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Lenticular girder – structural shape and proposals for applications

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Abstract

In this paper are presented the principal structural rules of a lenticular girder, which can be basic modular form in processes of shaping of numerous types of spatial structures. The lenticular girder can be arranged in various ways into spaces of the designed structures, which can be applied for different useful purposes. There are also shown proposals of its applications in systems of simple trusses of large spans, in spatial roof structures, which can obtain various forms and can create support structures of large span covers. The morphological features of the lenticular girder cause that it can be also applied as the main structural system for multi-storey buildings. There are presented propositions of the tall building structural systems designed by means of lenticular girder.

Keywords: morphology of space structures, metal truss structure, timber-metal structure, tension-strut structure, pre-stressed structural system, large span roof, tall building.

1. Introduction

The structural system called lenicular girder is recently developed by the author as a result of research of a very lightweight, stiff and economic efficient structure for roof covers, as in Rębielak [1, 2, 3]. In the paper are shown only basic forms of this offered system. There are several other existing types of structural systems having forms similar to the lens shape. Form of the proposed structure is obtained as suitable transformations of a pattern of stress trajectories in simple beam. Therefore the lenticular girder is preliminary assumed as a system composed of tension and compression members, which have to be connected together in an appropriate way. From this assumption it follows that this system can belong to group of tension-strut structures, which usually have to be pre-stressed. The paper presents general description of some chosen structural forms of the newly proposed system.

2. Examples of basic forms

Next three figures show patterns of one of basic types of technical solutions possible to create by application of the structural formula of the proposed lenticular girder. Girder of the scheme presented in Figure 1 is built by means of two groups of compression members running along broken curves resembling isostatics lines inside the bending beam. These two groups of compression members are called compression strips. They are directed oppositely and mutually interpenetrate each other. Short tension members are located vertically and they connect appropriate chosen nodes of the compression strips. The necessary pre-stressing can be applied e.g. by means of fluently controlled changes of lengths of vertical members situated above the both supports. Secondary short members can be arranged in vertical lines and connected to corresponding nodes of compression strips in order to decrease the reduced buckling lengths of long tension members. One can notice that the girder is suitably composed of two simple cantilever structures, which may be considered as a starting form for shaping of other types of spatial structures.

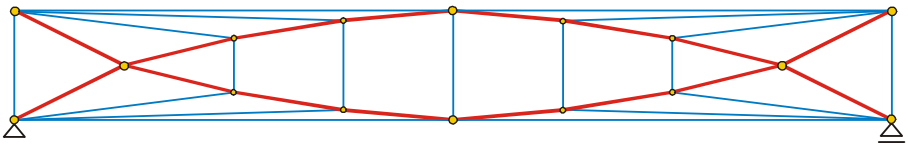

Figure 1: One of basic shapes of lenticular girder

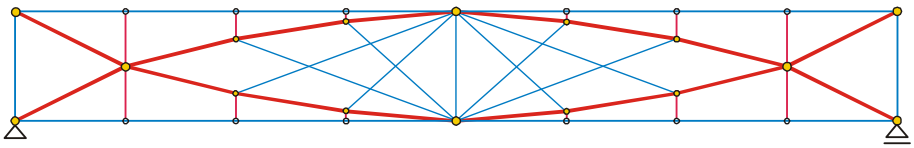

Figure 2: Another form of basic shapes of lenticular girder

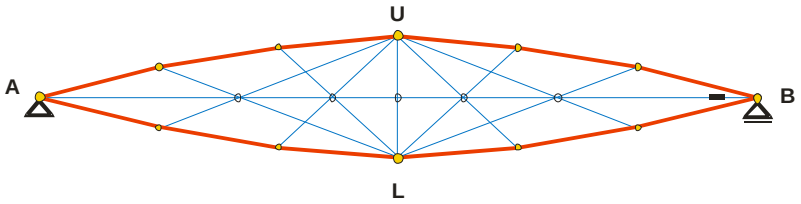

Figure 3: Simple form of basic shapes of lenticular girder

Second example of basic forms of lenticular girder, shown in Figure 2, has also structural form inscribed inside an elongated quadrangle. In this case the system of long tension members is of different shape and location. It consists of members, which directions are focused respectively in two nodes, in the upper and lower chord, which nodes are placed in

