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UTILIZING MODERN METHODS AND TECHNOLOGIES IN CONCRETE DESIGN PRODUCTS

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Abstract: *This report examines the process of designing, engineering, and manufacturing an outdoor conversation fire pit using contemporary concrete product design and modeling technologies. The item in question is voluminous and substantial in weight, and its shape is difficult to achieve, as it requires great precision and symmetry. The goal is to create a distinction between the traditional methods for sculpting natural stone and the newly developed software and technical concepts for creating modern concrete products. Thus the main pros and cons of the processes in the industry will be highlighted, based on the technological time of manufacture, resources and materials, quality of details, and the value of the final product.*

Key words: *Concrete, 3D modeling, molds, design.*

1. INTRODUCTION

If we were to answer the question "What is the design style of the 21st century?" it would be challenging to provide a definitive answer.

In the past, different periods such as the Baroque, Renaissance, Rococo, and others have defined not only art but also architecture, music, literature, clothing, furnishings, and everything else related to the development of human civilization. However, nowadays we cannot boast the same kind of cohesion, as each area is influenced by various factors that define it as "modern and current." [1,2]

When it comes to interior and exterior design, we cannot pinpoint the exact names of contemporary trends, but there is certainly one style that is more popular and prominent: Minimalism.

Inspired by the phrase "less is more," it is highly favored in the design of upscale and luxurious buildings and spaces. Opulence, extravagance, and glitter give way to simplicity, clean lines, and natural colors. This shift is strongly influenced by the fast-paced lives of modern individuals, whose focus is primarily on functionality.

Modern minimalism embraces the use of clean and simple materials that create a sense of solidity, tranquility, and refinement. Materials such as natural wood, polished concrete, glass, and metal work best within this aesthetic. [3]

As society evolves and adapts to new lifestyles, design trends follow suit. For example, the rise of minimalist design in recent years can be attributed to the growing desire for simplicity and a focus on functionality.

The emergence of social media and digital platforms has also had a significant impact on the formation and dissemination of contemporary design trends. Platforms like Instagram, Pinterest, and design blogs have become sources of inspiration for both designers and homeowners. [4]

Inspired by a photo on the Internet, the project's clients decided to make a dug-in concrete conversation fire pit in their garden, with built-in benches forming a circle around the fire, where they could gather with family and friends.

Fig.1. The finished dug-in concrete fire pit, created entirely by modern software and technological processes

Fig.2. Another company's solution that offers a polygon shape, as round cannot be achieved by their technology

2. MAIN PROBLEM

2.1 Natural cut stone

The options proposed by competitors to the client for the construction of the fire pit were as it follows:

The first option involved using natural stone for the elements, which required hand-cutting granite. However, this process was not only extremely slow and labor-intensive but also very expensive because there is a large amount of leftover material post-cutting. Another drawback is that natural stone is highly porous and hygroscopic, drying much slower after rainfall compared to standard polished and sealed concrete.

Since the client wanted to maintain a minimalist design, the material choice was crucial, and they opted for polished concrete in its purest form, without any textured effects (which is a known natural stone attribute), to maintain an elegant and simplistic aesthetic in their yard.

2.2 Handcrafted concrete

The second option given involved handcrafting and casting concrete elements on-site.

While it was not impossible to execute, the cost and the time involved in the production made the tradeoff in quality and the pre-selected design completely futile. Traditional methods of reinforcing, plastering, and building concrete structures entail significant risks such as material cracking when applied in large quantities. Also, they can cause inhomogeneity and unevenness during inclined placement.

Another problem is the possibility of climate change while concrete is being cast. In high temperatures or during precipitation, the quality of the concrete deteriorates, or casting must be entirely suspended, lengthening the production process.

The client had already accepted the notion that the oval fire pit would take on the form of a polygon (Fig. 2) until they met our team, which presented them with everything that could be accomplished thanks to newly implemented technologies and modern design software.

We presented them with an innovative project and an entirely new technique of execution that fully met their requirements for visuals while providing excellent quality and durability over time. The cost was significantly lower, and the fabrication time was several times shorter.

3. PROBLEM-SOLVING

In today's rapidly evolving world, designers must stay up to date with the latest technologies to unveil new possibilities across various industries. In the fields of engineering, design, and manufacturing, it has become evident that integrating modern techniques, software, and robotics completely revolutionizes traditional practices.

