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Floating Platforms for Generating Emission Free Electric Energy

Janusz Rebielak

Wroclaw Branch of the Polish Academy of Sciences, Wroclaw, Poland

ABSTRACT

The article presents two concepts of constructing floating platforms at sea intended for emission-free production of electricity. In the first one, electricity is generated using photovoltaic panels placed along the edge of a large circular floating platform. In the second and most important concept each platform consists of two main parts stacked horizontally on top of each other, the lower of which is a floating platform. These two separate components of the platform are connected to each other using special support nodes. Each of these nodes has the general shape of a cone and is free to rotate around the vertical axis of the cone. The kinetic energy of sea waves is absorbed by the lower platform floating on the water, setting it in motion, which motion is transmitted to the upper platform via support nodes. The rotating support nodes are connected to electric current generators. The energy generated in this way can be sent directly to external recipients or temporarily stored in the platforms themselves. The paper includes drawings showing examples of appropriate design solutions.

***Corresponding author**

Janusz Rębielak, Wroclaw Branch of the Polish Academy of Sciences, Wroclaw, Poland. Tel: +48 601 592 525.

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Introduction

In the era of rapidly progressing climate change there is an intensive development of modern electricity generation technologies with significantly reduced levels of greenhouse gas emissions or complete elimination of such gas emissions. The efficiency of new energy technologies can be significantly increased by applying new structural solutions.

The paper presents proposals for shaping platforms designed as artificial floating islands, which can also be the basis for the food and energy self-sufficient residential habitats, where electricity is generated from the movement of sea waves.

Structural Concept of System of Composite Foundation

The composite foundation system has been developed for the foundation of heavily loaded buildings, including high-rise buildings, located on ground with very low load-bearing capacity and in areas of seismic activity or mining damage, which is presented in detail in paper [1]. Module of its intermediate system has a lenticular shape, see Figure. 1a, and it is constructed of straight members, under axial compression or tension, located in a narrow space between two beams parallel to each other or located on two sides of one beam (1) placed on a horizontal base plate (2). The intermediate system is connected to the material of each beam (1) by means of joint nodes of the types (Cn) and (Ce) distributed evenly along the neutral axis of the beam. Nodes of type (C) or (B) connect adjacent lenticular modules of the indirect system and not join the beam matter (1).

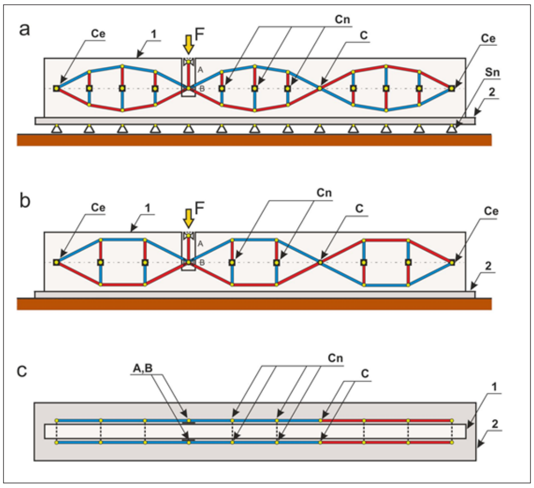

Figure 1: General Schemes of Structure of the System of Composite Foundation Together with Suggested Arrangement of Special Support Nodes (Sn)

The lenticular modules connect to the matter of the beams (1) via nodes (Cn) and (Ce). The forces loading (F) the overall foundation structure are applied to type nodes (B, C, Ce) via a short vertical member, placed in appropriate guides, capable of the small vertical displacements. This lenticular module can take simplified shapes, see Figure. 1b, and be replicated endlessly along the horizontal direction due to which surface of the foundation can be theoretically unlimited and stresses in the ground below this foundation can be very small. A top view of such a structural system is shown in Figure. 1c. Beams (1) can be arranged along different directions to form, for example, orthogonal structures like units shown in Figure. 2 and in Figure. 3.