the middle of the girder length. Additional system of vertical located short struts, supporting long external tension members running in horizontal way, is visible in this figure. The third of basic forms of the lenticular girder is shown in Figure 3. It has simple and exactly shape of a lens, and it is composed of two strips built of compression members and system of tension members designed like in the previous case. Directions of the half number of long tension members are focused in the upper central node U and directions of the second half of these members are running straight to the node L of the lower chord located in the middle of the lenticular girder, compare Figure 3. Long horizontal tension member is placed directly between two main support nodes A and B of the girder. This tension member is provided with accessory device, like e.g. turnbuckle, which makes possible to control its length and precise application forces of the initial pre-stressing. All members and nodes of the girder have to be designed in suitable way in order to ensure independent strains of all components of this system.

Schemes shown in Figure 1, Figure 2 and in Figure 3 represent only a few examples of structural shapes of the plane girders or plane trusses possible to create by application of general formula of the proposed form of lenticular girder. Several next examples can display the range of other and various structural forms of the offered system. Scheme shown in Figure 4a represents an example of the lenticular girder application in the roof structure of typical hall building. The same form of a plane girder may be used in the more complex manner, what presents scheme shown in Figure 4b. Plane lenticular girders are connected together at right angel, they are perpendicularly placed to the main surface of the roof and supplemented by means of additional members forming suitable bracing system.

As it was beforehand mentioned there are numerous possibilities of application of structural formula of lenticular girder what may give in result many various forms of the tension-strut structures. Patterns of plane girders can be different, they can be connected together and arranged in space of the designed structure in various ways. Support structures shaped by means of proposed girders can be very stiff and at the same time very lightweight.

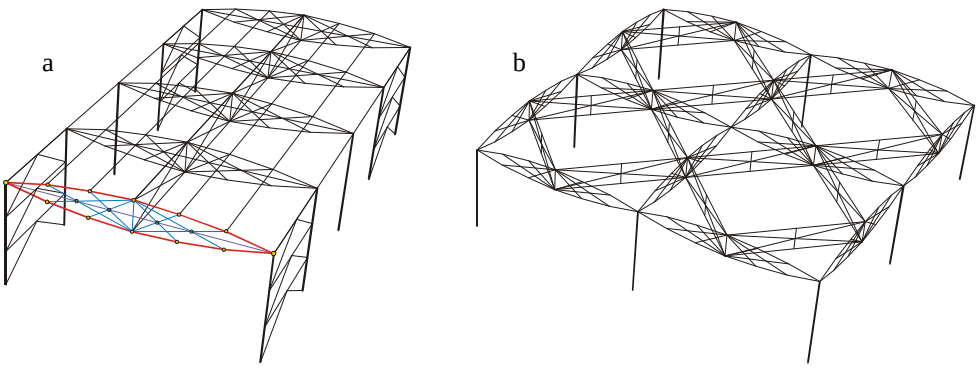

Figure 4: a) Scheme of a typical hall system, b) example of more complex form of the roof hall structure designed by means of simple form of the lenticular girder

3. Example of a basic form of spatial type of lenticular girder

Plain form of simple lenticular girder is composed of two symmetrically parts. Each of these parts can be considered as a half of a girder, which can be repeated in space in the way shown in Figure 5. Upper node U and lower node L are common nodes of the set of three basic components. Vertex nodes A, B and C are connected by means of long tension members located along the border edges of a spatial module having triangular form.

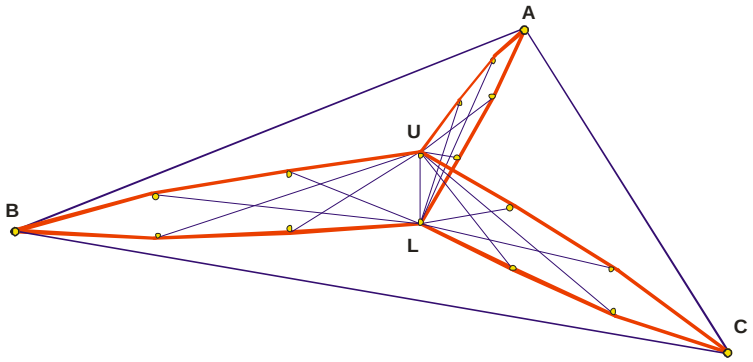

Figure 5: Example of structural module shaped as spatial form of lenticular girder

The basic set of component parts will be supplemented by means of additional members creating necessary bracing system according to general concept of the designed support structure. Form of a spatial module presented in Figure 4 can be applied in many various ways due to which it will be possible to design different structural forms of roof covers.

