014).

From a broader perspective, sgraffito is not only a decorative technique but also a means of safeguarding cultural heritage. Its application in historic buildings preserve both the aesthetic and structural integrity of these sites. In European cities, many buildings featuring sgraffito decorations have survived into the modern era, making it imperative to prioritize correct contractor selection and project management to prevent further degradation (Morkūnaitė, 2019).

Sgraffito remains a vital and versatile technique in both traditional and modern ceramic practices. Its historical significance, coupled with its ongoing evolution through modern technology and education, ensures that Sgraffito continues to be a valuable method of artistic expression. Whether used in pottery, tiles, or architectural surfaces, Sgraffito offers a unique blend of artistry and craftsmanship that transcends time and cultural boundaries.

The emergence of three-dimensional (3D) printing technologies, also known as additive manufacturing (AM), represents a manufacturing revolution. 3D printing is a set of advanced manufacturing techniques that fabricate parts from 3D CAD models digitally sliced into 2D cross-sections. This allows for the flexible creation of complex and precise ceramic structures that are challenging to achieve with traditional methods like casting or machining. Consequently, the application of 3D printing in ceramics enables the efficient preparation of intricate and customized designs, enhancing production speed and enabling the use of diverse feedstock materials (Chen et al., 2019)

In all mediums, the criteria for refining material play a significant role in determining an object's visual characteristics. Clay, as a uniquely amorphous material, exhibits a diverse aesthetic range shaped by multiple distinct factors that set it apart from other substances. The physical methods used to shape clay are typically divided into three main categories: hand-building, wheel-throwing, and slip-casting. While each of these techniques employs unique processes to create ceramic objects, they also produce distinguishable aesthetic outcomes. Recently, within the historical context of ceramics, a new category—digital manufacturing—has begun establishing its position in the field (Chau, 2017).

In this experimental study, Sgraffito—a technique traditionally performed by hand—was adapted and implemented using a computer-controlled engraving machine to enhance precision and repeatability. The study was carried out in collaboration with the State University of New York Ceramics Department, which provided essential materials such as clay, color stains, and glazes. The department also supplied studio equipment, including glazing tools, electric and gas kilns, and 3D ceramic printers. Throughout the first six months of the project, regular consultation meetings were held with Associate Professor Bryan Czibesz to discuss progress and refine the application process. The process of producing a printer that engraves on ceramic surfaces was initiated. The mechanical parts were assembled, and the electronic circuits were connected. The configuration and firmware processes were then completed. The 'Carbide Create' software was used to generate engraving codes, and its templates were employed for initial experiments on ceramic materials. These templates enabled the application of designs onto ceramic tiles with varying hardness levels, using end mills of different thicknesses.

Experiments on Sgraffito in Ceramic Tiles

The initial testing involved three types of clay bodies: plastic consistency, leather-hard, and dry. A 'V'-shaped end mill with a depth of 13mm was applied to all three clay bodies. The aim was to identify the most suitable clay hardness for Sgraffito techniques. Traditionally, hand engraving in Sgraffito requires the clay to be at a leather-hard stage. However, various clay body hardness levels were tested in this study to determine the optimal condition for machine engraving.

Clay chipping was observed at the edges of the lines during the engraving process on plastic consistency clay (see Image 1). This issue caused complications in complex patterns, as the chips adhered to the surface, making cleaning difficult and resulting in pattern distortion.

Fragmentation was observed on the clay surface during the engraving process on dry ceramic tiles, leading to surface breakage on both sides of the engraved lines. Moreover, the process generated dust particles, posing potential health and safety risks in the working environment.

Engraving on leather-hard clay resulted in the accumulation of clay chips on both sides of the engraved lines. However, due to the clay's hardness, these chips did not adhere to the surface and could be easily removed either during or after the engraving process.

Image 1. Clay chips on the surface.
Source: Sanver Özgüven's Archive

Following the testing of three different types of clay, a predetermined template design was applied to leather-hard ceramic tiles using the Carbide Create software (see Image 2).

