

# Application of Catalan surface in designing roof structures – an important issue in the education of a future architect engineer

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**Abstract** - While teaching descriptive geometry and engineering graphics emphasis should be put on knowledge and skills necessary in the future engineering activity, as well as development of creative inventiveness of a future graduate. Attention should be paid to get deep into topics connected with course of studies which leads to cooperation with Faculty staff. After careful analysis of features and needs of a future engineer which should be shaped during classes a curriculum has been worked out for descriptive geometry at the Faculty of Architecture of the Silesian University of Technology. The classes are conducted for first year students and therefore should especially influence the space perception of a student, which in turn influences his/her creativity. Within this subject practical knowledge is put together with actions aiming at shaping minds in the best possible way. Topics, methods and means of classes realization have been selected appropriately. Modern architecture demands that the design theory is treated as philosophical base for designing. Therefore, contemporary demanded expression forms are a logical result of a designing idea not an aprioristic assumption. The paper discusses issues connected with a designing task of construction roofs designed on the basis of Catalan structures.

**Index Terms** - Catalan's surfaces, didactic solutions, engineering aspect of architecture, geometry and engineering graphics.

## INTRODUCTION

*'It would be a tragedy if, in the minds of young generation, the production of cubic structure on rectangular plane won as a synonym of all architecture'*

Felix Candela

It is the roof which forms one of the most important elements of a building. Apart from strictly usable features such as protection against weather conditions, a roof plays much more important role since, thanks to its distinctness, its diverse form determines the character of the whole object. The roof is often referred to as the fifth elevation due to the fact that one can get a full picture of the whole building also from above.

In the last century in architecture the boundaries of the objects became unclear, inner space joined with the outer space, the boundary between a roof and a wall blurred. Therefore, the concept of a roof has been broadened and the notion of roof surface has become more common. It covers not only all constructions based on walls or poles but also constructions which constitute shields 'from above' and from 'the side'.

Depending on the used materials, techniques of constructing or the very type of construction a vast number of roof surfaces can be distinguished. Roof surfaces constructed on the basis of Catalan surface form one of the most interesting ones as far as architectural form is concerned and quite often have surprising geometrical structure. Thanks to such solutions an architect has a possibility to obtain wonderful form with very daring constructions, which add an element of variety and freedom to the city landscape, being more of a sculpture in urban space than a building in traditional meaning of the word.

While conducting Descriptive Geometry classes at the Faculty of Architecture I considered it a very important issue to make students familiar with problems of this type of construction.

My didactic research was based on the conviction that in every architectural and constructional design the conditions of building geometry must be included. The very geometrical analysis referring to one issue only is usually connected with architectural planning and gives an architect a lot of space for considerations. Topic seemingly narrow becomes, thanks to geometry, broad and a designer by means of geometrical reasoning obtains proper solution.

## GUIDELINES OF DIDACTIC RESEARCH

In modern designing of roof structures an important element is formed by the achievement of maximum of artistic and special effect with minimal construction mass. This can be done only if such a construction is created with materials which 'work' in possibly the most favourable conditions. The influence of geometrical form on strength, economical aspects and functionality of a construction (in this case roof structures) justifies the demand for analysis of shapes and form classification. Taking way of creation as classification criterion – law according to which generatrix moves in space – we can differentiate the following Catalan

surfaces: cylindroids, conoids and hyperbolic parabola ( so called 'saddle surface').

The notion 'shell' can be associated with forms occurring in nature and then we relate it to two specific features: 'curved shape' and 'strong material' for construction. For construction forms such as shell these features are also important. In engineering practice while designing shells, apart from the above mentioned features, other restraining conditions are also included e.g. the fact that a form of geometrical shell should be possibly simple in order not to cause difficulties in realization on building site. Descriptive geometry makes it possible to present a piece of surface under investigation in a visual way and in this way to facilitate its static work.

Catalan's structures used in architecture as roof structures give not only economical advantages and relatively easy realization, but also a possibility of obtaining a variety of forms and esthetic features.

It is always a must in order to make architecture real to use the techniques of constructing and quality of materials. It happens, first of all, when architectural knowledge draws on experience of civil engineering.