3.1. Roof structure for sport stand cover

General form of spatial configuration shown in Figure 4 was applied in a conceptual design made very recently by the author for the roof spaced over stands of a small sport stadium in Złotów, located in the north of Poland. Shape of a triangular module was assumed as the starting point for shaping process of the steel roof structure. One of its final results presents scheme in Figure 6. Basic module is of form of equilateral triangle of edge length equals 11,40 meters, what is the distance of main columns, which are placed directly below nodes L1 or L2 each of the triangular module. Columns of second row are arranged beneath nodes of the type B1, C1 or B2. Vertex nodes of triangular modules are joined by means arches made of steel tubular members. Positions of these arches are stabilized by means of system of the secondary tension members, directions of which are focused in nodes of the type U1, U2 or L1, L2. Vertex nodes of the type A are directed towards the sports ground of the stadium. Additional system of tension members is put in triangular fields placed between two adjacent basic modules. General schemes or views of the entire structure are shown in Figure 7 and in Figure 8.

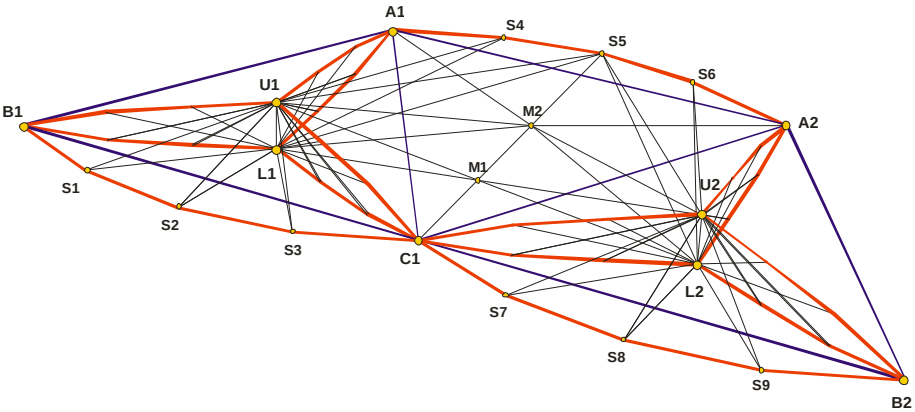

Figure 6: Scheme of general concept of the roof structure over sport stands

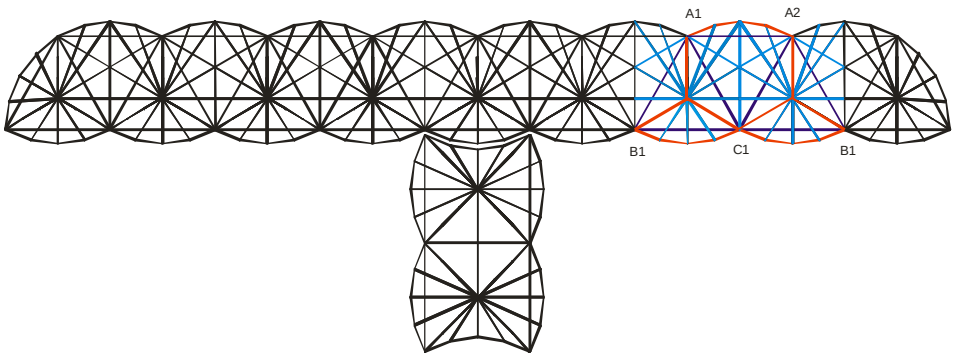

Figure 7: Top view of the whole roof structure

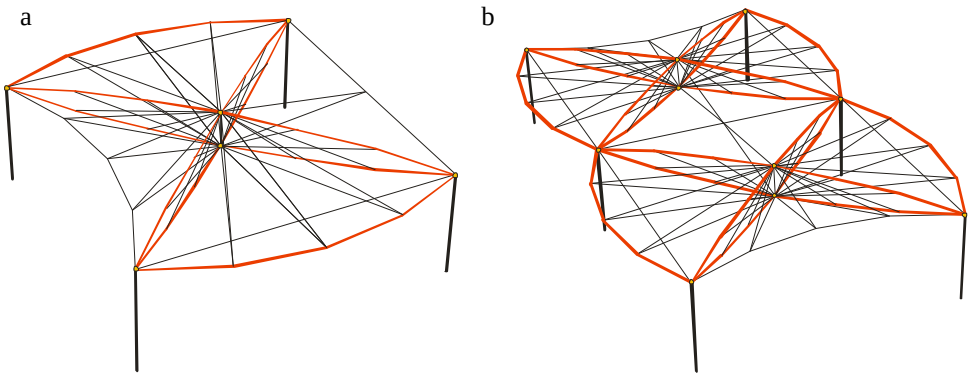

Figure 8: a) Scheme of single segment, b) general view of two segments of roof structure of a coupler located between stands and technical building of the sport stadium

Clear span of the cantilever roof structure equals 6,58 meters, while the construction depth of a single triangular module is assumed as 1,35 m. Main compression members are designed as steel tubes of the cross-section diameter 193,7 mm and the steel consumption of the roof structure, except the weight of columns, per square meter of a covered area is estimated on level of about 22 kg. Cladding system of the roof cover is designed by means of suitable semi-translucent membrane. Some views of the roof structure are shown in Figure 9 and in Figure 10.

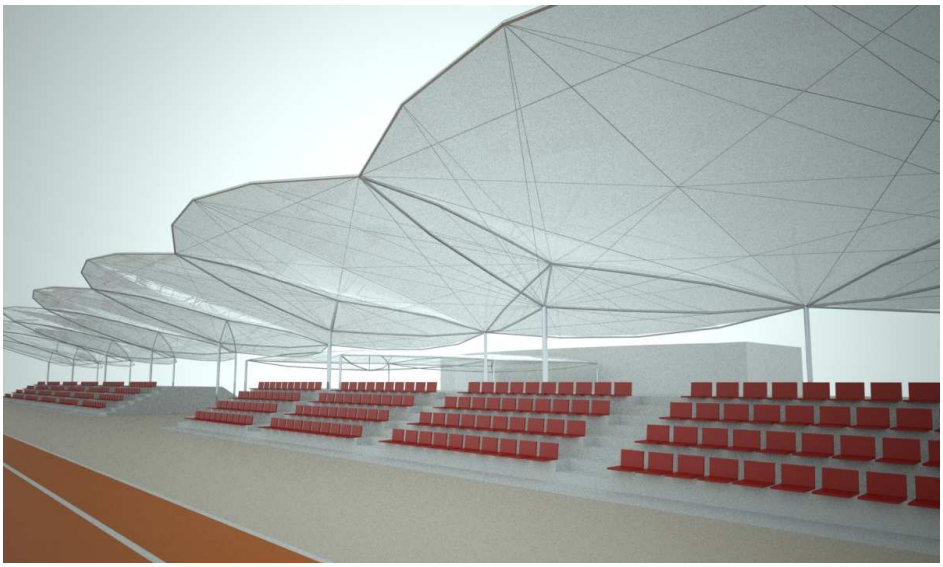

Figure 9: General view of the stands roof from the sports ground

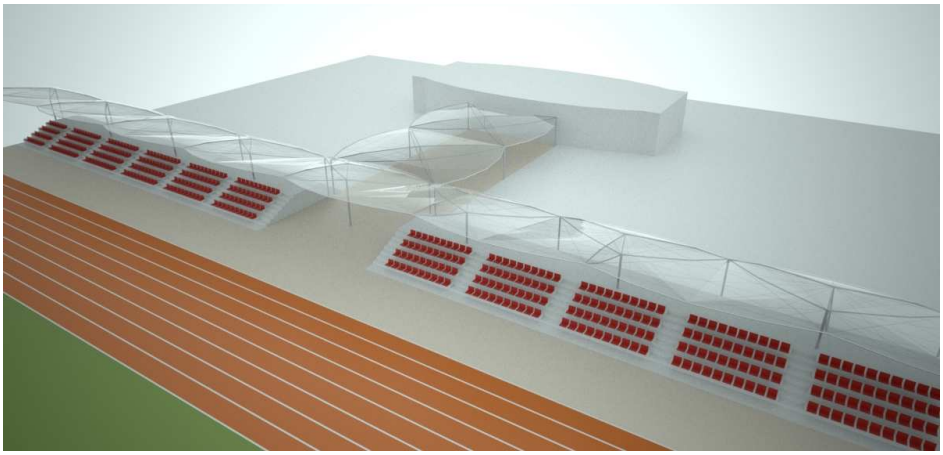

Figure 10: Top view of the stands roof structure with a coupler and technical building

