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Attachment 4

SUMMARY OF PROFESSIONAL ACCOMPLISHMENTS

Rzeszow, April 2019

1. Name and surname

Jolanta Dzwierzynska

2. Diplomas and academic degrees

PhD in technical sciences in the discipline of civil engineering,
Rzeeszow University of Technology, Faculty of Civil and Environmental Engineering, Rzeszow, Poland **2005**

Title of PhD dissertation*: **Application of Two-projective Partly Composed Representations for Direct Construction of Developments of Cylindrical and Conical Panoramas of Space E_3***

Supervisor: Professor Bogusław Januszewski, (Rzeszow University of Technology)

Reviewers: Professor Anna Błach (Silesian University of Technology)
Professor Aleksandra Prokopska (Rzeszow University of Technology)

MSc in civil engineering,
Rzeszow University of Technology, Faculty of Civil and Environmental Engineering, Rzeszow, Poland **1989**

Title of MSc thesis: ***Swimming Pool Design***

3. Information on previous employment in scientific institutions

1988 – 1989 – **Trainee Assistant**, Department of Descriptive Geometry, Faculty of Civil and Environmental Engineering, Rzeszow University of Technology (V year of studies)

1989 – 1997 – **Assistant,** Department of Descriptive Geometry, Faculty of Civil and Environmental Engineering, Rzeszow University of Technology

1997 – 2005 – **Assistant,** Department of Geometry and Engineering Graphics, Faculty of Civil and Environmental Engineering, Rzeszow University of Technology

2006 – 2012 – **Assistant Professor,** Department of Geometry and Engineering Graphics, Faculty of Civil and Environmental Engineering, Rzeszow University of Technology

2012 – – **Assistant Professor,** Department of Architectural Design and Geometry and Engineering Graphics, Faculty of Civil, Environmental Engineering and Architecture, Rzeszow University of Technology

I would like to mention that I was on maternity and parental leave during the period of 15.04.**1991** – 08.09.**1997.**

4. **Achivement as indicated in Paragraph 16.2 of the Act of 14 March 2003 on Academic Degrees and Title and degrees and Title in the Arts.** (Dz. U. 2016 r. poz. 882 ze zm. W Dz. U. z 2016r. poz. 1311)

a) Scientific achievement :

A monograph: ***Algorithmic-aided shaping curvilinear steel bar structures***

b) Author/authors, titles of publication, year of publication

Jolanta Dźwierzyńska

Algorithmic-aided shaping of curvilinear steel bar structures
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publishing reviewers: **Professor Edwin Koźniewski**
Professor Jerzy K. Szlendak

c) discussion of the scientific objective of the work and the results achieved, as well as their possible application

Introduction

The subject of shaping structures undertaken in the monograph titled "Algorithmic-aided shaping curvilinear steel bar structures" was inspired by the area of research conducted by eminent Professors, employees of the Department of Building Structures, Rzeszow University of Technology, who for many years dealt with the issues of shaping structures in theory and engineering practice.

The issues of shaping building objects, including their structures, is very broad and covers many aspects. Over the years, various methodologies have been developed for shaping building objects in accordance with the development of design thought and depending on technological and material conditions, as well as the applicable canons of beauty and current trends. Shaping a building object can be defined as an optimization of the shape and form of the object, so that it meets the assumed preliminary criteria as much as possible. Due to the fact that the shaping phase is the phase preceding all subsequent stages of the design process, it is the most creative stage, and at the same time it has a significant impact on the final form of the object. Due to the different specificity of architectural conditions in comparison to structural conditions, in theoretical considerations, and sometimes in engineering practice, architectural shaping is separated from structural shaping [M64]. In architectural shaping, the most attention is paid to ensuring the best possible function of the object and its aesthetic values, whereas structural shaping is the search for a structural system that meets, first and foremost, strength and reliability requirements at the assumed rational construction cost. It is, however, obvious that the architectural and structural conditions for object shaping are interdependent. The form of the object depends on the function. In turn, the adopted form enforces structural, technological and material solutions that affect the overall aesthetics. For this reason, the interdependence of the architectural form of the object and its structural arrangement is the main goal of rational shaping presented in the monograph.

New aesthetic trends imply the emergence of more and more complex and demanding forms, which dictate the need for constructor's participation already in the initial design phase. Therefore, one of the aims of the monograph is to try to show the possibility of developing a certain platform for cooperation and communication between the architect and the structural engineer with the use of modern digital tools. Such a platform may constitute algorithmic-aided shaping structures, enabling the free flow of information between the geometric and structural model.

The need to develop a design framework for the complex process of shaping the structure has been noticed by many scientists. Professor Wacław Zalewski, considered the precursor of rational construction in Poland, the creator of the theory of shaping a structure in accordance with the flow of forces, in his studies [M137] included guidelines for shaping the structure in order to obtain the most favorable static and aesthetic effects. In turn, prof. S. Kuś, one of his eminent collaborators carries out considerations regarding shaping a structure that meets the requirements of both function, building mechanics, aesthetics as well as minimal cost, paying attention to the ambiguity of structural shaping with architectural shaping or construction optimization [M64]. In the shaping guidelines contained in [M64], he sees, among other things, the need for rational and effective shaping of bar sections, modular shaping and shaping in accordance with minimum elastic energy. However, the most universal and broad criterion for shaping the structure described in [M125] is the minimum risk criterion, and the basic criterion for shaping the criterion of the highest reliability of the structure. The approach to shaping curvilinear steel bar structures presented in the monograph takes into account the guidelines of rational shaping developed by eminent scientists and constructors and shows how these guidelines can be applied using modern digital tools, so that the process of structural optimization can be implemented at the initial stage of design. Due to the fact that the conceptual phase of designing is associated with a multi-variant analysis of the initial solutions, it requires the use of comprehensive tools defining the structural model, and also taking into account the team nature of design. The research presented in the monograph focuses on the rational and effective shaping of curvilinear steel bar structures, the aim of which is to shape the appropriate geometry of the structure with the intended functionality according to structural requirements, so that the newly shaped structure is compatible with two basic design intentions: "form follows function", and "form follows forces".