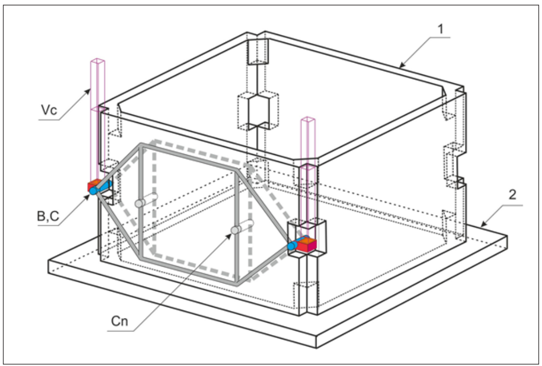

Figure 2: A Simple One-Story Shape of a Rectangular Unit of the System of Composite Foundations

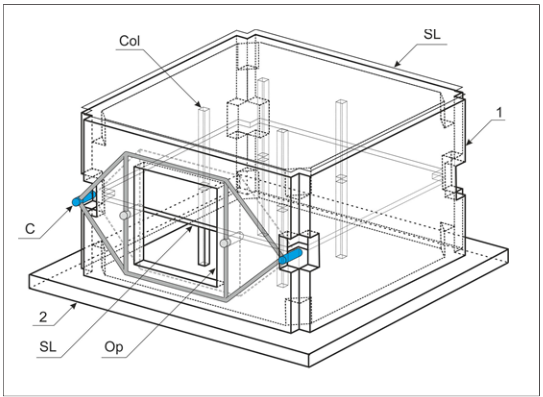

Figure 3: An Example of a Two-Storey Shape of a Rectangular Unit of the System of Composite Foundations

It is assumed that a square will be the most favorable shape for the base of an orthogonal unit. If the horizontal geometric dimensions of such a unit are quite large, an appropriate number of columns (Col) should be placed inside it, see Figure. 3. In these cases, the construction depth of the beams (1) can also be big. Therefore, for structural and functional reasons, it will sometimes be necessary to design horizontal ceilings (SL) for at least two floors. Their spaces can be intended to perform various functions. For them to be met effectively, technical openings (Op) must be properly arranged in the materials of the basic beams (1).

As mentioned earlier, beams (1) can be placed in different directions, for example creating orthogonal structures composed of large watertight boxes which, when properly connected to each other, can form large artificial floating islands as it is shown in Figure. 4. Such artificial islands with large geometric dimensions, suitably anchored in the bottom of the coastal zone of the tropical sea, can be the bases for objects of numerous utility functions, such as e.g., residential, commercial, warehouse, industrial function or others.

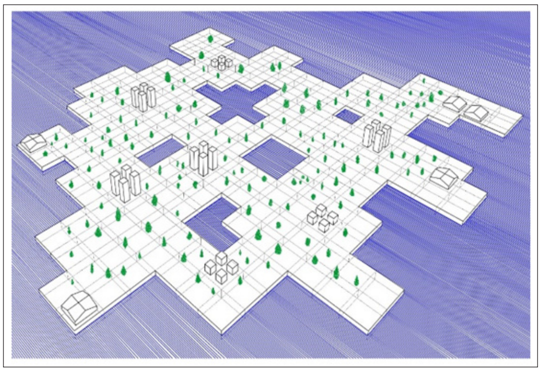

Figure 4: Bird View of Floating Habitable and Industrial Artificial Island

Artificial Island Called Ocean Agave

The Ocean Agave, see Figure 5 – Figure 10, is planned as an artificial island floating in subtropical ocean areas, in a far distance from land, the sailing direction of which can be controlled by means of set of ship propellers moved by electric engines together with set of rudders. It is indented as an independent settling unit that is self-sufficient in terms of energy and food supply and able to house a group of less than 200 persons [2]. The main bearing structure of the Ocean Agave is exactly the system of composite foundation. Although it has been developed for foundation of the very heavily loaded structures constructed on unstable background but due its structural features, like having a small construction depth, it can get numerous and various applications.

