

## GEOMETRIC STUDY IN THE REALIZATION OF CONCRETE FURNITURE

**Abstract:** When we are looking to make a piece of furniture, indoor or outdoor, we immediately think that the requirements related to functionality, ergonomics, flexibility, aesthetics and design will be met. At the same time, through these pieces of furniture, we give the space personality. But in order to obtain the desired shape, we go through a series of studies based on geometrical study. With the unlimited possibilities offered by technology, we have the opportunity to obtain increasingly complex forms of furniture, with a high degree of industrialization, from various materials. Concrete is a beautiful, affordable, weather-resistant material, versatile and suitable for any space, interior or exterior. The purpose of this work is to present such a creative process and the stages that take place in the realization of the concrete furniture piece.

**Key words:** descriptive geometry, concrete, shape finding, furniture design, cylindroid, conoid, interior and exterior space design.

### 1. INTRODUCTION

As the fundamental piece in the arrangement of the space, the furniture is made by a complex design process. The evolution of furniture design is based on the continuous improvement of people's living standards and the rapid development of technology. In the past, people could create and produce furniture based on structural knowledge, basic geometric landmarks, so that it would be functional and provide the room with extra comfort and safety. That is why, in a relationship as tight as possible with the space, in the design process of the piece of furniture, the same principles of realizing the character and artistic expression are used as in architecture: "firmitas, utilitas, venustas", i.e. stability, utility, aesthetics, as Marcus Vitruvius Pollio said in the treatise "De Architectura", written between 30-20 BC.

Today, through a balanced relationship between form, practical function and aesthetics, designers fulfil the predestined purpose of the piece of furniture. But the furniture manufacturing technology has surpassed traditional construction principles and now, more than ever, we need a well-defined appearance and design. Thus, in order to meet the aesthetic requirements, one of the main conditions of the design object, we can turn to a geometric study of the form. Certainly, there are major differences in the design of furniture objects depending on their destination. However, at the present time, minimalism is taking shape, that is, the style in which the house is minimally decorated, only with the strictly necessary, the furniture bodies being simple, rectangular, symmetrically, orderly, straight and so on. For the most sincere relationship between form and material, since it is a minimalist form of contemporary modern furniture, concrete was used.

The purpose of the work is to show the way in which descriptive geometry, compositional geometric methods and processing in a computer program, Rhinoceros 7 software, facilitate the definition of shape in the design of concrete furniture. Geometric construction has been used many times in the past, both by artists and designers

recognized worldwide, as can be seen in the analysis of some design objects from the history of furniture, as well as some current examples that will generate future visions.

### 2. HISTORICAL REFERENCES OF THE GEOMETRIC STUDY IN FURNITURE DESIGN

Over time, the composition of volumes and geometric figures can be found in ornament, painting, sculpture, furniture and architecture. Geometric rules based on ideas of proportions and symmetries formed fixed tools for furniture design. With the elimination of ornament in the 1900s and the birth of new aesthetic currents between the two world wars, 1914 and 1933, minimal, geometric design was approached by artists such as: Josef Albers, Marcel Breuer, Frank Lloyd Wright, Theo van Doesburg, Bart van der Leek, Gerrit Rietveld, Robert van 't Hoff Wright, Figure 1 [1].



**Figure 1** 1. Josef Albers "Nesting Table"-1926 [2];  
2. Marcel Breuer "Wassily Chair"-1925 [3];  
3. Frank Lloyd Wright "Barrel Chair"-1904 [4];  
4. Theo van Doesburg "Corner Chair"-1920 [5];  
5. Gerrit Rietveld "Red Blue Chair"-1918/1923 [6];  
6. Robert van 't Hoff-1920 [7].

New technologies and new materials offer a variety of forms, among them is concrete, which we find everywhere around us: on the sidewalks under our feet, in architecture, in landscaping, in art or object design, a common material, which has long been the favorite of minimalists. For example, in a space, a coffee table can create a cold, industrial look. The atmosphere can then be enhanced by adding rugs to create a stunning contrast and give personality to the space. This material, usually associated with construction elements, allows the creation of spectacular, even light and delicate forms. Achieving these qualities depends on how it is used.



**Figure 2** Willy Guhl "The Loop Chair" [8].

In 1951 the Swiss company Eternit sent a letter about its proprietary material "fiber cement" to the Zurich University of the Arts administration, hoping that someone might find a new application for the weatherproof surface, used to make roof tiles and façade panels. Willy Guhl, the Swiss furniture pioneer, who was working there as a teacher, was the only one who took the prompt. [9] The Loop Chair by Willy Guhl, Figure 2, was first designed in 1954 for Eternit but its clean shapes and minimalistic approach make it just as relevant today.[10] In the same category of concrete furniture is the 'Paracarro' coffee table by Giovanni Offredi for Saporiti, 1970 Figure 3.