The method of shaping a structure depends also on the type and capabilities of the design tools used. Nowadays, shaping takes place with the support of modern digital tools, which greatly facilitate both the process of creating complex geometry, as well as performing advanced analyzes and structural calculations in an increasingly short computational time. Most digital tools considerably simplify and speed the work of the designer, however, they are not comprehensive, which means that separate tools are used to generate complex geometry and design calculations. Still, the development of new technologies based on smooth digital modeling based on Rational B-Splines (NURBS), and their application, have helped to introduce and develop concepts for creating non-linear forms in a dynamic and parametric manner, which resulted in a significant change in geometrical shaping. Another revolutionary change was the development of digital tools enabling algorithmic shaping of geometric shapes, such as the tools working in the environment of Rhinoceros 3D by Robert McNeel & Associates. In turn, synchronization of geometrical shaping with structural analysis possible using Rhinoceros 3D and Karamba 3D creates opportunities for rational shaping from the first design stage. The emergence of new design tools always brings about aspects of their correct use and the best, innovative use.

The purpose of scientific work

In reference to the above-mentioned conditions, the monograph discusses the algorithmic-aided shaping of curvilinear steel bar structures using design tools operating in the Rhinoceros 3D software environment. The reason for choosing such a topic was to establish procedures for shaping curvilinear steel bar structures, in order to integrate geometry and structural efficiency as a single goal in the initial design phase. The need to develop such procedures is caused by both the growing popularity of parametric methods in design and their huge potential in creating new, unconventional and effective forms.

The goals of the monograph can be specified in the following way:

- presentation of the effective procedures for generative shaping curvilinear steel bar structures consisting in forming grids of bars by placing their nodes on so-called base surfaces being surfaces with favourable geometrical and mechanical properties, namely Catalan surfaces, minimal surfaces like Enneper surface and free forms stretched on arches of circles as well as funicular structures obtained as the result of dynamic relaxation,

- examining how the mechanical properties of the base surfaces affect the load transfer through bar structures shaped on their basis,

- transforming the principles of structures' shaping into logical-geometric and structural dependencies by developing universal algorithms describing geometrical and structural models of single and complex bar structures that can be used in simulations, enabling, among others, assessment of the mechanical performance of structures, as well as the selection of the optimal design solution depending on the adopted criteria,
- comparing the results of algorithmic-aided shaping curvilinear steel bar structures obtained using design tools working in the Rhinoceros 3D

environment with the results obtained by conventional software tools such as Robot Structural Analysis Professional 2019, as well as assessment of the usefulness of parametric tools,

- analyzing how the adopted patterns of the rods of the considered structures, as well as the method of dividing the spatial rectangular grids into triangular meshes affect the strength and behavior of curved steel bar structures under load
- analysis of the usefulness of the genetic process of one-and multi-criteria optimization as a tool to search for rational structural forms through the use of genetic optimization to minimize the mass of the structure and find the most beneficial way of supporting the structure,

- development of original, free-form curvilinear, steel bar structures obtained by means of the "form-finding" method characterized by favorable mechanical properties,

- indication of the possibilities and benefits of algorithmic shaping for both the architect and constructor cooperating together in a joint creative process.

Achieved results

The active use of Rhinoceros 3D / Grasshopper software in the architectural design process is becoming increasingly popular in the world mainly as a tool for generating models with complex geometry. However, algorithmic structural shaping, which is a process in which both the geometric model and structural analysis are carried out using algorithms, is a new field of research. Therefore, the approach presented in the monograph to shape curvilinear steel bar structures of canopy roofs is innovative. Nowadays, the use of curvilinear steel bar structures is getting wider. The variety of forms and structural solutions shows that it is easy to adapt these structures to different shapes, as well as being a various design ideas. However, always shaping, designing and developing this type of structures is accompanied by a number of issues that often require an unconventional and interdisciplinary approach. The possibilities of a comprehensive approach to shaping structures are created by the parametric shaping consisting in the optimization of the structure through the identification and successive refinement of the parameters describing it. During the tests, in order to generate geometric models, the Rhinoceros 5.0 version is used in combination with the parametric Grasshopper design tool, allowing the creation of complex generative algorithms in the parallel exploration of shaped geometric models in the Rhinoceros 3D viewport. In general, the method of shaping the structure presented in the monograph begins with the creation of scripts describing the parametric geometric model of the structure. Then, on the basis of the created geometric model of the structure and the adopted boundary conditions concerning the method of support, load, as well as the type of joining rods and material properties, integration of geometrical shaping and structural analysis takes place through the Karamba 3D. The developed structural model is subjected to analysis, which may take place in two stages. The first analysis concerns the structure loaded with its own weight, in which the topology of the structure as well as the support method are optimized and pre-determined cross-sections of bars, taking into account the minimum mass of the structure, minimum deformations and the maximum loads of bars. Then the previously optimized model is subjected to another analysis assuming different combinations of loads taking into account the loads from snow and wind and dimensions. The process of dimensioning and optimization of cross-sections can be carried out either using the Rhinoceros 3D program in combination with Karamba 3D or using traditional software for structural analysis. The general scheme of conducted analysis is shown in Fig.1, but for each structure considered in the monograph, the shaping path is determined individually. In some cases of shaping, the optimization of the base surface geometric model used to form the bar grid is carried out, taking as the optimization criterion the the minimum surface area.