Until recently, the creation of concrete conversation fire pits was solely done by hand and seemed unattainable for a large portion of the population. However, with a well-organized process and workflow system, it can now be achieved using cutting-edge technologies that offer unparalleled advantages and a more accessible price.

This article explores the significance of embracing new technologies in the pursuit of designing and manufacturing concrete garden fire pits with enhanced precision, speed, cost-effectiveness, and intelligence.

The days when manual labor and time-consuming processes were the sole means of bringing complex designs to life are long gone. With the advent of powerful software tools, designers and engineers can now visualize their concepts in two and three dimensions. These software applications facilitate the creation of intricate shapes and details that surpass the limitations of traditional methods. By harnessing the capabilities of automation and robotics, the production process of concrete elements has become faster, more precise, and more efficient.

4. CREATING MOLDS BY DIFFERENT METHODS

When creating a custom concrete product, figuring out a method to create its mold is of the greatest importance. It's most crucial due to the the final price of the product depending on it and also the quality of the casting, the time for finishing work, and the weight of the concrete element. The desired texture and the risk of linear distortions in the more elongated elements must be considered.

Another extremely important thing is to predict the number of castings needed in order to choose an appropriate mold-making method – them being disposable or reusable, respectively.

4.1 Two-dimensional design

The first step in designing the fireplace is creating a two-dimensional model through a technical drawing. (Fig. 3)

Thanks to the AutoCAD software, the necessary calculations of radii, distances, and dimensions were made. Additionally, all fireplace elements (seats, backrests, steps, base) were divided into composite parts with the same shape and size in order to create molds. This allows for faster production, reduces the volume and weight of individual elements, and facilitates the installation. It also avoids linear distortions that would occur in long castings, such as stairs. [5]

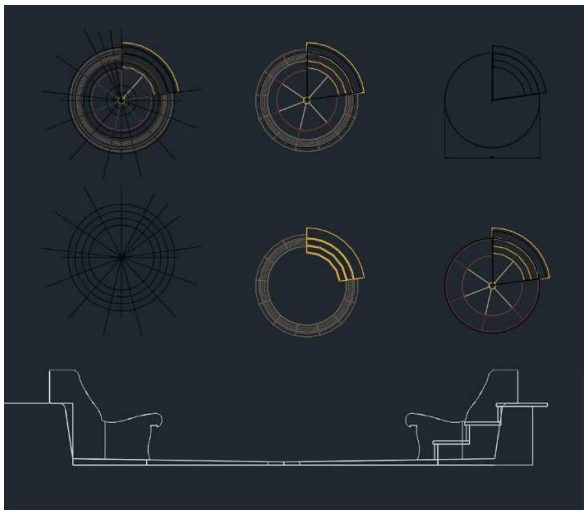

Fig.3. Two-dimensional drawing of the components of the fire pit, created in AutoCAD

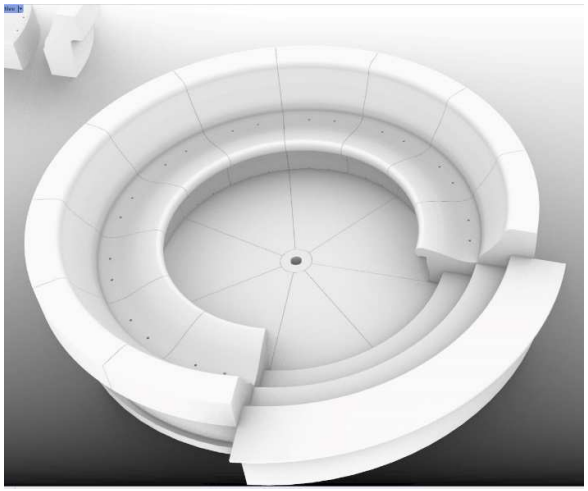

Fig.4. 3D model of the fire pit, made in Rhino

4.2 3D modeling

The next step is creating a 3D model (Fig. 4), which can be done using various 3D design software such as Blender, 3Ds Max, Rhino, etc.

We used Rhino for visualizing this project. In addition to illustrative purposes, the 3D design software was used to create the stair diagram as well as the most important 3D object, namely the seat and backrests.