**Figure 3** Giovanni Offredi "Paracarro"[11].

The thick glass top sits on a concrete base with exposed aggregate finish and chrome cross bar supports. As simple as this design is, it is clearly very considered keeping inline with modern design styles of that period along with brutalism influences. [12] The furniture characterized by geometric shapes makes its presence in today's modern spaces, defined by a formal minimalism, modularity and flexibility in use through a reconfiguration of the whole. We can see that the geometric shapes represent a characteristic that highlights the contemporary style and gives personality

to the space. Through the High-tech movement style around 1970, Figure 4, the furniture design finds its refinement through the works of the apple architect Mario Botta and Richard Meier.



**Figure 4** 1. Mario Botta "Seconda Chair"-1982 [13];  
2. Richard Meier "Armchair #810A"-1982 [14].

In the Postmodernism movement around 1980s, the architect and designer Michele De Lucchi creates "First chair" Figure 5, utilizes geometric forms to mimic a sitter. A flat disc in black wood, edged in tubular metal, rests on four tubular metal legs. A circular hoop of tubular metal rises from the front legs, tilting backward at an acute angle and supporting both a turquoise disc at the top of the hoop, serving as a backrest, and two black balls that serve as armrests [15].



**Figure 5** Michele De Lucchi creates "First chair" [16].

Also in the Post-modern period, the artist Peter Shire creates "Bel Air Chair", Figure 6, whose geometry combines influence "by the Los Angeles culture of surfing and hot rodding, as well as Art Deco and 1950s Space Age architecture in Southern California and the state's mass culture." [17]



**Figure 6** Peter Shire "Bel Air Chair" [18].

### 3. DEFINING THE SHAPE OF THE FURNITURE DESIGN

#### 3.1 Geometric shapes

Everything that people can see in their lives is made up of geometric shapes. The forms and structures from nature that inspire artists, designers, engineers are the same as those that justify the development of geometric ideas. Natural elements contain certain geometric rules, which causes people to consider them pleasant. Likewise, in object design, geometry plays an important role, a role of controlling the harmony of forms, so that its absence would make the object not clearly defined. Thus, in order to have unity, a thing must have a certain simplicity, so that it can be easily understood by the human mind and produce delight.

Thus, for the realization of this furniture design, the ruled surface was used, which is a surface formed by the movement of a straight line through a space, which moves according to a certain rule. For instance, a line,  $D$ , lying on three arbitrary curves  $\Gamma_1$ ,  $\Gamma_2$  and  $\Gamma_3$  in the space, called directrices, may intersect three surfaces. The  $D$  line is then called generator of the ruled surface.

The non-developable ruled surfaces are generated by a line lying on three curved directrices Figure 7 [19].

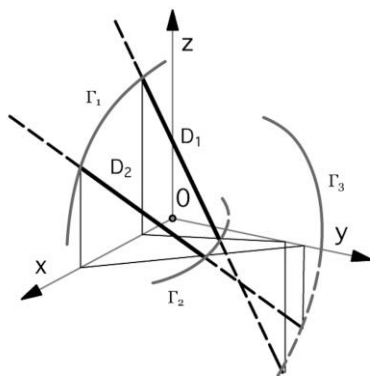


Figure 7 The non-developable ruled surfaces.

#### 3.2 The cylindroid

One of the surfaces that inspired parts of the furniture is the cylindroid. The cylindroid represents a warped surface with a directrix plane whose generatrix is supported on two directrix curves that are not situated in the same plane and which remains parallel to a given plane.

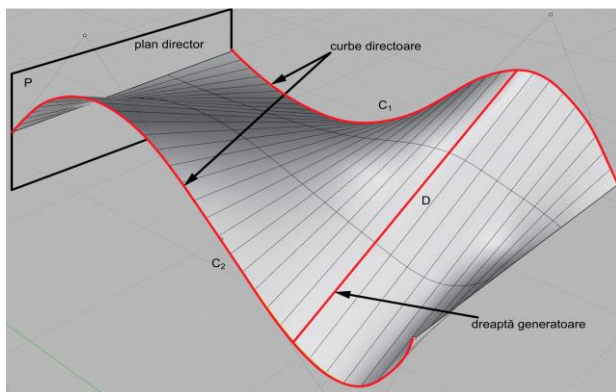


Figure 8 The cylindroid.