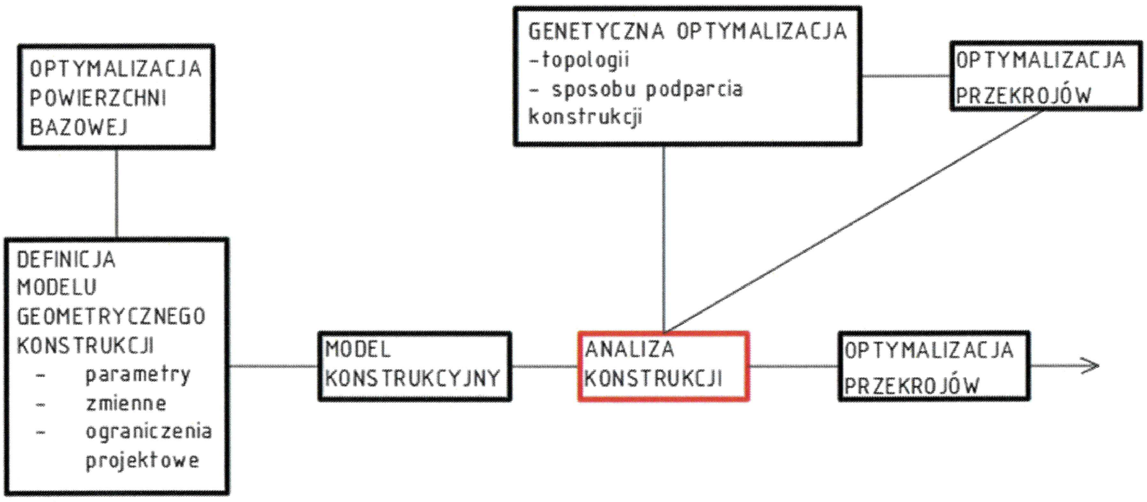


Figure 1. The scheme of the integrated process of shaping structures

Shaping the structures presented in the monograph by means of developed procedures consists in creating curvilinear, steel bar structures by placing structural nodes of bars on the so-called base surface. However, in order to obtain an effective curvilinear steel bar structure, it is necessary, as shown in the research, to select as a base surface, the surface with favorable geometrical properties due to the shape or the possibility of subdivision or mechanical properties, such as minimum surfaces.

Shaping curvilinear steel bar structures based on Catalan surface

One of the groups of surfaces proposed as base surfaces for the shaping of bar structures are: ruled surfaces, in particular Catalan surfaces, constituting a group of skew surfaces, which rulers are parallel to the given plane. Depending on the type of curves that define surfaces, they are divided into hyperbolic paraboloids, cylindroids and conoids.

The research began with the analysis of curvilinear steel bar structures shaped on the basis of a hyperbolic paraboloid, which is a quadtic, determined by two oblique lines, as well as cylindroids defined by two curves being parabolas. Quadrics as surfaces have found application in various solutions of building coverings, mainly as reinforced concrete or steel coverings made of bent sheets. Therefore, most studies on parabolic hyperboloid coverings cover the theoretical and practical aspects of the above roofs. Although the hyperbolic paraboloid as a ruled surface can be a good base surface for forming bar grids, there are no studies on the effect of division of hyperbolic paraboloid and spatial patterns of rods obtained due to division on load bearing capacity of the resulting bar structure. Therefore, the aim of the conducted research and presented in the monograph was to compare the effectiveness of the canopy roof structures that are curvilinear steel bar structures formed on the basis of hyperbolic paraboloids and cylindroids covering the same surface Fig.2, as well as defining the most effective topology of the bar structure based on the above surfaces by genetic optimization with given boundary conditions.

(a)

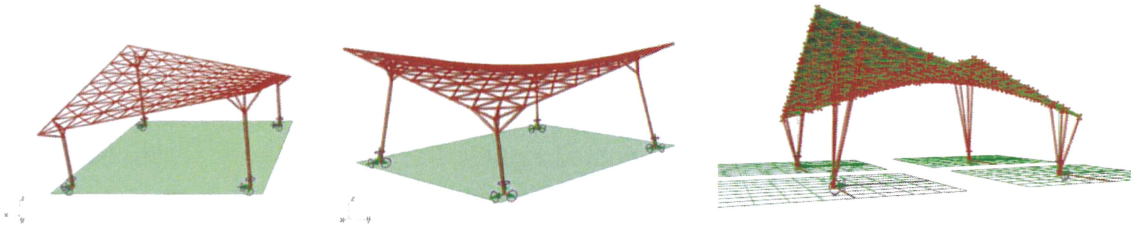
(b)

Figure 2. Analyzed roofs of the shape of: (a) hyperbolic paraboloid; (b) cylindroid

The research was carried out on the assumption that both structures are supported on four supports, two of which have a fixed position, while the positions of the other supports constituting the bases of columns perpendicular to the roof surface are variable. Each surface constituted the base surface for forming triangular grids. These grids were created on the basis of quadrate grids created by the distribution of each of the surface boundaries to the same number of parts. Depending on the method of dividing the spatial quadrilaterals, which can take place along a shorter or longer diagonal, two different patterns of triangular grids have been obtained. The starting point for the analysis and optimization of the structure was the creation of algorithms describing the geometric model of each structure and then the algorithms describing the structural models. As design variables, the dimensions of the square, the roof height, the length of the grid bars, column lengths, x, y coordinates determining the position of column bases, sections of all types of bars included in the structure and the ranges of these variables were assumed.

Optimization of the roof structure of hyperbolic paraboloid shape and of cylindroid shape using two triangular patterns of bars formed as a result of the division of four-sided grids proceeded several stages. At the beginning, a multi-criteria, evolutionary optimization of structures loaded with dead load was used to determine the optimal position of supports, pre-fix the topology of the bar grid, and the lengths and cross-sections of the bars. Three optimization criteria were adopted: the minimum mass of the structure, the greatest load of the elements and the smallest deflections of the structure. Due to the fact that the defined objective function was a combination of three different criteria, which are mutually contradictory criteria, the result of the optimization did not give one optimal solution. Therefore, for each of the structures, a collection of non-dominated solutions, called the optimal set in the Pareto sense, was analyzed, which was separated from the entire acceptable search space. The best solutions were obtained in the case of structures covering the square place. Structures were pre-dimensioned and multi-objective optimization was repeated, however, in this case bar cross-sections were fixed. The values of cross sections were minimum permissible bar cross sections, adopted equally for both structures. Then, from the Pareto front, four optimal solutions for two different bar patterns of structures were selected, which were to be further evaluated.

