HISTORICAL CONTINUITY OF USING TRANSCENDENT RULED SURFACES IN ARCHITECTURAL DESIGN

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Summary: *This paper analyzes transcendental ruled surfaces in terms of their application in architectural design. Ruled surfaces are more frequent than double-curved surfaces in architectural objects. This paper discusses the historical continuity of the application of transcendental surfaces, presenting and analyzing selected cases from the beginnings of our civilization to contemporary architectural structures.*

Keywords: *transcendent ruled surfaces, architectural design, applied geometry*

1. INTRODUCTION

Ruled surfaces are more frequently used in the design of architectural objects than double-curved surfaces since their application is simple and rational. This paper analyzes the transcendental ruled surfaces and their application in the architectural design regarding the aspect of the historical continuity [1]. The paper presents the selected architectural structures spanning the period from the beginnings of our civilization till the contemporary period, whose form is based on these surface. The presented examples are expected to facilitate the recognition of these surfaces in numerous designed objects. Figure 1 presents an example of the use of these surfaces in the architectural design of the *Randers Museum of Art* in Denmark. The figure displays the preliminary design of the awarded competition proposal. Transcendental ruled surfaces may be used in the design of the visually attractive forms, which appear to be still popular regardless of the dominant trends in architecture. This property adds a certain timeless dimension to these designs. [2].

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Figure 1. Randers Museum of Art, Randers, Denmark, 2009. (3XN)

2. TRANSCENDENTAL CURVES

Transcendental curves are used as diretrix for creating transcendental ruled surfaces. Transcendental curves may be plane and space curves. The plane transcendental curve is intersected by the coplanar line an infinite number of times [3]. This means that transcendental curves are the curves of the infinite order. There have been attempts to classify transcendental curves, but their complexity has so far discouraged the accomplishment of one satisfactory and comprehensive classification. Plane transcendental curves comprise all spiral, sinusoid and wave curves, some of which are presented in Figure 2 [1] [4] [5].

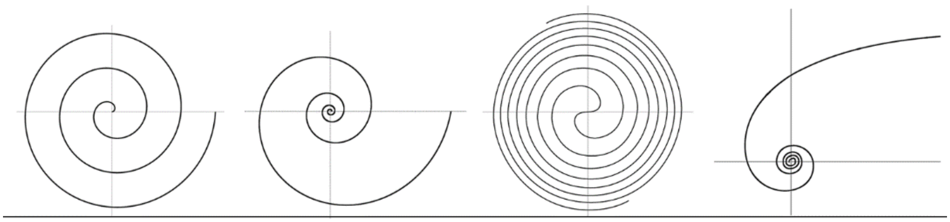

Figure 2. Spirals, flat transcendent curves

Helix belong to the space transcendental curves. They are formed by the point moving along a straight or curved line (the meridian of a certain rotary surface) while they are simultaneously rotating around the axis of the rotary surface, whereas the movement of the point along the meridian is proportional to the rotation angle. Helix may be formed on any rotary surface, which then represents the helix carrier. Figure 3 shows several helix employed in the further analysis [1] [6].

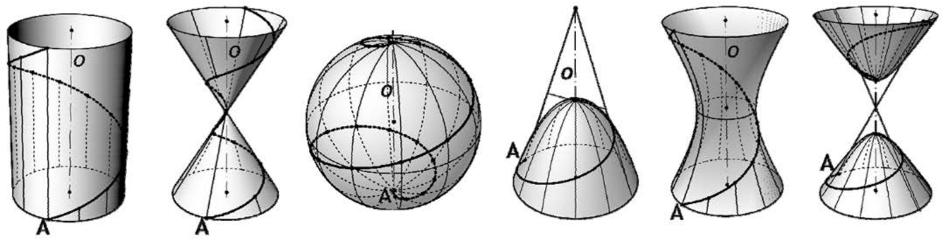

Figure 3. Types of helix

3. APPLICATION OF TRANSCENDENTAL RULED SURFACES IN ARCHITECTURE

Since ruled transcendental surfaces presently gain significance when applied in architecture, the paper further describes historically important architectural designs whose form is based on the application of the aforementioned surfaces. These objects are presented chronologically, with respect to the time of construction, with the purpose of studying the historical continuity in the application of transcendental ruled surfaces in architecture. The most frequently used are transcendental cylinders, conoids, cylindroids and helicoids, as well as transcendental cones. The application of transcendental ruled surfaces results in the creation of rational spaces that are visually and aesthetically attractive and whose basic form is relieved of stylistic determinants. The presented surfaces are universal and applicable in all architectural styles [1]. Regarding the contemporary architectural context, especially interesting are computer-generated forms that are considerably simple to create with the rationality of construction maintained. Contemporary materials and technologies enable their new interpretation and perception [7].