4. Lenticular girder in structure of a tall building

Because each plain form of simple lenticular girder can be considered as an appropriate composition of basic cantilever girder therefore it is morphologically justified to apply it for needs of shaping of the support structure for a multi-storey building. Schemes of exemplary patterns of such elementary cantilever lenticular girders are presented in Figure 11. These girders, vertically positioned, can be arranged along perimeter of a tall building or located inside the inner space of that object. There are some possible ways of application of the proposed system in the design of a multi-storey building, which may give in results

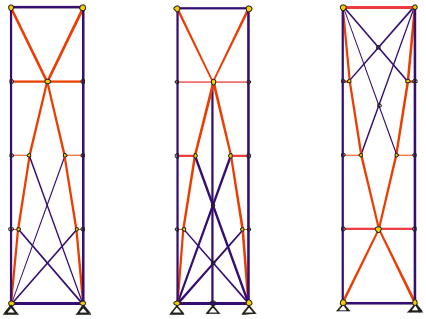

Figure 11: Patterns of several basic types of cantilever lenticular girders

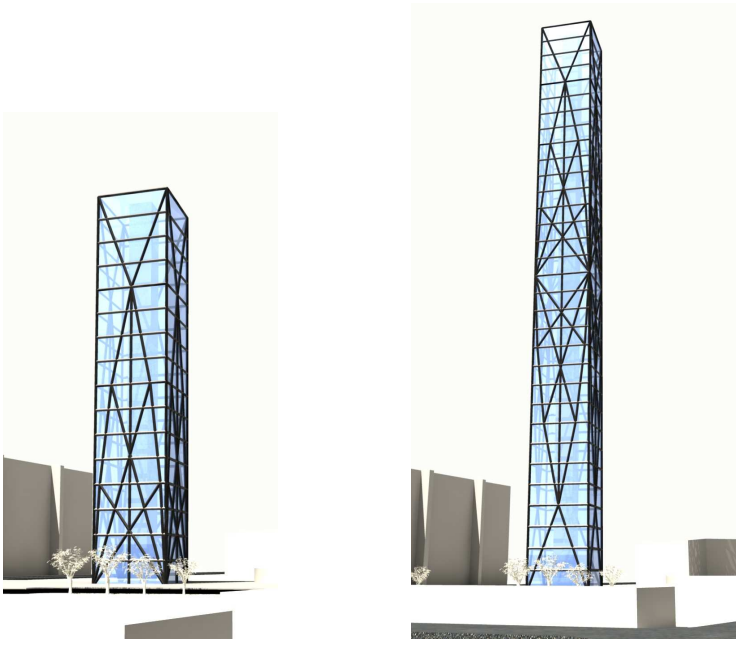

Figure 12: Exemplary forms of tall buildings shaped by means of lenticular girder

some interesting and efficient shapes of the bearing structures for that type of architectonic objects. Draft forms of such buildings are presented in Figure 12. Big sizes of geometrical dimensions together with immense values of load applied to the tall building structure cause, that the pre-stressing process seems to be very difficult or almost impossible but under some condition it can be done by means of appropriate structure of some chosen components, located horizontally and being integral parts of the floor structures.

5. Conclusions

The proposed structural system, called lenticular girder, can be applied as the main support structure of various types of engineering and architectonic objects. The paper presents only the outline of basic forms of these types of structural systems possible to design by means of this girder. It is especially devoted for lightweight roof structures, which can be designed in different ways and which particularly can be of large spans. Structural features justify to apply it as the main support structure of tall building. In all cases buildings designed by application of lenticular girder can be of individual and interesting architectonic views. All the expectations have to be verified by results of numerous comprehensive structural, static and dynamic analyses. Numerical models of these structures will be very helpful in these research processes.

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