The research showed that the structure based on cylindroid is much heavier than the structure made on the basis of hyperbolic paraboloid, which is why further analysis and optimization of the hyperbolic paraboloid was made. Four different solutions were tested (two for two different grid patterns) selected from a set of optimal solutions in the Pareto sense. Each structure was dimensioned taking into account the snow and wind loads. Optimization of bar cross-sections was made, assuming the minimum mass of the structure as the optimization criterion. The calculations were performed in two ways using the Autodesk Robot Structural Analysis program and using the Karamba 3D in the Rhinoceros 3D environment and the results were compared. This was to assess the accuracy of the calculation results obtained using the Karamba 3D and to evaluate the suitability of the above structure analysis tool. Similar structural analysis results were obtained using both tools. However, the permissible cross-sections of the grid bars fixed with the plug-in Karamba 3D were larger. This difference was caused by adopting larger simplifications assuming snow loads in the case of analysis using the Karamba 3D, consisting in a smaller variation in the magnitude of the loads adopted for individual roof sections. Therefore, the adopted impact of snow load differed slightly when used for analysis of both Autodesk Robot Structural Analysis and Karamba 3D tools. However, the adopted simplifications resulting from the difficulties of the precise definition of loads acting on curved surfaces when using the Karamba 3D are not important due to the fact that, the phase of shaping the structure is the initial, estimated stage of the design process. However, the possibility of conducting an evolutionary optimization of the structural model using different prerequisites justifies the advisability of using the Rhinoceros 3D program with the Karamba 3D plug-in to analyze the structure. As previously mentioned, triangular grids of curvilinear steel bar structures analyzed in the study are obtained by dividing spatial quadrate grids, and the division can take place along the longer diagonals or shorter ones. The research revealed large differences in the weight of the structure and assortment of bars depending on the method of shaping triangular grids based on quadrangular grids. The analysis of the structure carried out by both programs showed that the grid structures obtained by dividing quadrangle along the longer diagonals are much lighter than the grid structures formed when dividing along shorter diagonals. However, comparing the diversity of the assortment of bars used in both types of structures, it can be concluded that structures formed during the division along the shorter diagonals are more effective, because the range of bars included in these structures is smaller. The optimal structure with the analyzed boundary conditions was obtained by dividing the base surface into five elements along the boundary lines and using a triangular grid with division along shorter diagonals and using square tube pipes as bars. The analysis was also made of hyperbolic paraboloid bar structures supported by four single columns being vertical columns or inclined columns, but perpendicular to the surface of the roofing, Fig. 4a, 4b.



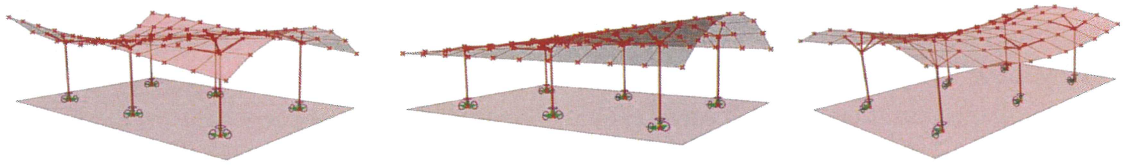
(a) (b) (c)

Fig. 3. Roofs subjected to analysis supported: (a) by vertical columns; (b) by columns perpendicular to the surface of the covering; (c) by bunch of columns

Ten roofs with the same total height and two different heights of the roofing structure as well as two different ways of supporting systems were examined, assuming that the roofs cover a square-shaped surface with variable side length. The weight of the above structures was analyzed. The tests have shown that the structures supported by columns perpendicular to the roof surface are much lighter than comparable structures supported by vertical columns. The percentage difference in weight of the above structures decreases with the increase of the structural span. An alternative to structures supported by single columns may be similar structures supported by bunch of columns, Fig. 4c. The efficiency of the above structures was analyzed, assuming support with four bunches of columns and adopting four columns in each bundle. The tests showed a large reduction in the mass of the structure in the case of using bundles of columns compared to the mass of the structure using single columns, as well as a reduction in the range of bars included in the structure. Similarly as in the case of roof structures with the use of single columns, the percentage difference in the weight of the structure also decreases with the increase of the structural span.

Bi-Directional Evolutionary Structural Optimization (BESO) in the case of structural optimization is a new activity. An attempt was made to carry out BESO, enabling both the removal of inefficiently used structural elements, as well as adding them in places where they could be needed due to the work of the structure. This type of optimization, made possible by the Karama 3D increases the probability of finding a potentially optimal structure. However, the results of this type of optimization for the considered bar structures were not satisfactory. Obtained meshes, resulting from the optimization through successive reduction of the mass of the structure have always been characterized by an irregular and unsightly pattern, which allows to state that BESO has little application in the case of bar structures.

Analyzing the curvilinear steel bar structures formed on the basis of the Catalan surface, a comparison was made between the efficiency of the cylindroid-shaped structure and the hyperbolic paraboloid, which is the translational surface resulting from the moving of the curve being a parabola along the second parabola.



(a) (b) (c)

Fig. 4. Analyzed roofs of: (a) cylindroid shape; (b) conoid shape; (c) hyperbolic paraboloid shape

It was assumed that each of the roofs should be a cover of the same rectangular square, and its structure is a quadrilateral grid supported by means of six vertical columns spaced symmetrically. The optimum positions of the structural columns of the analyzed roofs were determined as a result of the application of evolutionary one-criterion optimization, whose optimization criterion was the mass of the structure. With the given boundary conditions for each of the structures concerning the load, the acceptable range of the length of the grid bars, the height of the columns, the roof height and its covering, the optimal support method was determined. The most effective structure turned out to be the roof structure with the shape of hyperbolic paraboloid characterized by the smallest mass, the displacement of the bars defined in the end and middle points of the bars, as well as the smallest load of bars. Obtained results confirmed the assumption that the mechanical properties of the base surface used to shape the bar structure affect the properties of the shaped structure as hyperbolic paraboloid is a saddle surface, with properties similar to the properties of minimal surfaces. It is worth noting that the quadrilateral bar grid used on the hyperbolic paraboloid is a grid in which quadrilateral elements formed by bars are flat. This is due to the fact that in the case of a hyperbolic paraboloid, which is a translational surface, always two sides of polygon formed as a result of the division of the surface are parallel to each other. This gives the possibility of using flat roof panels, which is very beneficial due to the reduction of production costs. The other cylindroid and conoidal surfaces do not have this property, so they are less economically efficient. As in the case of a hyperbolic paraboloid structure defined by skew lines two, the effectiveness of the structure was compared using single columns and bundles of columns. In this case, the structure supported by means of bundles of columns proved to be much lighter.