Designing technique influences psyche, inspires imagination and reasoning. Practical efficiency, endurance and the purposefulness become a motive of searching as well as the quest of such a shape which can be described as beautiful. It is all possible when an architect uses constructing values of a structure and a constructor appreciates the beauty of architecture.

This approach to architecture has become a motivation to take up didactic research.

#### ASSUMPTIONS FOR DESIGNING TASK

Within the subject of Descriptive Geometry at the Faculty of Architecture the teaching staff quite often face a problem of a new approach to space- its shaping and transformation. However, there is one thing they are sure of: sticking with traditional methods of object creation, based on projections it is necessary to focus stronger on modelling. There is an issue of subject responsibility for development of skills in using traditional tools for drawing and making models. At the conceptual level of designing, an architect engineer will not give up a piece of paper or a pencil, and abilities to make a model is especially valuable in designing offices and is a favourable way of presenting designs to investors.

Education in any domain always aims at developing abilities of rational problem solving, using knowledge on laws and rules governing a given discipline.

There is one hour of lecture and two hours of classes per week of Descriptive Geometry taught at the Faculty of Architecture. After a lecture on Catalan's surfaces students make sketches of a concept of roof surface. This is set as homework. Next stage is a project which consists of drawing a designed construction in three projections. Then after teacher's approval students make a model of roof surface.

Main designing guideline is function of a building and thus, projection of an object and its cubic capacity. Designed roof surface can be placed above all the structure or only a

part e.g. the entrance section. Another conceptual assumption is using Catalan's surface in elements of 'small architecture': summerhouses, bus stops, underground entrances etc.

While making a model main Catalan's surfaces should be made of durable material such as balsa, plexiglass, metal etc. and generatrix surfaces form wire, fibre, string etc.

#### DIGRESSION

It should be noticed that students most often choose hyperbolic parabola i.e. so called saddle surface as roof structure created on Catalan's surfaces. Similar phenomenon happens in professional practice of an architect where this type of shell structure is a favourite form of engineers, constructors and architects. It is enough to mention Raleigh Arena designed by prominent Polish architect Maciej Nowicki in 1950. This object paved the way of contemporary constructions of suspended structures. Load bearing structure is made of preliminary tight string grid in a shape of hyperbolic parabola. This object was awarded AIA honorary prize in 1953 and was included in 10 most distinguished buildings in the history of architecture by Architectural Record in 1957. It inspired many followers for example Saarinen (ice rink at Yale University in New Haven, Dulles Airport terminal in Washington).

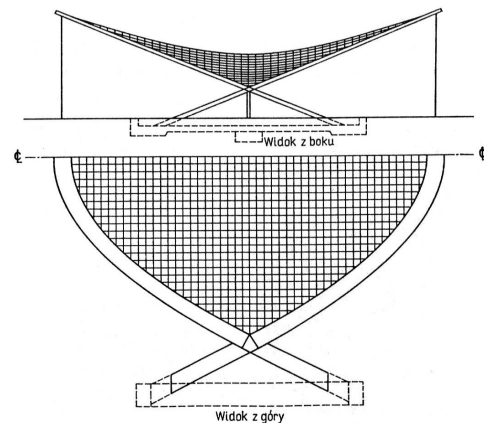


FIGURE 1  
RALEIGH ARENA, VIEW FROM SIDE AND ABOVE.

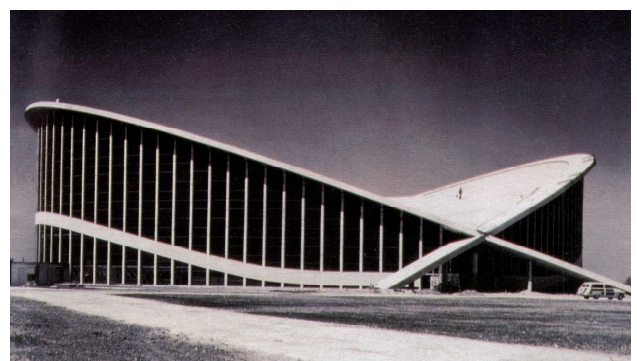


FIGURE 2  
RALEIGH ARENA, SO CALLED COW PALACE.