The seating area is divided into two parts, a seat and a backrest respectively. This way they are easier to cast and install. It is important to include a drainage system to prevent water from pooling in the bottom of the seat. (Fig. 5) [6,7]

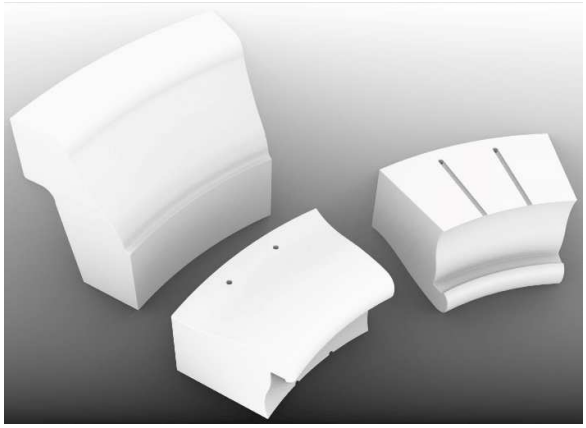

Fig.5. The two component parts of the seating area. The upside-down seat shows the water drain channels

4.3 CNC milling and traditional molding

Based on these 3D-designed elements, full-scale models are created from Styrofoam, which will serve as molds. The Styrofoam elements are cut using a three-axis CNC router.

These routers are equipped with cutting tools that rotate at high speeds, allowing for precise milling and shaping of materials. The method involves subtracting material (Styrofoam) until the desired shape of the element is achieved. The CNC router moves along predetermined trajectories, carefully removing material from the Styrofoam block. The cutting tool creates smooth and precise cuts, enabling the creation of complex details and shapes. [8]

Once the Styrofoam elements are cut, molds are made out of them (Fig. 6).

Fig.6. Styrofoam model milled on a CNC router

The most suitable method for creating molds of this shape and size is the traditional method, using polyester resin and fiberglass (glass cloth).

Traditional fiberglass molding, also known as fiberglass lay-up, has been widely used for years. It involves layering glass fabric with polyester resin to create a strong and durable composite material. The resin dries and hardens, bonding the glass fibers together to form a solid yet lightweight structure resembling a shell. This method allows for the creation of complex forms, and the molds themselves can be reused to produce hundreds of castings

The drawback is the time required for production, as each layer needs to dry before the next one is applied. [9]

The base of the fireplace, which serves as the actual floor, is the easiest element to mold.

The round base is divided into an inner and outer circle, each consisting of seven identical elements. Two types of matrices are created: red elements for the central part and green elements for the outer circumference. (Fig. 7)

CNC routing is also used here to cut pieces of formwork plywood that, when assembled, resemble a tray in which the concrete mixture is poured. It is important to monitor the ambient temperature when the concrete is drying so that cracks do not occur from the sudden drying of the mixture.

The advantage of this method is that it is extremely fast and cost-effective. The disadvantage is that only about ten castings can be made from one mold since the material (plywood) is not durable.

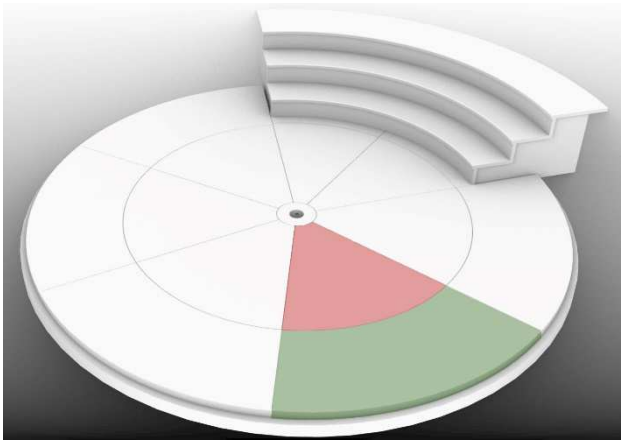

Fig.7. Elements whose mold is made of plywood

Fig.8. Steps cast in molds made using a vacuum-forming machine

4.4 Vacuum forming

For the stairs, another contemporary technology called vacuum forming was used (Fig. 8).

Traditionally, these machines are used to create blister packaging, but if the desired mold has a simple shape and low relief, this method is highly suitable.