Shaping of curved steel bar structures based on minimal surfaces

Due to the special properties of minimal surfaces and the possibility of computer aid in their determination, there is an increase in research on the use of these surfaces in the implementation of innovative architectural objects. However, engineering design of structures with a minimum surface shape is mainly used in the construction of lightweight membrane roof structures. The minimal surface is the surface with the smallest possible area among all surfaces stretched on the given lines. This is important from an architectural and economic point of view, because the use of minimal surfaces means the use of a minimum surface area of claddings, thus minimizing costs. In addition, the use of minimal surfaces brings tangible benefits in shaping structures, since minimal surfaces exhibit an optimal system of forces and stresses. This aspect justified the purposefulness of choosing the minimal surface as the basis for shaping curvilinear steel bar structures. The research, on the other hand, was aimed at checking how the mechanical properties of the base surfaces affect the properties of bar structures shaped on their basis. It have been analyzed structures shaped both on the basis of known and defined minimal surfaces like Enneper's surfaces, as well as surfaces formed on the basis of free minimal forms obtained through optimization. The Enneper's surface as a form for the implementation of building covers has little use in construction. However, it is a surface of an interesting shape, which can take various forms depending on the choice of parameters defining it. Therefore, the subject of further analysis were curvilinear steel bar structures formed on the basis of Enneper's surface and covering a round place. The shaping process began with the creation of algorithms describing the bar grid whose nodes are located on the Enneper surface adjusted by parameters so that its horizontal projection is a circle. In addition, surface-defining variables have been selected to obtain three different surface forms which were the basis for forming three different curved bar structures with three, four or five support points.

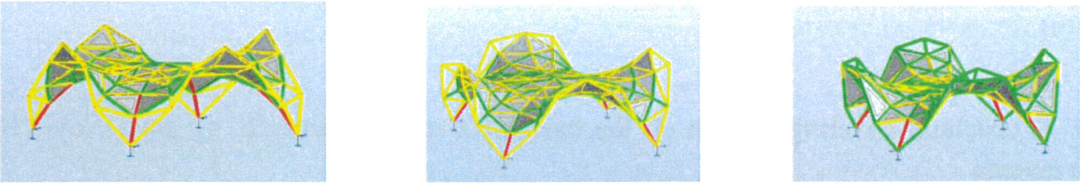
Due to the fact that the topology of the adopted bar grid affects the load-bearing capacity of the structure, triangular grids have been used, which can be more easily adapted to the shape of the surface under consideration and which are characterized by greater stiffness than quadrangular grids. The curvilinear steel bar structures with three different triangular grid patterns and two different construction heights of 2 m and 4.5 m as well as three different support systems were initially analyzed. For each structure an identical division of the grids along the radius and perimeter of the covered square was assumed, and round tubes with pre-arranged uniform cross-sections for all bars were used as structural elements. Using the Karamba 3D, an analysis of the behavior of structures loaded with their own weight and glass panels was performed. The tests showed that in the case of structures with height equal to 2.0 m, the increase in the mass of the structure caused an increase in the deflections of the elements, whereas in the case of a structure with height of 4.5 m, such regularity was not observed. Regardless of the adopted bar grid topology, the structures supported in four places are characterized by the least deformations. Therefore, these structures were subjected to further analysis by adopting a grid pattern that provided the smallest mass of the structure. However, in order to obtain an effective bar roof structure, additional further modifications were applied, consisting of:

unification of the length of the structure's bars by dividing the base surface into an

- even number of parts along the perimeter,
- removing some bars in the upper part of the structure to unify the size of the panels, ensure greater access of light and reduce the weight of the structure,
- raising the upper part of the structure, in order to ensure a 5% drop for easier drainage of rainwater,

- removal of the highest external elements of the structure, performing mainly the decorative role and slight modification of the structure to minimize the obstacles caused by the snow load.

Three structures, Fig. 5, were selected from several possible solution variants, which were optimized, assuming as the optimization criterion the smallest mass of the structure, which was also associated with the lowest number of bars and nodes used.

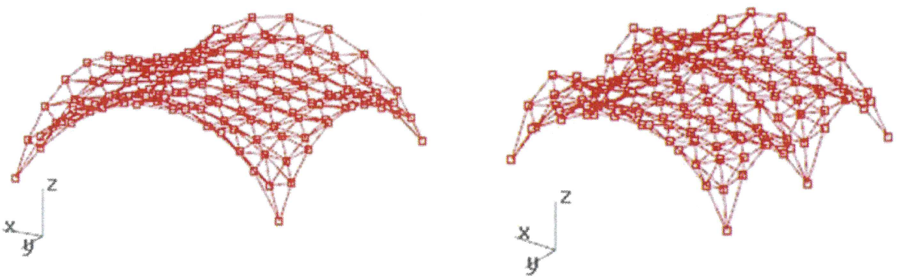


Rys. 5. Analizowane konstrukcje prętowe z czterema punktami podparcia

The developed scripts for shaping curvilinear steel bar structures based on the Enneper surface after some modifications of the parameters describing the structural model allow to obtain and analyze structures with many different interesting forms, which may be proposals for various types of building covers.

A different group of shaped and analyzed structures were curvilinear steel bar structures shaped on the basis of minimal surfaces being free surfaces. The base surfaces were shaped as minimal surfaces spread over four arches. The shape of the arches was adjusted to the design requirements and the boundary conditions adopted or it resulted from the genetic optimization of the base surface.

Several effective and representative curvilinear steel bar structures were formed on the basis of free minimal surfaces whose shape and surface area were obtained as a result of evolutionary optimization. One of the structures was the structure of a roof over a square place with dimensions 24m x 24m. The base surface for forming the above structure was pre-shaped as the minimal surface spread on the four arcs of circles, and then two of the opposite arcs were lowered so that the area of the obtained new minimal surface spread on the two arcs of the circles and the two arcs of ellipses was minimized and the surface shape was adapted to the possibility of draining rainwater from the roof. The above surface was formed by evolutionary optimization, taking as the optimization criterion the minimum surface area of the newly formed optimal form. The created surface form was the starting base for shaping the single-layer structural cover of a two-layer roof supported in the corners of the square, Fig. 6a.