Figure 8 shows a cylindroid represented by the projections of the direction curves  $C_1$  and  $C_2$  of the generators and by the position of the direction plane  $P$ , projecting against the horizontal plane  $H$ . A generator is parallel to the direction plane, so in the horizontal projection it will be parallel to the horizontal trace  $P$  of the direction plane.

#### 3.3 The conoid

Another surface that inspired another version of the furniture is the conoid. The conoid surfaces are ruled surfaces generated by a straight line that lies on a straight directrix  $D$  and a curve directrix  $C$ , staying parallel at all times to a plane called director plane  $P$ , Figure 9 [20].

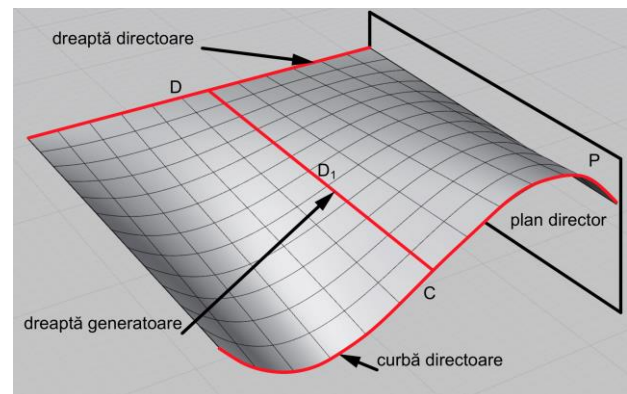


Figure 9 The conoid.

The conoid surfaces are a particular case of ruled surfaces, generated by a straight line that lies on three given arbitrary directrices, but where one of the directrices opens onward, creating the conoid with a director plane: it may be right or skewed. A right conoid with a director plane that has a circle as a curve directrix, as a directrix line a line parallel to the plane of the circle and as a director plane a plane perpendicular on the directrix line, Figure 10a.

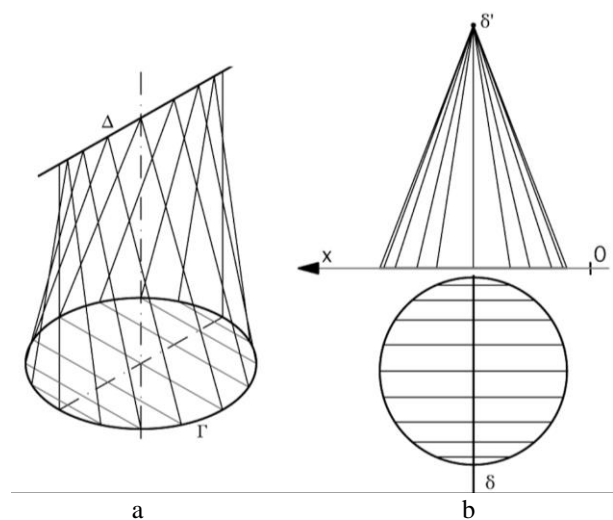


Figure 10 The right conoid.

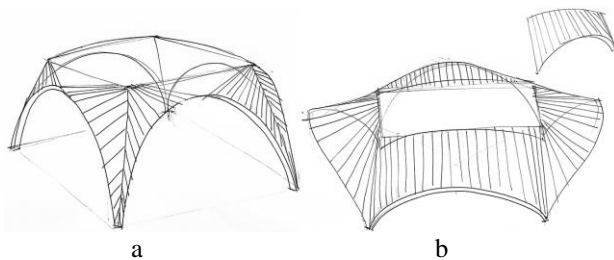
In Figure 10b we can see the double orthogonal projection of a right conoid. The two sheets of the conoid intersect after the straight-line directrix that is called the



surface's line of striction. This straight line represents the shortest distance between any two generators of the surface. Sometimes, the curve directrix  $\Gamma$  may be replaced with a surface  $S$ , tangential to all the conoid's generators. In this case the surface  $S$  is called a nucleus or a core. Thus we may define a right or skew conoid circumscribed to a given sphere. If the curve directrix  $\Gamma$  is a helical line then the conoid becomes a helical surface with a director plane. And if the curved directrix  $\Gamma$  is reduced to a straight line then the conoid may be confused with the hyperbolic paraboloid. The conoid surfaces are parabolic-like surfaces, meaning that in any of the surface's points one of the main curvature axes is infinite [21].