The vacuum-forming process begins by heating a thermoplastic sheet until it becomes flexible. It is then pressed onto the mold, and vacuum is applied beneath the sheet, sucking out the remaining air. This causes the thermoplastic to adhere tightly to the mold, forming the contours of the mold. Once cooled and hardened, the resulting plastic retains the desired shape, which represents a negative of the mold.

The mold is ready for direct use, in just a few minutes.

Depending on the temperature of the room and the thickness of the sheet, the entire process ranges between 5 to 10 minutes. When it comes to the usual traditional methods of casting - they take 4-5 days to process a typical resin mold and finish each drying cycle.

In this case, we observe that with the vacuum forming method, the time is optimized about a thousand times.

The second aspect that distinguishes this process as being very effective is the ten times cheaper price of the raw material.

Since the final matrix is a negative of the relief, it can be used right away for the intended purpose. As a result, when polymer concrete is mixed and poured, the finished, dried product resembles the model exactly. This sort of mold is incredibly simple to detach from the casting due to the thin, smooth walls and flexibility of the thermoplastic material, which with other methods can occasionally be a huge difficulty due to the adhesion of the concrete to the resin.

The cost and production times are low, but the mold can yield no more than 80 to 100 castings. [10,11]

4.5 GFRC (Glassfibre Reinforced Concrete) technology

This is another modern technology used in creating the fire pit, thanks to which the final product is much lighter and there is no unnecessary material waste that would increase the cost of the end product.

GFRC is a technique used in creating concrete elements that offer several advantages.

It involves spraying a special mixture of concrete reinforced with alkali-resistant glass fibers onto the surface of the desired casting. (Fig.9)

In this case, the spraying of the concrete mixture is done on the molds made of resin and fiberglass, which are crafted for the seats and backrests of the conversation pit. After the first layer has dried, 2 to 4 more layers are applied depending on the density of the material and the desired thickness of the final product.

The result is a lighter and thinner concrete product with increased strength, improved crack resistance, and enhanced durability. This technique allows for the creation of complex forms, making GFRC a popular choice for architectural and decorative elements, and lightweight furniture. [12]

Fig.9. The image shows the process of spraying layers of concrete mixture on an uneven surface using GFRC technology [15]

5. ADVANTAGES AND DISADVANTAGES OF INTEGRATING MODERN TECHNOLOGIES

In order to be completely realistic in evaluating these methods, it is appropriate to consider the advantages and disadvantages of integrating modern technologies into industrial design and the production process of concrete products.

It would be challenging to stay relevant if we do not develop our processes at the pace at which the industry is advancing. In doing so, it brings numerous benefits for both manufacturers and consumers.

The use of software tools and automation significantly reduces the time required for design and production processes, enabling faster product delivery to meet market demands. The profitability of robotic processes allows for increased productivity on a larger scale, providing a competitive advantage in the industry.

Another crucial factor is the precision and accuracy achieved through technological integration. They guarantee consistent and unchanged quality, eliminating human errors and increasing customer satisfaction. For instance, we can ensure uniform shapes, textures, and color nuances in the production of concrete elements.

3D modeling and simulation software allows designers to visualize and evaluate their ideas with greater detail and precision. This saves a tremendous amount of time previously spent on experimental iterations. Nowadays, with programs like SolidWorks, all tests related to strength, hardness, tension, and durability can be conducted with exceptional accuracy in a matter of minutes. This not only saves time and resources but also enables informed decision-making.

Furthermore, advanced production technologies such as CNC machining facilitate the realization of complex designs, offering unparalleled levels of detail and customization.

The increased speed and effectiveness of design iterations is a further noteworthy benefit. Designers may quickly iterate and improve their designs with the use of computer-aided design (CAD) tools, developing many design variants and evaluating their performance in real time. This iterative method enables the development of alternate solutions and ongoing improvement, ultimately resulting in more creative and effective designs.

The use of new technology also encourages interdisciplinary cooperation and knowledge sharing. Designers may work fluidly with specialists from a variety of sectors, including engineering, material science, and production, by utilizing digital platforms and cloud-based tools. This idea of cross-pollination encourages an innovative culture and makes it possible to create ground-breaking solutions that holistically tackle difficult problems.