(a)

(b)

Fig. 6. A structural covering formed on the basis of a minimal surface: a), single layer b) double layered

Alternatively, a two-layer structural cover supported by six supports was formed over an identical square. The base surface for shaping this cover was the surface being the sum of two minimal surfaces, each of which was spread on two arcs of circles and two arcs of ellipses with half-reduced diameter compared to the previously obtained single-shell structure, Fig.8 b. Both shaped structures are effective structures, carrying loads mainly through axial forces in bars, however, comparative analysis of shaped structural coverings showed greater efficiency of one-coat roofing.

The next issue analyzed in the monograph is the possibility of optimal shaping of curvilinear steel bar structures being structures of canopies with free forms adjacent to existing buildings. In this case, the shape of the base surface being the minimum surface is not predetermined, although it results from the boundary conditions determined by the function of the shaped object. Freedom of shaping in this case consists in the task of not only boundary conditions for shaping, but also acceptable ranges of their variability associated, among others, with the shape of curves defining the base surface, the height of the roofing, the way and location of supporting or fixing the roof to adjacent buildings. The form of the base surface is obtained by means of evolutionary optimization as the minimum surface with the smallest surface area among all possible areas generated for boundary conditions adopted from the permissible ranges. The use of the bar network on the surface with the smallest surface area gives the possibility of obtaining the minimum mass of the structure. The analysis was carried out using single and double-layer structural coverings and their effectiveness was compared.

Another issue presented in the monograph is the analysis of the effectiveness of curvilinear steel bar structures created by a method called "form-finding". As a result of this method, there are funicular structures whose form is adapted to the size and position of the loads acting on it. The geometry of the equilibrium for the analyzed bar structures, presented in the monograph, is determined in an interactive structural analysis, which is the process of dynamic relaxation. Three representative structures were analyzed covering a square, and resulting from the simulation consisting in transforming flat bars of bars or spatial bar structures with horizontal upper and lower bar layers into curved forms. In order to carry out the simulation, it was assumed that the mass of the structure is concentrated in nodes and the rigidity of individual nodes was determined. In addition, it was assumed that the individual structures were loaded with their own weight determined opposite to the gravity. The form of each structure was generated in an iterative process assuming the same number of iterations, after which the geometry of each form was updated. Two design solutions have been proposed for covering the given square, a double-layer truss structure supported by bundle of column, and a single-layer truss structure supported by single columns Fig.7.

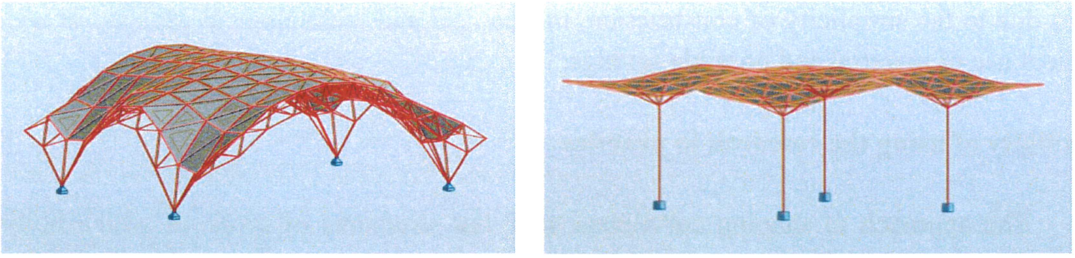

(a) (b)

Fig. 7. A structural cover formed by means of the "form-finding" method: a) supported by bundle of columns, b) supported by single columns

The structures were optimized with the assumption of the least favorable combination of loads and then a comparative analysis of the above structural solutions was made, both physically and mechanically. Despite the differences in weight, as well as the degree of complexity of structural nodes, both structures proved to be effective in terms of the load transfer method.

The research carried out and presented in the monograph allowed for the formulation of several important final conclusions.

The analyzes carried out showed that although only nodes of shaped structures are contained in the base surface, the mechanical properties of this surface affect the properties of the shaped structures. In shaped structures based on minimal surfaces, the loads are mainly transferred by axial forces, while the share of bending moments is minimal, so these types of surfaces can be an excellent base for forming curvilinear steel bar structures.

- Minimizing the area of the base surface as a result of evolutionary optimization leads to the minimization of the mass of the curvilinear steel bar structure based on this surface.

- The use of columns perpendicular to the surface of a hyperbolic paraboloid covering gives significant benefits in the form of mass reduction of the structure compared to the structure with vertical columns.

- Similarly, the introduction of bundles of columns in place of single columns may result in a significant reduction in the mass of the structure.

- Of the Catalan surfaces, the hyperbolic paraboloid is the only surface that gives the possibility of forming effective bar structures being quadrilateral grids whose quadrilateral elements are flat.

- The method of dividing quadrilateral grids into triangular grids has a significant impact on the efficiency of bar structures.

- The research has shown that evolutionary optimization can support the process of shaping curvilinear steel bar structures being an effective tool for searching for rational structural forms due to the simplicity of construction, mechanical and technological aspects, as well as efficient use of material and possible savings.

Possibility of using the research in practice

The approach to shaping curvilinear steel bar structures of roofs, in which both the geometric model as well as the structural analysis are carried out with algorithmic support, is innovative. For this reason I consider the innovative, skillful use and combination of the capabilities of the latest design tools to propose effective structural solutions and their analysis to be an important and fundamental achievement of my work. Moreover, the outlined examples of curvilinear steel bar structures, developed and presented in the monograph after further analysis or modification, may be treated as proposals of structural solutions. Furthermore, the developed scripts for shaping curvilinear steel bar structures with changing parameters describing the structural model allow one to obtain a wide variety of interesting structural forms, which can be proposals for various types of building coverings. Algorithmic description of models of the analyzed structures gives the possibility of easy changes and optimization in order to adapt the structure to the assumed initial conditions. The developed procedures for shaping curved steel bar structures can be further developed creatively depending on the needs. On the other hand, the obtained results of analyzes and optimizations presented in the monograph may provide some hints in the design of similar curvilinear steel bar structures.