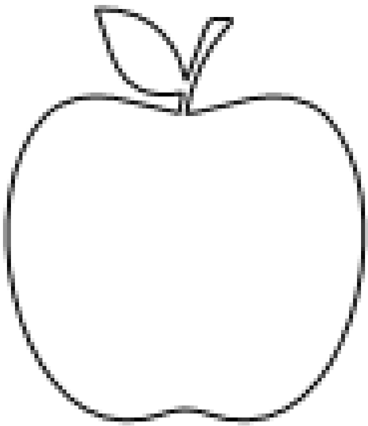

Image 2. A template drawing in Carbide Create.
Source: Sanver Özgüven's Archive

In Carbide Create, a printing area of 65 x 65mm was defined, and engraving codes were generated for depths of 0.1mm, 0.2mm, and 0.4mm. These codes were tested on clay to determine the optimal end mill diameter for the Sgraffito technique at various depths.

Image 3 illustrates an example of the Sgraffito technique, which was performed using a 'V'-shaped end mill at an engraving depth of 0.1mm. In this process, the leather-hard clay was first coated with a layer of blue engobe, which was allowed to dry completely before the engraving began.

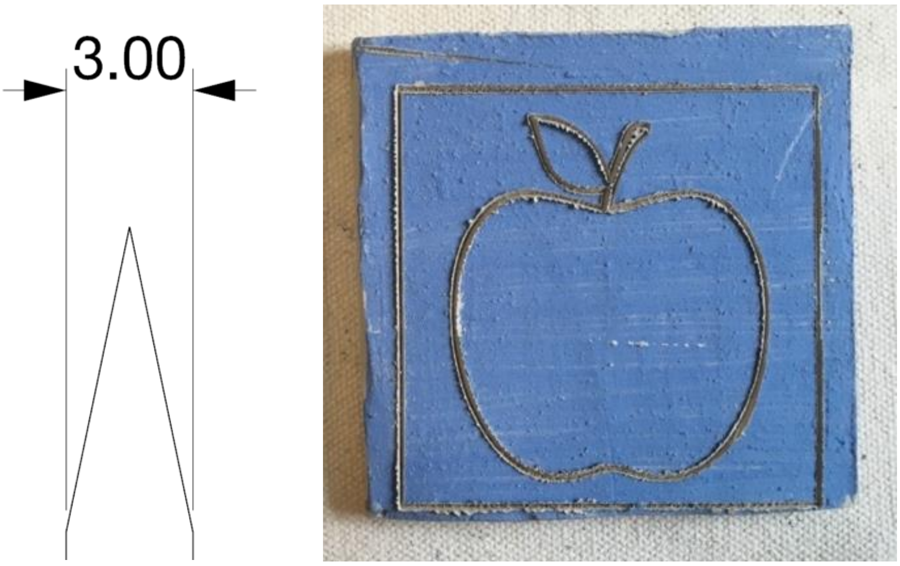

Image 3. Sgraffito testing on tiles, 0.1mm depth.
Source: Sanver Özgüven's Archive

For the second test, an engraving at a depth of 0.2mm was created using the same template design and end mill type (see Image 4).

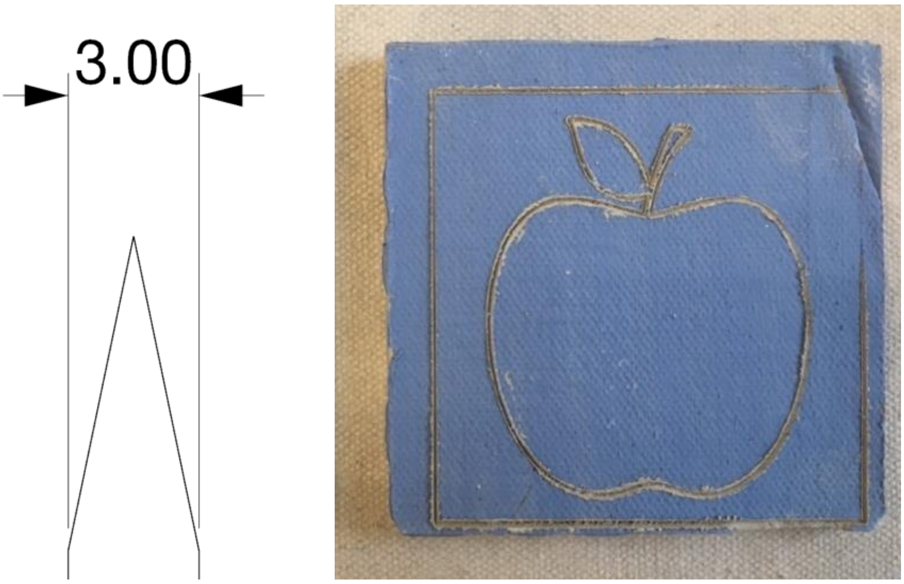

Image 4. Sgraffito testing on tiles, 0.2mm depth.
Source: Sanver Özgüven's Archive

For the third test, the same image was used, but a different type of end mill was employed. This end mill, featuring a flat surface of 0.1mm, resulted in an engraving depth of 0.1mm, as illustrated in Image 5.