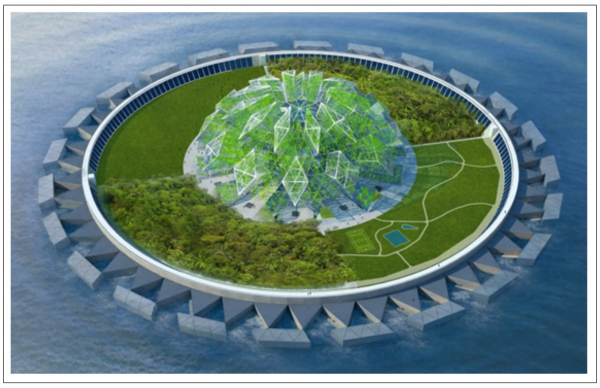

Figure 5: Bird View of the Ocean Agave

Figure 6: Simplified Elevation of the Ocean Agave

The platform of the Ocean Agave has the structural system of composite foundation having a circular shape, see Figure 5, and it is built by using properly connected, sealed, steel-reinforced concrete boxes, having mostly trapezoidal shapes with construction depth of 15 meters. Between them are located component parts of the intermediate system having various structural forms. The interior area of this artificial island is protected by the main reinforced concrete breakwater running along its perimeter and having height of ca. 25 meters. The boxes form a circle, having slightly more than 400 meters in diameter, surrounded by perimeter breakwater, which is supplemented with a set of triangular, reinforced concrete elements forming loading bays, constructed similarly to the boxes themselves and with properly placed trapezoidal reinforced concrete elements, which act not only as the circumferential breakwaters, but also, they are basic parts of engineering devices able to obtain energy from movement of the sea waves. Another source of electric energy are the photovoltaic panels situated on the oblique internal surface of the circular breakwater.

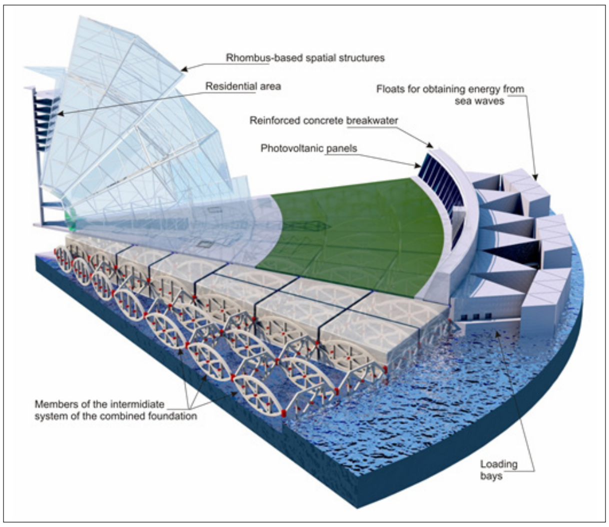

Figure 7: General Scheme of Arrangement of Structural Component Parts Inside Whole Space of the Ocean Agave

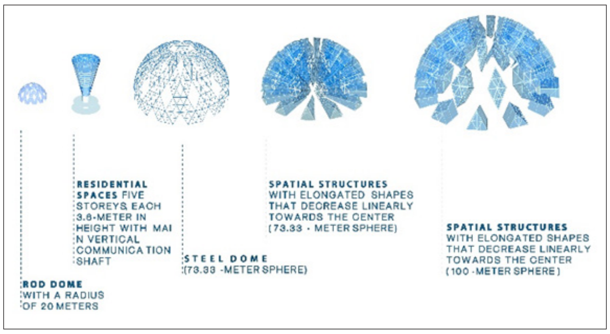

Figure 8: Spatial Structures Forming the Structural Agave

Species of trees, shrubs and grass having high resistance to the increased amount of salt contained in the air are in a wide ring belt located between the central part of the Ocean Agave and its coastal zone.

The assumed shape of central part of the Ocean Agave is dictated by the pursuit of allowing the best possible lightning conditions for plants with low tolerance for presence of salt in the air in proximity of the sea water. For this reason, they were placed in enclosed, air-conditioned glass spatial structures with elongated shapes. The plants are grown in appropriate pots that contain fertile soil and are watered by drop irrigation. The pots are evenly placed within each structure and are stably mounted into proper nods by rods and ties.

The lower parts of the spatial structures are mounted onto the nodes of a smaller lattice dome with a radius of 20 meters. Other supporting nodes of these structures are proper indirect nodes that also function as openwork nodes of steel dome with radius equal to 73.33 meters. The residential spaces for permanent inhabitants of Ocean Agave are situated in its middle on five storeys, each 3.6-meter in height.

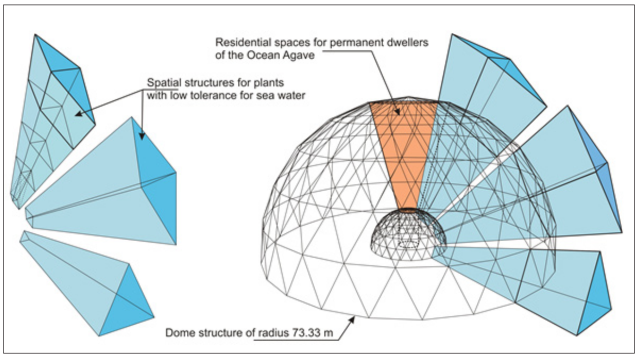

Figure 9: Shapes of the Main Types of Spatial Structures Located in the Center of the Ocean Agave