The new approach to shaping structures presented in the monograph using the genetic optimization of the structures, thanks to its advantages, may deserve attention and application in the designing activities to improve them, so as to achieve effective structural forms meeting both architectural and strength requirements without blocking the creative process.

Nevertheless, in addition to the possible practical applications, there is also a need to continue the initiated research. The considerations regarding the optimization of the structure with the adopted criterion of minimizing its mass taken into consideration in the monograph, which are also very important due to the cost of the structure, should be extended to the issues of analysis and optimization of the method of joining bars. In addition, issues discussed in the monograph regarding the unification of the length of bars of shaped structures require a broader analysis. However, the research and the results obtained have outlined many possibilities and directions of their continuation both to rationalize the shaping process and to optimize and improve the shaped structures.

5. Discussion of other scientific and research achievements

My scientific and research interests run in two ways and are specified in the following points a and b. They include shaping structures with algorithmic aid, as well as the continuation of issues related to engineering panoramic mappings taken in my doctoral thesis.

a) **The interdependence of the architectural form and the structural system as the goal of effective shaping in a creative and dynamic process**

The problem of shaping curvilinear steel bar structures on the basis of hyperbolic paraboloid described in the monograph is extended by shaping the structures of multi-shell roofs composed of repetitive elements. A comparative analysis of roof bar structures composed of four grid modules was presented in the publication [IIE11]. The presented research results concern the comparison of the efficiency of the structure depending on the type of grating used, as well as the method of arranging the mesh modules in the structure.

The above subject matter presented in the publication [IIA2] is extended to four-module, shell, thin-walled roof structures designed from reinforced concrete and formed not only from modules that are sections of hyperbolic paraboloid, but also cylindroids and conoids. In addition, the issues related to algorithmic shaping of the structures presented in the monograph I expand, trying to take into account at the stage of shaping as many environmental aspects that affect the creation of an effective structure. On the one hand, it is important to minimize the mass of the structure, which has a significant impact on the environment, on the other hand, environmental conditions can become an important factor in the search for the optimal, effective form of structures. The results of studies analyzing such issues have been included in one of my latest publications [IIE1], where the method of shaping the roof in the optimization process is shown. However, the final choice of the shape of the roof is additionally influenced by the analysis of the shadow cast by the shaped roof and a set of adjacent buildings in the assumed calculation period. For this purpose, in addition to the Karamba 3D used for structural analysis, I also use other tools that work in the Rhinoceros 3D / Grasshopper environment, such as Ladybug and Honeybee.

b) Analysis of the construction and reconstruction of the mappings of perspective wide-angle projections on the developable surfaces

Perspective wide-angle projections, including panoramic projections, are considered one of the first forms of representation and graphic communication. Currently, due to the huge development of digital panoramic technique, ie the spread of simple programs for creating panoramas, or high-quality panoramic scanners, there is a large development of various panoramic mapping methods. At the same time, it also returns to creating panoramas in a traditional way.

Scientific activity before the doctorate

Prior to the doctorate, my scientific activity as an assistant at the Department of Geometry and Engineering Graphics concerned the issues of engineering geometry related to the way of constructing and mapping perspective wide-angle projections (panoramas) on the developable surfaces. Every classical panorama, as well as created with the use of modern techniques, must be subordinated to geometrical principles, significant and characteristic for these kinds of performances. The analysis of these principles, as well as the use of computer aids for the direct recording of panoramas, were the main topic of my research interests. The result of my work in this field is the development of a direct, geometric method of constructing a cylindrical and conical panorama on a developed background. In the above method, the panorama can be created in two ways; as a single-point non-linear perspective or as multipoint, non-linear perspective. The use of center projection from dispersed points in the case of a multi-station panorama, made it possible to obtain panoramic images very close to the images received by the panorama observer. However, the derivation of geometrical projection dependencies between images of figures obtained on the undeveloped panorama background and the images obtained on the developed background, allowed the derivation of analytical algorithms and their use with computer-aided panorama mapping. The proper functioning of the algorithms was tested in the Mathcad program, but they were effectively used to construct panoramas in AutoCAD. However, they can also be used in any graphics packages. The results of the above tests have been presented in my doctoral dissertation.

Scientific activity after doctorate

I continue the subject undertaken in the dissertation [IIE4, IIE6]. The result of my work in this field is the extension of the method of direct construction of cylindrical and conical panorama, and the use of this method for the direct construction of the so-called inverse panorama. Geometric projection dependencies between images of figures obtained on the undeveloped panorama background, and images obtained on the developed background allowed for the derivation of analytical algorithms and their use in the computer aided mapping of inverse panorama, both on the cylindrical and conical background [IIA1]. Like in the case of classical cylindrical panorama, it was possible to develop a direct and effective method of mapping a reverse panorama with computer aid on a developed cylindrical and conical background [IIA1], both using a fixed and variable observation point. It allowed to enlarge the scope of application of the developed method in various documentations, when objects are presented on cylindrically or cone-shaped surfaces. The results of the above research have been presented in numerous conference speeches and publications listed in [IIE9, IIE12, IIE13, IIE 19, IIE20].