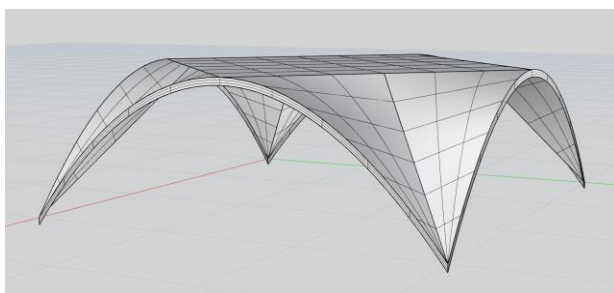
#### 4. DIGITAL DESIGN OF FURNITURE

Using the classical method of creating the modelling of the furniture object, through sketches and perspectives, it is not possible to effectively capture all the design requirements. Figure 11.a shows a version of the furniture that uses the conoid and Figure 11.b. presents a version of the furniture that uses the cylindroid.



**Figure 11** Hand sketches of the furniture.

In order to face these deficiencies and keep up with these requirements for modification, creation, analysis or optimization of a certain design, CAD computer based software, 3D was used, Figure 12.



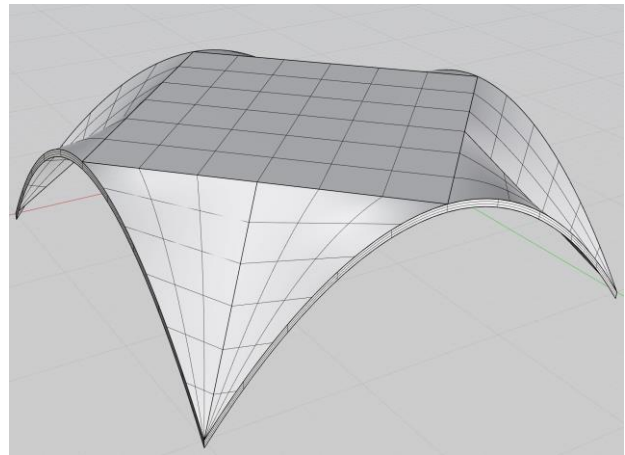
**Figure 12** Digital design of furniture.

Today we are faced with the challenge of satisfying an increasing demand on the consumer market in the execution of furniture objects and at the same time, of producing more and more complex shapes. This method facilitates the creation of the mould, the component elements prior to the creation of the final object and we can study in detail the quantities required in the composition of the concrete. Thus, the following quantities were obtained: Water - 6 liters; Acrylic polymer - 3 liters; Plasticizer - 0.1 kilograms; Portland

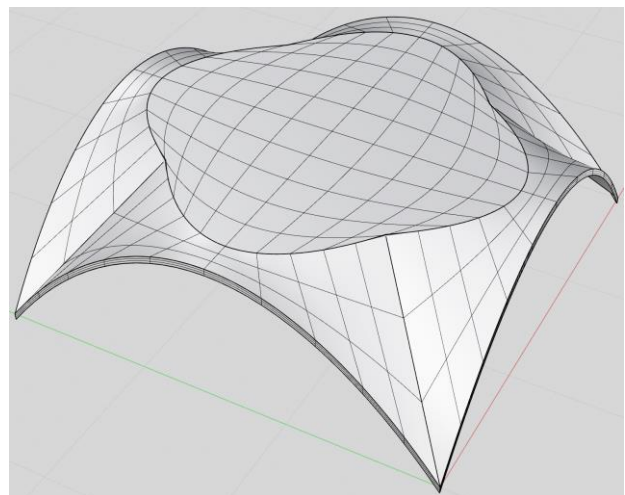
cement - 12 kilograms; Fine sand 0.1 - 0.3 mm - 15 kilograms; Coarse sand 1 - 2 mm - 6 kilograms; Glass fiber - 1 kilogram.

Having the ruled surfaces available were combined with a plane in a unique result, a concrete coffee table.

By adding geometric surfaces we obtain a combination of shapes with the help of alternation or repetition, so that the final shape is easily perceived. This design method is used when we have to deal with a few geometric surfaces. With the help of the computerized design of the furniture, we manage to eliminate the errors determined by wrong measurements, while offering at the same time the optimal method of assembling the various component parts, both of the mould and of the furniture, where appropriate Figure 13, that uses the conoid and Figure 14, that uses the cylindroid.