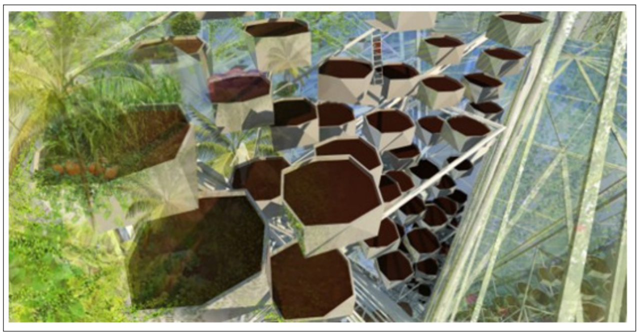

Figure 10: Interior View of Spaces of the Elongated Structures

The center of the artificial island houses a structure called Structural Agave, divided into several dozen spatial structures with elongated shapes that decrease linearly towards the center, and whose axes converge in the central point of the whole settlement. Their cross-sections are mostly rhombus-based, while only these directly connected to the upper platform's level have their cross-sections shapes into triangles. A structure built this way possesses a form that closely relates to a shape of 100-meter sphere. These spatial structures are made of stainless steel and covered with appropriate glass panels, which are covered finally by semi-transparent photovoltaic foils.

The permanent dwellers can obtain the protein food from fish in waters surrounding Ocean Agave or bred along with other species of sea animals within appropriate underwater devices, available from numerous loading bays. External re-supplying is to be handled by means of keelboats transporting goods between Ocean Agave and a ship located nearby. Although the Ocean Agave theoretically may not possess its own propulsion, but the potentially huge amount of electric energy generated by devices installed on it induces to equip the floating structure with sets of electric engines used to drive ship propellers immersed in water at an appropriate depth.

Structure of Special Type of Support Node

The composite foundation system, together with a special type of support node, constitute a unified structural unity and have been developed for the safe foundation of dynamically loaded objects. This mostly concerns the foundation of buildings placed in seismically active areas or located in areas of mining damage. The structural system of one of the basic types of such a support node is shown in Figure. 11-14.

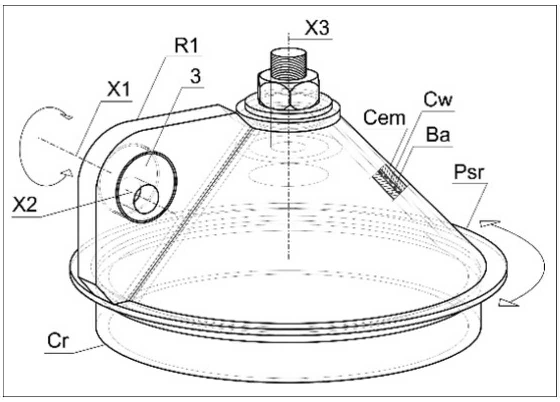

Figure 11: Conical Form of Main Body of Special Support Node with a Single Rib

The basic type of the support node structure is made of two sets of conical bodies, while each set consists of two conical modules, of which the basic one (Ba) is fixed permanently by means of a circular ring (Cr) in the upper (Up) or in the lower (Lo) part of the floating platform. Each conical support node is fitted with a conical external module (Cem), which is fully rotatable around the vertical axis X3. Between the basic inner conical module (Ba) and the conical external module (Cem) there is a conical washer (Cw), made for example of Kevlar, which facilitates the rotation of the conical external module (Cem) on the