Tower of Babel is mentioned in the *Book of Genesis* in the *Old Testament*. The excavations conducted by the German archaeologist Koldewey on the territory of the ancient city of Babylon, south of Baghdad, resulted in the discovery of the remains of the *Tower of Babel*. It has been determined that it was most likely the ziggurat Etemenanki, mentioned in numerous historical sources. This ziggurat, 90 meters wide and supposedly 90 meters high, had 7 “terraced floors” topped by the temple dedicated to god Marduk. Certain historical visualizations of the *Tower of Babel* present it as a design of the transcendental ruled surfaceFigure 4 [1] [8].

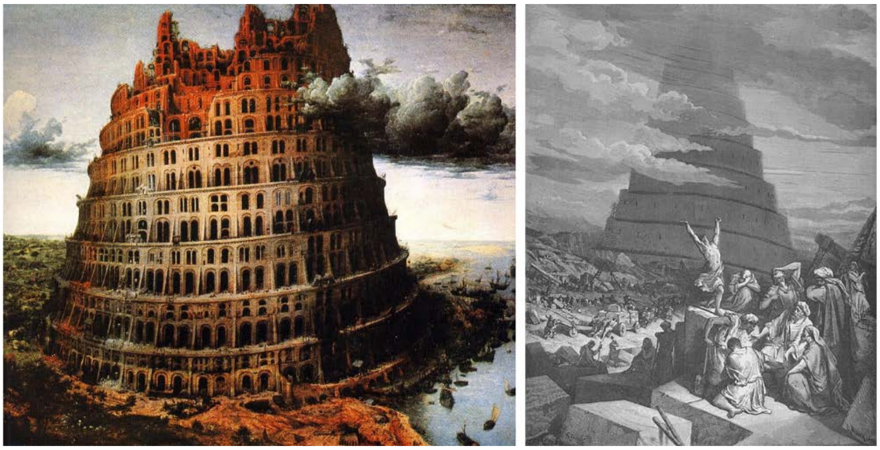

Figure 4. Tower of Babel, visualisations: Pieter Bruegel, 1563. and Gustave Doré, 1865.

Minaret at the Great Mosque of Samarra in Iraq was built in the 9th century Figure 5, on the left. Its form is that of the transcendental cylinder created by the line going along the cone helix. The cone helix basis is designed as the Archimedes spiral, which is appropriated to the requirements of the design of the pedestrian ramp – a staircase, the distance between the successive spiral points being always the same. The generatrix of the cylindrical surface is parallel with the cone basis, the helix carrier. The surface on which the spiral staircase leading to the minaret top was designed has the shape of the normal helicoid [9]. *The Minaret of the Mosque of Ibn Tulun* in Cairo, Egypt, which is smaller in size, was designed in an almost identical way in 879, Figure 5, the central part. *Church of Our Savior* in Copenhagen was built in the 18th century, whereas the helical part of the tower was completed later in 1752, Figure 5, on the right. The tower is in the form of the transcendental cylinder produced by the movement of the line along the cone helix. The manner in which the tower was constructed is identical to that of the aforementioned *Minaret of the Great Mosque in Samarra*. The helical part of the tower rises above the octagonal basis, while thus constructed outside staircase leads to the very top [1].

Figure 5. Minaret at the Great Mosque of Samarra, Iraq, 848.
Minaret of the Mosque of Ibn Tulun, Cairo, Egypt, 879.
Church of Our Saviour, Copenhagen, Denmark, 1752.