The developed method of direct construction of panoramas after some modifications allows for the mapping of perspective images on developed polyhedral backgrounds, both prismatic and pyramid ones [IIE6]. In turn, the approximation of the cylindrical panorama background with the use of a multi-wall background allowed the development of a method for the

construction of the shadow cast of objects shown in the panoramic image and their mapping by computer aid[IA3].
The developed analytical algorithms for the construction of the panorama, after some transformations, were used to reconstruct 3D objects presented in the panoramic image, as well as to recreate 2D some missing elements of the panorama, which can be used in the renovation of traditional panoramic images[IIE10, IIE15].
However, after some simplifications, the reconstruction method developed can be used to reconstruct building objects depicted by means of perspective on a flat background. That's why it can be used to recreate historical objects based on photographs. The results of such research are presented in publications [IIE5, IIE7]. Developed method can be particularly helpful in the case when the object being reproduced does not exist and the photograph is the only source of information about the object

c) Quantitative and punctual listing of scientific and research achievements

My publication attainment embraces **43** publications and **36** publications after attaining the PhD degree.
All of the publications after attaining the PhD degree were published in English and include:

- **1** scientific monograph,
- **3** publications from the A list of MNiSW included in the Journal Citation Reports (JCR) base,
- **12** publications included in the Web of Science, (additionally 1 publication accepted for print),
- **10** publications from the B list of MNiSW, (additionally 1 publication accepted for print),
- **11** publications oncluded in conference materials,

The total impact factor of all my publications as of 2017 amounts to **3,637**.

Number of cited publications according to Web of Science (WoS): **27**
Number of cited publications according to Scopus : **33**
Hirsch Index according to Web of Science (WoS): **3**
Hirsch Index according to Scopus: **3**

A detailed list of my scientific and research achievements is included in Appendix 5. In the table below, a quantitative and point-based summary of my scientific attainment after doctorate has been presented.

For publications issued in year 2019, the binding punctation from year 2018 has been used.

Publication type	Number of publications		Total	Number of points according to MNiSW	Number of points according to MNiSW (after splitting by co-authors)
	Independent	Co-authored			
Scientific monograph	1	-	1	25	25
Articles from JCR database	2	1	3	85	76
Other articles	19	2	21	222	212
Conference materials	6	5	11	9	5.83
Total	28	8	**36**	**326**	**303.83**

Furthermore, after gaining the PhD degree, I have been presenting the results of my research on 23 conferences, including 22 international.

d) Participation in organizing commitees of international and national scientific conferences

I took part in the work of the International Programme Commitee of the below listed conferences [IIIC]:

1. The 2018 International Conference on Construction, Aviation and Environmental Engineering, ICCAE 2018, Vanung University, Taoyuan City, Taiwan, 23-25.11. 2018

2. International Conference on Engineering Graphics BALTGRAF-14, Tallin University of Technology, Centre of Engineering Graphics, June 1-2, 2017, Tallin, Estonia

3. 12-th International Conference Engineering Graphics BALTGRAF 2013, Riga Technical University and International Association BALTGRAF-12, June 5-7, 2013, Riga, Latvia

4. International Conference on Engineering Graphics BALTGRAF-11, Tallin University of Technology, Centre of Engineering Graphics, June 9-10, 2011, Tallin, Estonia

e) International and national awards for scientific or artistic activity:

1. **2018** Award of the Provost of the Rzeszow University of Technology, individual, 3rd degree for scientific achievements

2. **2017** Award of the Provost of the Rzeszow University of Technology, individual, 3rd degree for scientific achievements

3. **2006** Award of the Provost of the Rzeszow University of Technology, individual, 3rd degree for attainment of the academic degree of PhD

f) Review of publications in international and national journals

I do undertake reviews in the below mentioned journals:

Journals from A list of the MNiSW listing of journals

1. ***Sustainability***
2. ***Journal of Asian Architecture and Building Engineering***

Remaining journals

3. *Buildings* from 2018
4. *Mathematics* from 2018
5. *The Bulletin of Polish Society for Geometry and Engineering Graphics* from 2017

Furthermore, I performed reviews of articles international conferences listed in [IIIP]

6. Didactic activity

a) A characteristic of didactic classes conducted

I am included in the minimum cadre of academic programmes in **civil engineering** 1st and 2nd degree as well as **architecture** 1st degree, conducted at the Department of Civil Engineering, Environmental Engineering and Architechture of the Rzeszow University of Technology.

I conduct classes for students of three programmes: civil engineering, architecture and environmental engineering.

Civil Engineering – geometry and engineering graphics: workshops, projects, laboratories

Architecture – graphical geometry: lectures, workshops, projects, laboratories

Environmental Engineering – information technology bases of design: lectures, laboratories

Currently, I am a coordinator of two modules: graphical geometry and information technology bases of design.

In the 2015/2016 academic year I was conducting workshop and project classes in English, in the course ***Geometry and engineering graphics*** for the civil engineering programme.

b) Participation in programmes and projects

1. In **2015** I took part in project „ ***Educating innovative staff at the Rzeszów University of Technology***" (UDA-POKL. 04.03.00-00-036/12-00)

2. In **2011** I took part in project „ ***Increasing the number of graduates in the field of civil engineering, environmental engineering and environmental protection***" (UDA-POKL.04.01.02-00-055/09-00)

3. In **2010** I took part in project „ ***Expanding and strengthening the educational offer and improving the quality of education at the Faculty of Civil and Environmental Engineering at the Rzeszów University of Technology***" (UDA-POKL.04.01.01-00-103/09-00)

4. I have been a participant of the ERASMUS and ERASMUS+ programmes. As part of these programmes, I traveled abroad three times to partner institutions with the aim of conducting didactic activities.

I also conduct yearly didactic activities for incoming Erasmus+ programme students studying at the Rzeszow University of Technology.

c) Authorship or co-authorship of didactic papers

I am a co-author of two scripts for students of the architecture programme as well as supplementary materials for the students of this programme. Furthermore, I am a co-author of supplementary materials in English for students of civil engineering and architecture programmes [IIIA].

I took part in the production of original, electronic tests used for teaching geometry and engineering graphics as well as verification of the study effects attained by students [IIE17].

7. Popularizing and organizational attainment

1. In the 2006/2007 academic year I performed the duties of the Manager of the Geometry and Engineering Graphics Institute, in the period of 15.02.2007-15.08.2007.

2. From 16.11.2011 I perform the function of an administrator of the departamental system of editing the study effects for the **civil engineering** programme.

3. In 2012 I took part in the production of programme study effects for the **civil engineering** programme, according to the new National Qualifications Framework.

4. From 15.05.2013, as a member of the Commission for Ensuring the Teaching Quality of the Department of Civil Engineering, Environmental Engineering and Architecture I take part in the proceedings of the Commission.