**Figure 13** Digital design of furniture using the conoid.



**Figure 14** Digital design of furniture using the cylindroid.

#### 5. FINAL RESULT

When one has theoretical knowledge in the field of composition, enriched by knowledge in the field of geometry and accompanied by an inner sensitivity of the designer, the obtained result reaches a high aesthetic quality.

The wet concrete became an immutable cast form, the solidified negative space of a mould. It is the end of a

process of amalgamation of materials, in the case of this table it is water, acrylic polymer, plasticizer, Portland cement, fine sand 0.1 - 0.3 mm, coarse sand 1 - 2 mm and fiberglass. Thanks to the glass fiber reinforcement, the concrete has a high resistance to bending and can be easily shaped into complex, three-dimensional shapes, which do not have to be thick to withstand its own weight and other external forces, Figure 15.



**Figure 15** Three-dimensional shape of the concrete.

Because the glass fibers are mixed in the mass of concrete, the resistance is everywhere in the volume of the piece of furniture. Fiberglass is usually between 6-50 mm long and 10 to 30 microns in diameter. It is recommended that 5% of fibers from the weight of the total cement mortar be included in the concrete mass, in order to obtain an optimal resistance to traction and compression.



**Figure 16** The mould.

The weight of the table has been substantially reduced due to the resistance of the glass fiber, which substantially reduces the thickness of the table, reaching 20 mm. When the mixture is placed in the mould, it must be compacted using vibration to remove air voids trapped in the concrete mass and to attract the pigment and cement particles to the desired surface, Figure 16.

It is essential that the mould is watertight, as any leakage of cement and pigment will leave an unsightly discoloration on the surface of the furniture item Figure 17.

The flat form was placed on a horizontal surface and the edges of the mould were raised to generate the conoidal surfaces during the pouring of the concrete, Figure 18.



**Figure 17** Placing the mold to make the conoid.



**Figure 18** Casting in pre-made mould concrete.

The material is able to take any shape, which facilitates its manufacturing process. The upper part, the underside surface of the table when standing vertically, is left exposed to be levelled with the trowel, after the manual vibration of the concrete mass has been achieved. The obtained result was left in the mould for at least 24 hours to harden before the formwork can be removed. A curved, fluid, soft plane was generated, which exemplifies movement through its shape, and through its silhouette it sends to a table top, a thin concrete surface, which usually sends to the immutable, petrification. A light honing smoothed the back and edges, and hand-sanding finished the rest of the surfaces.

The color of the table is that of simple, natural concrete and depends on the color of the cement, on the water/cement ratio – the higher the ratio, the lighter the tone, the lower it is, the darker the shade for the same cement, Figure 19.

With the help of creativity, you can get unique pieces of concrete furniture that will give any space a very special urban air.



**Figure 19** Final result.

## 7. CONCLUSIONS

As could be seen, the use of geometry cannot be missing in the design of a furniture object and the process of making it will select appropriate geometric constructions. The application of the geometric support is possible right from the beginning of making the sketches and drawings. What defines the designer's creative process is an optimal ratio of artistic research, geometric knowledge and artistic talent. This harmonious connection between science and the inner sensibility of the designer gives birth to objects of a very good aesthetic quality. Furniture was studied throughout history and we were able to observe a suite of unique examples of furniture, which used volume or geometric figures, and later, with the discovery of reinforced concrete, pieces of concrete furniture stood out. The combination of the two features, geometric volume and the concrete material presents several important advantages: durability, modern appearance through the simplicity offered by the form, easy to maintain being concrete treated with water-repellent solution, suitable in any type of space, interior or exterior, which gives a non-conformist note. Then we studied the geometric surfaces that we could use in the design proposed by us, graphically describing their geometric properties. The use of digital technology followed, with the help of which we obtain more accurate, faster information and we can correlate the surfaces with each other to generate new forms of design. As a result of this research, a refined piece of furniture was created, an outdoor or indoor fiber cement coffee table. It is thin, but resistant to weight, light, velvety, weatherproof, warm to the touch, even if it is made of concrete. Instead of steel reinforcement, glass fibers were used along with additional additives to produce a lighter and stronger concrete that can be cast in almost any shape or mould. This piece was made by hand, and the imperfections that appear through variations in color or finish give it a special personality, a unique piece that will keep its beauty for many years. Geometry facilitates the creation of a simpler and more balanced composition, obtaining an idea much faster, compared to objects that present sophisticated, incomprehensible shapes.

The current economic and social development causes people to prefer a simple and comfortable living environment, and the furniture characterized by simple geometric shapes has become a component of the contemporary style. This work provides a basis for future exploration of new concepts in furniture design.

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