Image 5. Sgraffito testing on tiles, 0.1mm depth.
Source: Sanver Özgüven's Archive

When comparing the two types of end mills, the flat-surfaced end mill yielded better results. In the subsequent stages of the study, engraving operations were continued using fully flat end mills. However, challenges were encountered with deeper engravings due to the 'V'-shaped profile of the flat end mill. As the engraving depth increased, the line thickness also increased. Consequently, a different type of end mill with a flat surface was tested.

Two additional tests were performed using a 0.8mm end mill at depths of 0.1mm (see Image 6) and 0.4mm (see Image 7). Despite the increased depth, the line widths remained consistent due to the shape of the end mill.

Image 6. Sgraffito testing on tiles, 0.1mm depth.
Source: Sanver Özgüven's Archive

Image 9. Sgraffito testing on tiles, 0.4mm depth.
Source: Sanver Özgüven's Archive

Based on the test results, 0.8mm diameter end mills were used for engraving ceramic tiles.

Preparation of Ceramic Tile

Following the engraving tests on clay bodies, designs for ceramic tiles was created using Rhinoceros software. The tile dimensions were set to 110mm x 110mm and featured Trojan patterns. This design was then applied to clay surfaces using the Sgraffito technique with a computer-controlled printer.

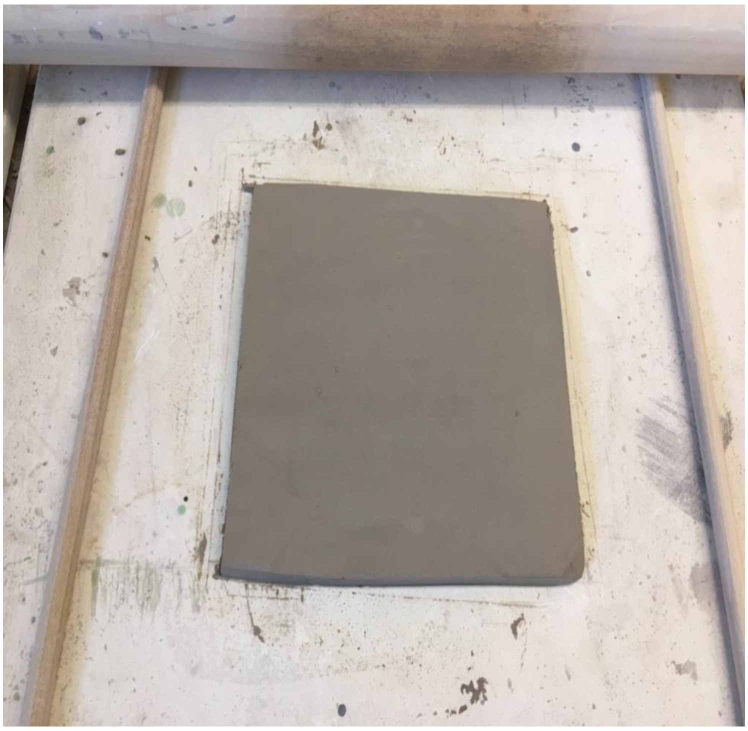

Image 10. Preparation process of a tile.
Source: Sanver Özgüven's Archive

Ceramic slab, measuring approximately 120mm x 120mm with a thickness of 6mm, was shaped using a roller. After shaping, the slab was dried for one day under controlled conditions to achieve the desired level of hardness for engraving (see Image 10).

Once dried, the surface of the ceramic tile was flattened using a saw and scraper. This step is crucial for ensuring consistent and uniform engraving depth.

Engobe Application Process

After the surfaces were flattened, a black engobe was applied to the tiles for the Sgraffito technique, with two coats applied to each tile (see Image 11). The engobe mixture was composed of 70% clay, 20% feldspar, and 10% black stains.