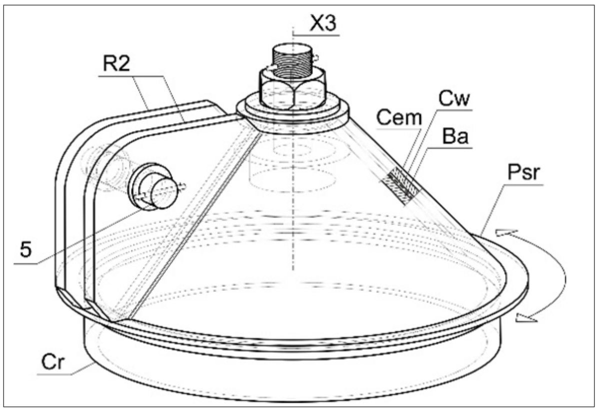

Figure 12: Conical Form of Main Body of Special Support Node with Double Ribs

internal module (Ba) around the vertical axis X3. The first set of conical body, see Figure 11, has a conical external module (Cem) equipped with a single vertical rib (R1) located along an element of a cone and is permanently connected to the conical outer module (Cem). The single vertical rib (R1) has a relatively large thickness and has a circular opening in which a circular roller (3) is accommodated in a fitted manner, for which the axis of rotation is the horizontal axis X1. Within the roller (3) there is a cylindrical hole, for which the axis of rotation is the X2 axis, also located horizontally and parallel to axis X1. Each conical external module (Cem) is equipped with a perimeter stabilizing ring (Psr). The second set of conical body has a similar structure, see Figure 12, except that this time two vertical ribs (R2) are permanently connected to the conical outer module (Cem), and the thickness of each is half that of single rib (R1). In each of the two ribs (R2) there is a cylindrical hole for placing a horizontal pin (5), whose task is to join in an articulate way the two sets of conical bodies into a single support node, see Figure 13 and Figure 14.

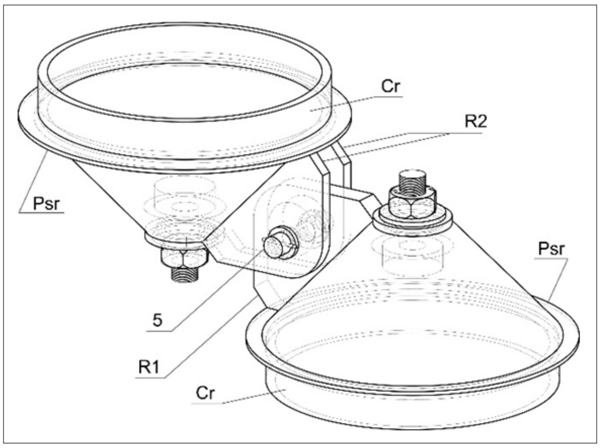

Figure 13: General View of Basic Variant of the Support Node Made of Two Conical Bodies

The support nodes built in this way and properly connected to the composite foundation system, compare Figure 1a, can constitute a horizontal dilatation of the structure of the object from its ground and thus meet the main requirements for the structures of objects loaded dynamically, which include buildings located in zones seismically active or erected in the areas of mining damage, as it is presented in [3-7].

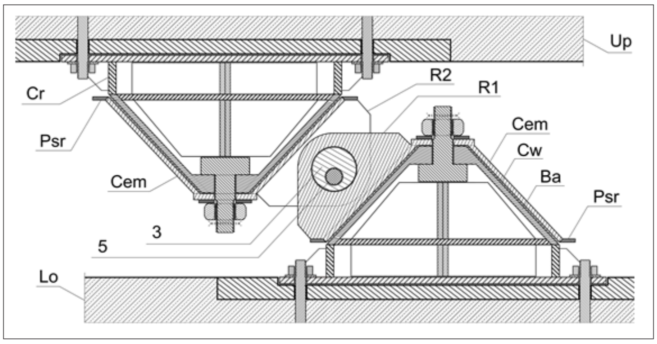

Figure 14: Vertical Section of the Support Node with Conical Forms of the Main Bodies

In each single foundation sector, the arrangement of single (R1) and double (R2) ribs must be identical, and the number of such support nodes will be quite large [8]. Thanks to this and due to use of appropriate conical washers (Cw), the deviations of the vertical axes (X3) of these nodes will be insignificant and their impact on the deformations of the components of the structure will be negligible, due to which the values of these deformations can be within the acceptable dimensional tolerance of the entire structure.

Floating Electric Power Station

The concept of a floating electric power station just presented has been formulated by application of the basic variant of the support node designed for dynamically loaded objects. In this case the set of nodes must provide effective separation of the two main components of the floating platform, the upper one (Up) and the lower one (Lo), which are located on top of each other. This set enables them to move smoothly between each other only in horizontal directions within a specific range of these displacements.

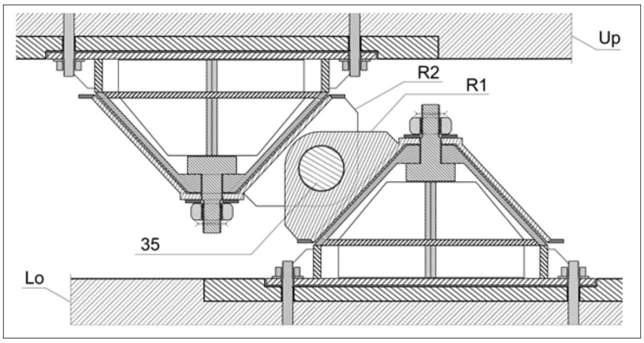

Figure 15: Vertical Section of the Support Node for Floating Platform Designed as a base of the Electric Power Station

Since in this case there is no need to ensure the possibility of mutual displacements in the vertical direction of the lower and upper parts of the floating platform, the presence of the horizontal pin (3) was eliminated and only the horizontal circular roller (5) was used, which has this time the diameter of the hole located in the single rib (R1) and passing through the all-vertical ribs (R1 and R2). In Figure. 15 and in Figure. 16 such a new shape of the horizontal circular roller is marked with the symbol (35). It may be permanently connected to the matter of the two vertical ribs (R2), for example by welding it along its peripheral contact edges with the outer surface of the two vertical ribs (R2).