The possible drawbacks that could result from the use of new technology in design practice must be acknowledgeda

Overreliance on technology runs the risk of eroding the tactile and hand-eye coordination that are essential components of design. Designers may get disassociated from the sensory parts of their work when they are not physically interacting with the materials and processes, which can restrict their capacity to properly comprehend and utilize the expressive potential of various materials and approaches.

It's crucial to create a balance between utilizing new technologies and keeping conventional practices in order to avoid these potential downsides. We can build a profound appreciation for craftsmanship and the capacity to use technology successfully by giving them a strong foundation in traditional design techniques, materials, and processes.

Although we wanted to use as much innovative and modern software and technologies as possible to design and build the conversation fire pit, we still relied on the traditional method of creating a resin-fiberglass mold for the seats because it is still the most suitable and secure approach. This serves as yet another example of the need to be familiar with the methods used over the years in order to advance, streamline, and improve the manufacturing of design elements from concrete.

By combining the best of both worlds, engineers can leverage technology while staying in touch with the tangible and experiential aspects of design.

One of the main disadvantages of modernizing production processes is the initial investment cost associated with the acquisition and implementation of new technologies. Small or start-up manufacturers may face barriers to entry, limiting their ability to take full advantage of these technologies.

Additionally, there is a need for ongoing training and upskilling to ensure that designers and industry professionals are proficient in utilizing the latest software tools and machinery. Continuous education and professional development initiatives can equip individuals with the necessary skills to navigate the evolving landscape of technology-driven design and production processes. [13,14]

6. CONCLUSION

In conclusion, the integration of new technologies revolutionized design practice and industrial design, offering unprecedented opportunities for innovation, efficiency, and creativity.

The use of modern methods in the design of concrete products offers huge advantages, enabling designers to push boundaries, increase precision, and offer lower prices and shorter lead times to users.

As the internet offers a huge variety of innovative ideas and spectacular concrete elements, the demand for attractive, high-quality products continues to grow. In this case, staying up-to-date with the latest technologies becomes crucial for industry professionals

These technological advances have opened up new horizons, allowing designers to break down barriers and realize complex concepts that were once unattainable. However, it is equally important to recognize and preserve the value of time-honored methods as they embody the essence of craftsmanship, culture, and the human touch.

It is important to achieve the balance between innovation and tradition, recognizing the value of traditional methods, and embracing the possibilities that modern technology brings. By doing this, we can ensure that design practice continues to evolve, pushing the boundaries of creativity and delivering meaningful and impactful solutions to the world.

Production using contemporary methods is a lot more accurate and time-efficient. The design and ergonomics can be applied easily due to the given software calculations. Said software can offer a variety of 3D rendered visuals thus assisting the client when it comes to making the adequate choice. When it is compared to manufacturing elements out of stone it can be firmly stated and proven that the production of polymer concrete products is 4 times shorter than its predecessor of a method. Stone cutting requires 6,720 manual labor hours and thanks to the contemporary mold making and concrete casting the time is shortened by 3/4. Furthermore, the end product's price including the material cost, manual labor, and deprecation of machinery is still half as low compared to the stone-cut method of executing the project.

Last but not least the environmental aspect should be considered: by utilizing concrete to cast designs, there is little to no waste of product.

This makes the polymer concrete technology supreme to its predecessor in many and various ways as listed above, which we should consider going forward with the research and development in the given area.

7. ACKNOWLEDGMENT

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Utilizarea metodelor şi tehnologilor moderne în crearea produselor de design din beton

Lucrarea examinează procesul de proiectare, inginerie și fabricare a unui cuptor de grădină din beton folosind tehnici avansate. Combinația de software și tehnologie utilizată permite crearea de produse complicate din beton cu forme și detalii complexe care depășesc limitele metodelor tradiționale. Metodologia presupune proiectarea bidimensională și tridimensională, precum și realizarea de matrițe, folosind un router CNC cu trei axe și o mașină de formare în vid. O altă tehnologie folosită este GFRC (Glassfibre Reinforced Concrete), în care betonul este pulverizat pe matriță, mai degrabă decât turnat. Rezultatul este un produs mai ușor, cu o calitate a suprafeței sporită, o rezistență mai mare și un aspect modern și plăcut.

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