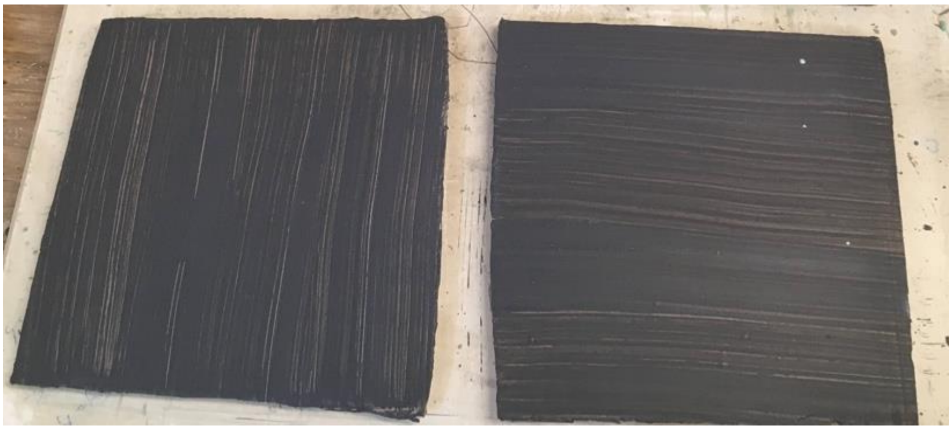

Image 11. Tiles with black engobe.
Source: Sanver Özgüven's Archive

Design and Production Process of Ceramic Tiles

Three different software programs were used to design tile patterns, generate codes, and control the printer.

1- Rhinoceros: The designs were created using Rhinoceros and saved in DXF format.

2- Carbide Create: Engraving codes were generated using the program and exported as an NC file.

3- Candle: Controlling the printer and reading the NC codes.

The engraving area was established as 120mm x 120mm, slightly exceeding the dimensions of the ceramic tiles (110mm x 110mm) as defined by the Carbide Create software parameters. The depth of the engraving was set to 0.2mm.

The tile design was inspired by Trojan art. The horse image was digitally redesigned using Rhinoceros software for the foreground, while a geometric pattern was created for the background. The design was then saved as a DXF file and imported into Carbide Create, where it was further refined, and the tile dimensions and engraving depth were set. The engraving depth was specified as 0.2mm, with a plunge rate of 500mm/min, a feed rate of 300mm/min, and a rotational speed (RPM) of 10mm/min. The engraving spindle diameter was set at 1mm.

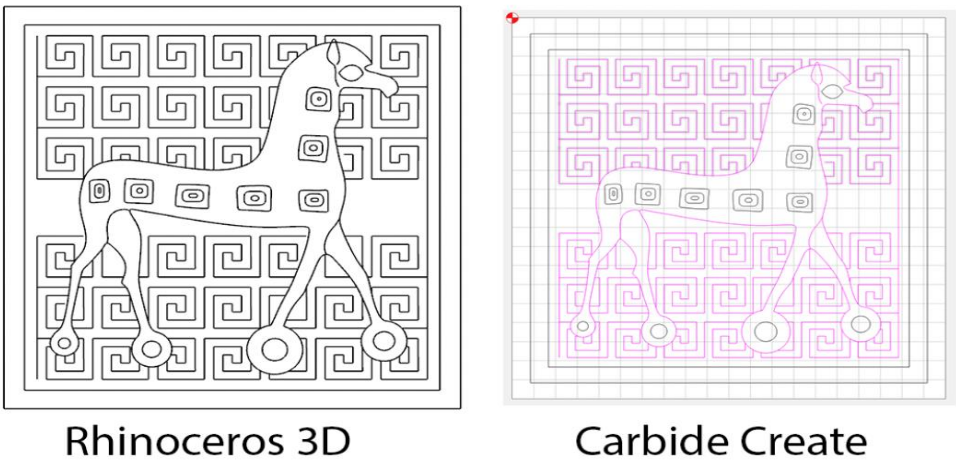

Image 12. Design process of tile
Source: Sanver Özgüven's Archive

The pattern was segmented into five distinct sections, and separate codes were generated for each. Each section was engraved onto the ceramic tile surface using the Candle software. Following the engraving process, the tile was refined and trimmed along its edges, then dried under controlled conditions to prevent deformation.