Figure 6, on the left, shows the School building erected near the *Expiatory Church of the Holy Family* in Barcelona. The roof represents a segment of the transcendental conoid, whereas the walls are the segments of the transcendental cylindroids. The roof is bisected by a straight generatrix of the transcendental conoid. Two sinusoid lines, one in the vertical and the other in the horizontal plane, are directrices of the transcendental cylindroid that forms each of the longitudinal façade walls. Figure 6, on the right, shows the details of the ceiling. The transcendental conoid is clearly visible, as well as the wooden carriers positioned in the direction of the surface generatrix. The bordering line between the ceiling and the wall is the sinusoid line, one of the conoid directrices. This design represented a model for the construction of numerous objects of similar form and structure, which has endured up to the contemporary times [1].

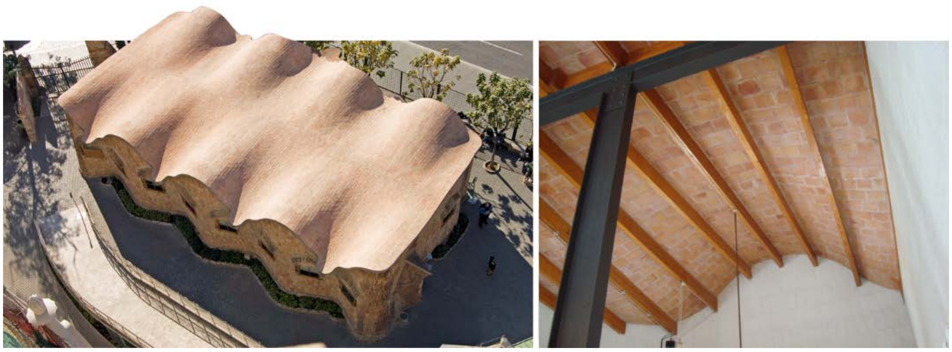

Figure 6. School building erected near the Expiatory Church of the Holy Family, Barcelona, Špain, 1908. (Antonio Gaudi)

Iglesia de Cristo Obrero is the church built in the city of Atlantida, Uruguay, in 1952, Figure7, on the left. The structure of the church is comprised of a series of transcendental ruled surfaces, mostly conoids with one sinusoid directrix. The side, longitudinal walls of the church are conoids. The shopping mall in Montevideo was built with respect to the structure of the church in Atlandita and was designed by the same architect. The basic surfaces are transcendental conoids and cylindroids, Figure 7, in the centre. *Iglesia de San Juan de Ávila* in Madrid, shown in Figure 7, on the right, was built with the same materials, while the aforementioned segments of the transcendental ruled surfaces were applied in the object design and construction [1] [9] [10].

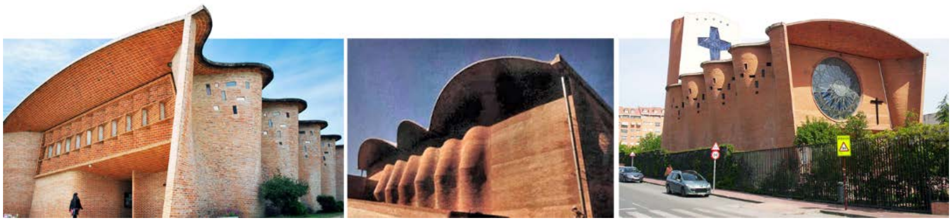

Figure 7. Iglesia de Cristo Obrero, Atlántida, Uruguay, 1952. (Eladio Dieste)
Montevideo Shopping Center, Montevideo, Uruguay, 1985. (Eladio Dieste)
Iglesia de San Juan de Ávila, Madrid, Spain, 1996. (Eladio Dieste)

Figure 8, on the left, shows the staircase in the *Garvan Institute* in Sydney. The normal helicoid is accomplished by the line along two generatrices, cylindrical helix and its basis. The presented example is particularly interesting in that its staircase, located in the gallery hall, is completely devoid of additional structural elements. *Spiral Lookout Tower* in Hong Kong was built in the city harbor. The pedestrian ramp was designed by the application of the helicoid and transcendental cylinder, Figure 8, in the centre and on the right.

Figure 8. Garvan institute, Sydney, Australia, 1997. (Ken Woolley)
Spiral Lookout Tower, Hong Kong, China, 1997.