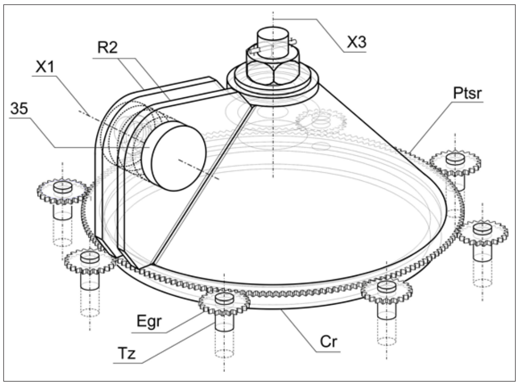

Figure 16: The Conical Body of the Support Node with a Circumferential Gear and a Set of External Gears

The main task of the structure of the conical support node is the effective damping of vibrations caused by the dynamic load applied from any direction through the controlled movement of the lower and upper parts of the object connected with a set of such nodes. At the very high values of dynamic loads, these displacements, in this case only in the horizontal plane, consisting in the mutual rotation of the basic conical bodies relative to the vertical axes, sometimes can be extremely fast, which may be dangerous for the whole device.

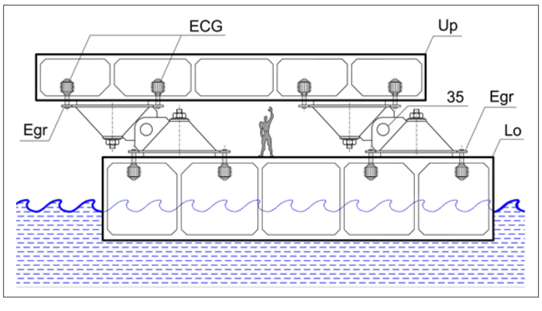

Figure 17: Scheme of the Vertical Section of the Floating Platform Structure

To make the vibration damping processes more effective it will be beneficial to transfer the kinetic rotational energy of each of the conical bodies to as many outside devices as possible (Egr), see Figure 16, which will be able to absorb this energy in a safe, controlled, and useful manner.

This can be achieved, for example, by making the circumferential stabilizing ring (Ptsr) in the form of a toothed wheel cooperating with external gears (Egr) appropriately spaced around the circumference of this wheel. If the vertical members (Tz) are connected directly to the electric current generators (ECG), they will transmit the kinetic energy from the rotation of the conical bodies to these generators, appropriately connected to the upper part (Up) and lower part (Lo) of the floating platform, see Figure 17 [8]. The mutual rotation of the upper (Up) and lower parts (Lo) of the floating platform will be caused by the energy of sea waves coming from any direction to its lower part (Lo). The platform can be of various sizes, it can form groups of platforms, be anchored in the coastal zones of seas and oceans, and can also be repositioned in sea basins. The electric energy generated in this way can be stored in battery packs located in the spaces of the lower and upper parts of these platforms or sent via electric cables to other users.

Initial verifications of the design and technological assumptions and preparation of appropriate drawing documentation were carried out based on numerical models of the designed structural systems defined in the Formian programming language [9].

Conclusions

The structural system of the composite foundation can take many different forms and be the basis for the safe positioning of heavily loaded objects, even on very unstable ground. Being made of waterproof boxes properly connected to each other, it can be the main supporting structure of artificial islands located in seas and oceans. The specially designed support node, as an integral part of the composite foundation system, allows for safe and useful absorption of the dynamic loads. Thanks to this sets of such support nodes can be used in the construction of the floating platforms applied to generate emission-free electricity due to the appropriate absorption of sea wave energy.

The proposed structural systems and equipment of the floating platforms must be subjected to thorough and comprehensive static, dynamic and strength analyzes as well as testing of the objects carried out on a natural scale, it also means the test studies of the structural system on a scale of 1:1, to assess their practical suitability for the proposed purposes.

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