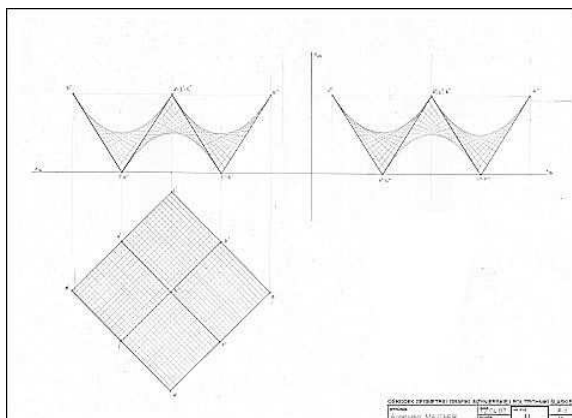
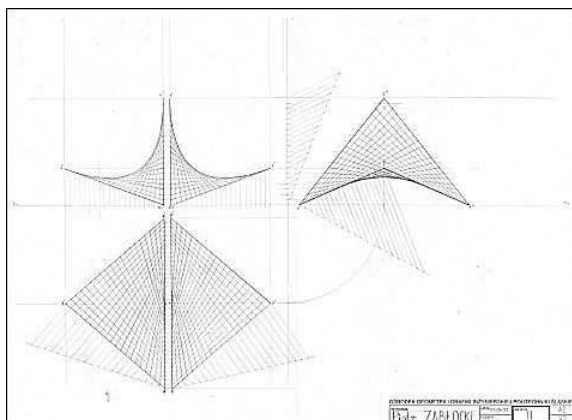
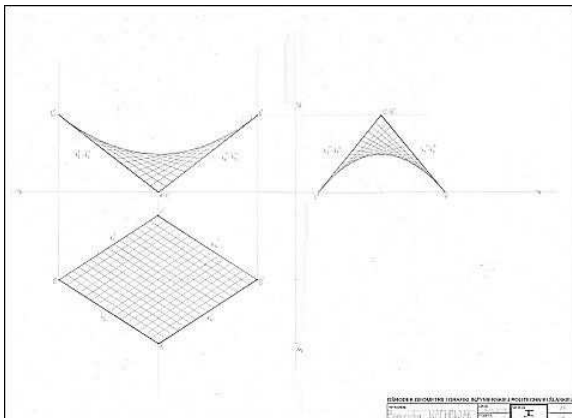
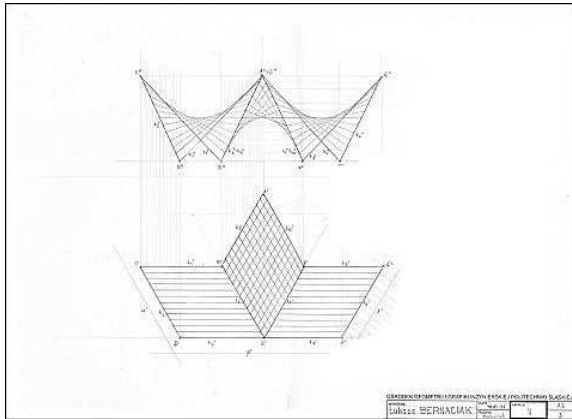