Bodegas Ysios, the winery in the region of Alava, Spain, Figure 9, was built on the rectangular basis with longitudinal walls in the form of the transcendental sinusoid cylindrical surfaces, whereas its roof has the form of the transcendental conoid. The roof is bisected by the conoid directrix. The roof basis is formed by numerous prismatic elements positioned in the direction of the conoid directrix. The roof geometrical structure is conspicuous even in the inside of the building owing to its wooden carriers [11]. The business building *Cocoon* in Zurich was designed in the form of the transcendental cylinder, Figure 13. The transcendental cylindrical surfaces, created by the movement of the line along the sinusoid, form the façade of the *Technical University of Munich*, Figure 9. The façade was constructed with wooden modular cassettes [1].

Figure 9. Bodegas Ysios, Alava, Spain, 2001. (Santiago Calatrava)
Cocoon, Cirih, Switzerland, 2007. (Camenzind Evolution)
Interims Audimax, Technical University of Munich, Germany, 2011.
(Deubzer Konig & Rimmel Architekten)

The competition proposal for the *Taipei City Museum of Art* in Taiwan was based on the form of the transcendental cone, created by the line along the cone helix. The cone top is not matched with the cone top of the helix carrier, though, Figure 10. The right part of the same figure shows the tower built in Phoenix with the helical panoramic ramp. The helical ramp surfaces were constructed by the generatrix along the spherical helix, loxodrome [1].

Figure 10. Taipei City Museum of Art, Taipei, Taiwan, 2011. (Influx Studio)
Observation Tower, Phoenix, USA, 2012. (BIG)

The shape of the protective walls of the *Puur Pavilion* in the Netherlands is the transcendental cone with the plane spiral directrix, Figure 11, with minor deviations from the aforementioned geometrical shapes. The accomplished visual effect is that of the perception of the spiral transcendental shape of the structure [12]. The basic form of the *House in Espoo* in Finland, built in 2013, follows the cylindrical helix, Figure 11. The wall surfaces are the second-level cylinders, whereas the floor and roof surfaces are normal helicoids, the transcendental helix ruled surfaces [1].

Figure 11. Puur Pavilion, Amsterdam, Netherland, 2012. (emma architecten)
House in Espoo, Finland, 2013. (Olavi Kopose)

ArcelorMittal Orbit is a sculpture or tower for the panoramic view of London, 115 meters high, Figure 12. It was, among other things, inspired by the *Tower of Babel*, while its helix ramp, intertwined with a totally freely constructed latticed carrier, might be perceived as the contemporary version of the *Tatlin's Tower*. *Evolution Tower* is a 255-meter high tower in Moscow, Figure 12. It is part of the International Business Center. Its façade is dominated by the straight generatrices of the normal helicoid, applied in the design of this object. The building was completed in 2014 [13] [1].

Figure 12. ArcelorMittal Orbit, London, Great Britain, 2014. (A. Kapoor, C. Balmond) Evolution Tower, Moscow, Rossia, 2014. (RMJM)

4. CONCLUSION

Transcendental ruled surfaces are suitable for the application in the design of various spatial structures. The analysis of the historical examples of different buildings and structures spanning the period from the beginnings of civilization up to the present day leads to the conclusion that there exists a certain continuity in the application of various transcendental ruled surfaces in architecture. This enormous and comprehensive source of knowledge and skills enables further visual research in the field of architectural design. It is of utter importance to enable architects to notice, analyze and apply these surfaces in their projects. Transcendental ruled surfaces contribute to the design of visually attractive forms, which are still very popular regardless of the dominant trends in architectural design. This property adds a timeless and aesthetic dimension to their quality so that they may be applied in the design of contemporary architectural structures.

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ИСТОРИЈСКИ КОНТИНУИТЕТ ПРИМЕНЕ ТРАНСЦЕДЕНТНИХ ПРАВОИЗВОДНИХ ПОВРШИ У АРХИТЕКТОНСКОМ ПРОЈЕКТОВАЊУ

Резиме: *У овом раду, анализиране су трансцедентне правоизводне површи и њихова примена у архитектонском пројектовању. Правоизводне површи чешће се примењују у формама архитектонских објеката, с обзиром да је њихова примена једноставнија и рационалнија у односу на двоструко закривљене површи. Овај рад приказује историјски континуитет примене правоизводних трансцедентних површи, приказујући и анализирајући изабране примере од почетка наше цивилизације, до савремених архитектонских структура.*

Кључне речи: *трансцедентне правоизводне површи, архитектонско пројектовање, примеwена геометрија*