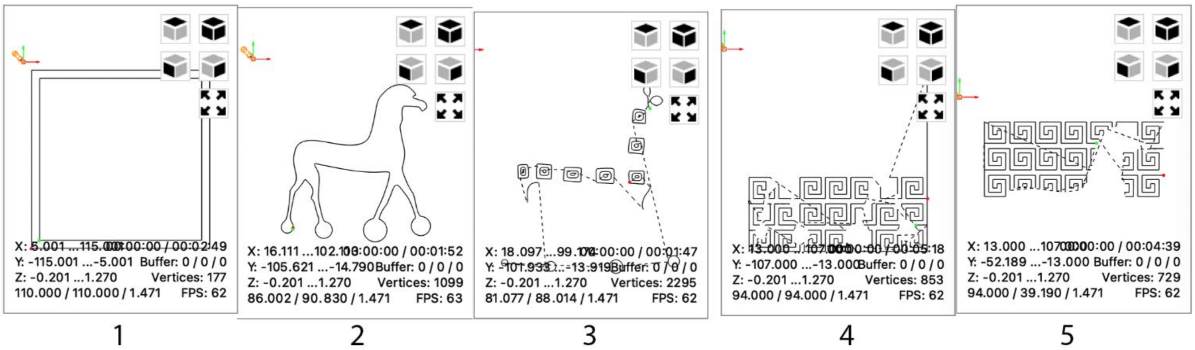

Image 13. Design process
Source: Sanver Özgüven's Archive

Image 14. Engraving process
Source: Sanver Özgüven's Archive

Firing and Glazing of Ceramic Tiles

Upon completion of the engraving process, the ceramic tiles were dried under controlled conditions to prevent any undesirable deformation of the clay. Following the drying stage, the tiles underwent biscuit firing.

The ceramic tiles were biscuit fired in top-loaded kilns at a temperature of 980°C. Subsequently, a transparent glaze was applied using a spraying technique to achieve a thinner and smoother surface.

Image 15. Results of ceramic tile.
Source: Sanver Özgüven's Archive

CONCLUSION

The experimental study on 3D Sgraffito explores the modernization of traditional ceramic engraving techniques using advanced technology. The project, supported by the State University of New York Ceramics Department, aimed to integrate computer-aided design (CAD) into ceramic art by applying sgraffito on ceramic surfaces with the help of three-dimensional ceramic printers. This modernization approach not only preserved the traditional aesthetics of sgraffito but also introduced new levels of precision and efficiency to the technique. The use of digital tools like Rhinoceros software for design and Carbide Create for engraving code generation allowed for detailed, repeatable patterns on ceramic tiles, offering a significant advancement over traditional hand-engraving methods.

The process began with testing various types of clay—plastic consistency, leather-hard, and dry—to determine the most suitable medium for 3D engraving. Leather-hard clay proved to be the most effective, minimizing issues like chipping and dust that were problematic with softer or drier clay bodies. The use of different end mills and engraving depths further optimized the results, with flat-surfaced mills producing the cleanest engravings at depths between 0.1mm and 0.4mm. This experimentation provided valuable insights into the technical requirements for successfully adapting Sgraffito to a machine-based process.

The study highlighted the challenges and solutions encountered during the application of the Sgraffito technique. One key finding was that the hardness of the clay played a critical role in achieving clean engravings without damage to the surface. Engraving on plastic clay caused chipping, while dry clay was too brittle, leading to fragmentation. Leather-hard clay struck the right balance, allowing for detailed engravings without significant surface damage. Another important aspect of the process was the application of engobe—a slip made of 70% clay, 20% feldspar, and 10% black stains. This was applied in two coats before engraving, ensuring a contrast between the surface and the engraved lines. The success of the technique depended not only on the precise control of the engraving process but also on the careful preparation of the clay and engobe.

Following the engraving, the ceramic tiles were dried, biscuit-fired, and glazed. The study employed a combination of traditional glazing methods and modern spraying techniques to achieve a smooth, uniform surface. This marked a notable improvement over earlier experiments where dipping and brushing methods led to uneven glaze application. The use of spraying ensured a thinner and more consistent glaze, which enhanced the overall appearance of the tiles.

In conclusion, this study demonstrates the potential of combining traditional ceramic techniques like sgraffito with modern digital tools and machine-based processes. By applying CAD software and 3D ceramic printing, the project was able to produce intricate, high-quality engravings that maintain the aesthetic value of traditional craftsmanship while benefiting from the precision and efficiency of modern technology. This innovative approach not only preserves the heritage of ceramic art but also opens new possibilities for its future development. The successful application of 3D Sgraffito on ceramic tiles exemplifies how traditional and contemporary methods can be merged to create unique and visually compelling artworks.

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