FIGURE 3, 4, 5, 6  
THREE OR TWO PROJECTIONS OF DESIGNED ROOF SURFACE

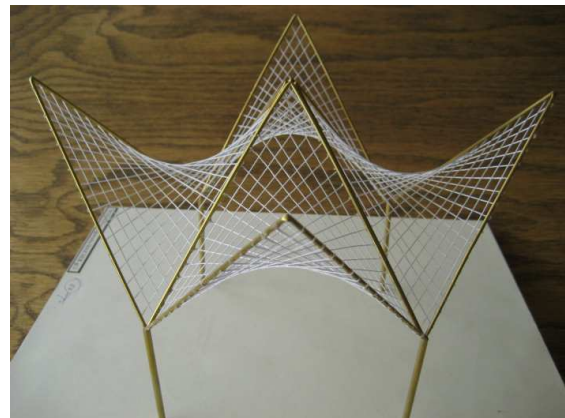
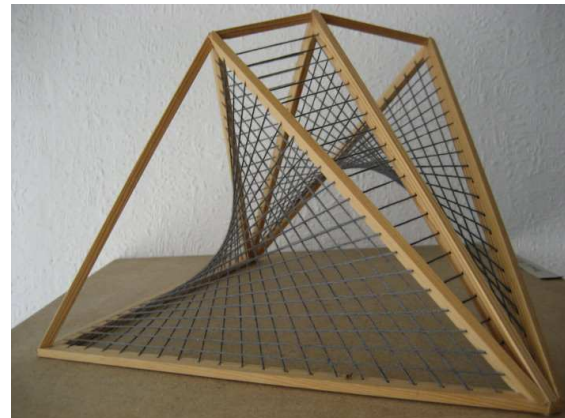
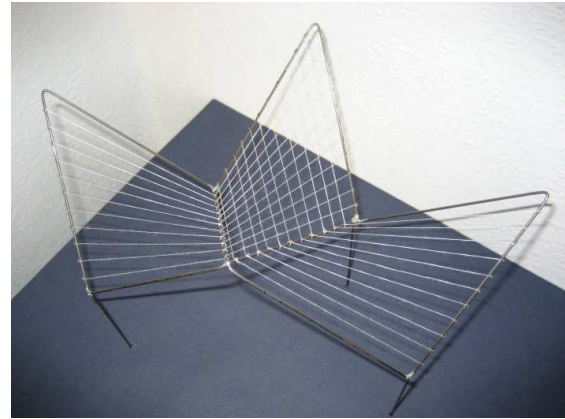


FIGURE 7, 8, 9, 10  
A MODEL OF CATALAN SURFACE MADE BY A FIRST YEAR  
STUDENT OF FACULTY OF ARCHITECTURE



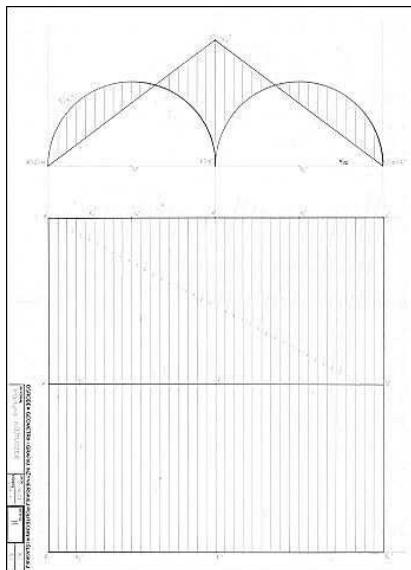
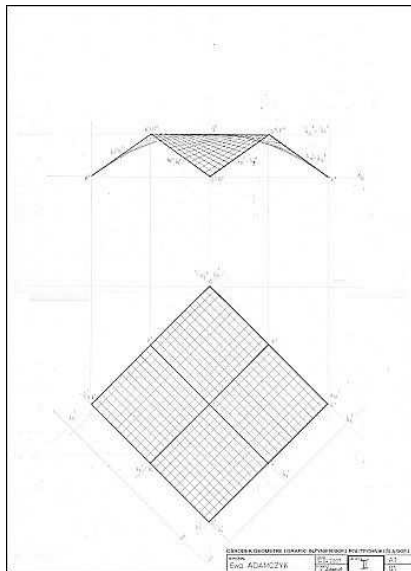
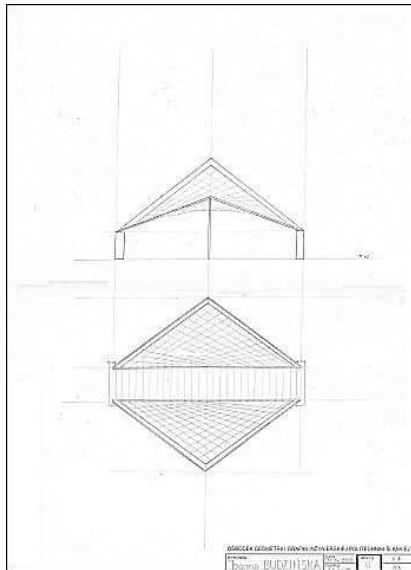


FIGURE 11, 12, 13  
TWO PROJECTIONS OF DESIGNED ROOF SURFACE

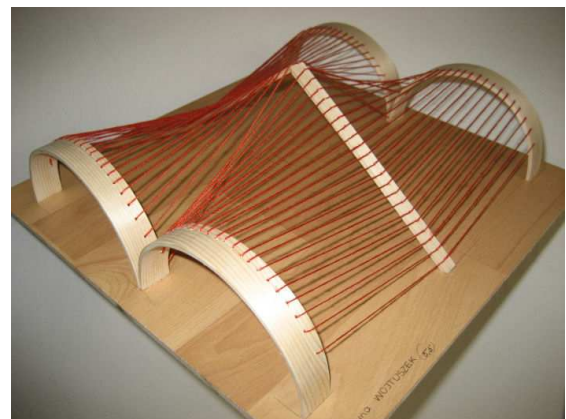
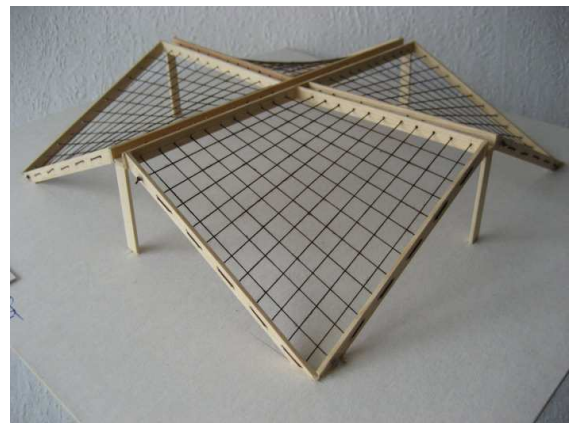
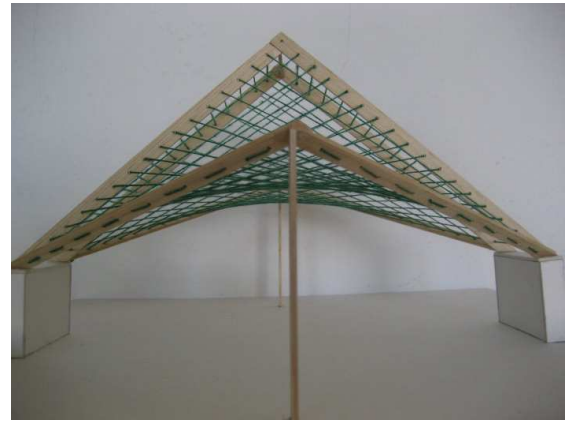


FIGURE 14, 15, 16  
A MODEL OF CATALAN SURFACE MADE BY A FIRST YEAR  
STUDENT OF FACULTY OF ARCHITECTURE

## CONCLUSIONS

The idea of carrying structure of roof structures based on Catalan's surfaces shapes constructive form. A given layout of supporting forces leaning on a set of directrices and generatrices decides on the form, which allow solving the problem of span, height and width of a roof structure. Constructive form of the roof structure, which aims at proper statics, inspires structural form, which is seen as special kind of piece of art of constructing and architectural composing.

A lecture prepared in a multimedia form, presenting a rule of creating and kinds of Catalan's surfaces has been very well received by students. The presented architectural objects with such roof structures broadened the knowledge on the usage of ruled surfaces. Exercise where students individually design roof structure develops creativity whereas creation of a model makes them aware of constructing Catalan's surfaces. Additionally, carrying classes gradually – from idea to making a 2-D drawing to presenting a design in a 3-D form leads to better understanding of the relations of mutual location of object elements. It makes one aware of advantages and disadvantages of descriptive and space method of mapping an object.

## REFERENCES

- [1] Borusiewicz, W, *Konstrukcje budowlane dla architektów*, Arkady, Warszawa, 1978, pp. 288 – 289, 351 – 354
- [2] Przewłocki, S, *Geometria wykreślna w budownictwie*, Arkady, Warszawa, 1982, pp. 87 – 123