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(54) **ULTRA-RESISTANT PNEUMATIC CONSTRUCTIVE ARRANGEMENT FOR MAJOR WORKS**

(57) A Pneumatic-Ultra-resistant Constructive arrangement for major works such as bridges 1 of extraordinary spans, which allows the construction of a bridge 1 with a span greater than 2000 (two thousand) meters,

thanks to the use of ultra-resistant fibers for the construction of modular elements in combination with an asymmetrical two- or three-dimensional tensioning.

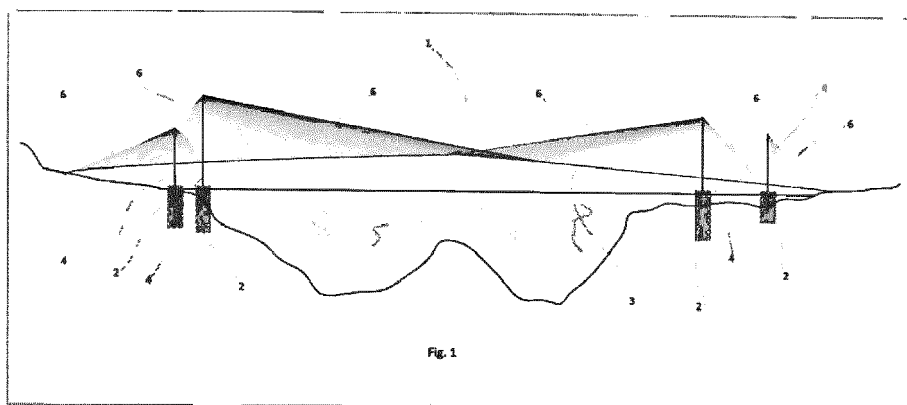


Fig. 1

Description

STATE OF THE ART OF THE INVENTION

Field of Invention

[0001] The present invention relates to the field of large civil, architectural, hydraulic, naval, aerospace and related works, more preferably to the arrangements, materials and forms for construction, and more preferably to a Pneumatic - Ultra-resistant Constructive arrangement for major works, such as bridges of extraordinary spans, which allows the construction of a bridge with a span of more than 2000 (two thousand) meters high, thanks to the use of ultra-resistant fibers for the construction of pressurized modular elements, in combination with a two- or three-dimensional tensioning, according to each project.

[0002] Even if reference is made in this description to a specific constructive arrangement for bridges of extraordinary spans, as an illustrative example of embodiment, it should be clear that the invention can be considered, adapted and used for any type of civil, architectural, hydraulic, naval or related construction, either independently or jointly with other related arrangements, without any inconvenience.

Description of the prior art

[0003] Generally, a "classic" suspension bridge consists essentially of its bases and towers of reinforced concrete and steel, plus a superstructure of high-strength steel main cables placed longitudinally between its towers, with its extreme anchors recessed into the ground, which support the load of the work and the overloads of traffic, winds, thermal and earthquakes.

[0004] The main cables, located longitudinally in classic suspension bridges, are suspended between the towers forming a catenary or parabola of 2° degree, and from them hang the secondary cables, called straps or pendulums, which support the steel or concrete spans that make up the flat structure of the deck. This set on each side of the deck is coplanar on classic bridges, including cable-stayed bridges.

[0005] This position, obviously, from the structural point of view, is technically the best, "if the bridge is considered only as a system of vertical loads", when in fact it is a structural system with gravitational loads, plus other important loads of stochastic type, of always random intensity and direction, linked to atmospheric meteors and telluric events, which are, to a large extent, the main causes of breakage.

[0006] In general, the straps or pendulums of the existing large suspension bridges are vertical. There are currently three large suspension bridges that have inclined straps in a direction parallel to their axis: Humber, Bosphorus and Severn, but it maintains its funicular structure in a coplanar manner.

[0007] On the other hand, a classic suspension bridge has two extreme towers on which the two main cables are hung, one on each side of the deck, which is placed at a predetermined level in order to maintain the level at a suitable level for navigation. For their part, the towers share a single foundation and, in general, have two columns closely linked throughout their height, which can be considered as a unitary element at each end of the bridge.

[0008] It is evident, for any person expert in the field, that the structural approach is aimed at supporting the gravitational forces of its own weight and work, although naturally the existence of lateral, ascending and descending forces, winds and earthquakes is taken into account in the calculation.

[0009] Obviously, the shape of the structure of a classic suspension bridge is not exactly very suitable to withstand horizontal efforts, except with the self-centering own weight due to pendulum effect, added to the rigidizing and aerodynamic reinforcements of the deck, which naturally increase the weight and cost. On the other hand, the winds produce lateral oscillations on both sides of the axis of the deck, reaching in the case of the Akashi-Kaikyō Ohashi bridge, with a span of 1991 m, at 34 meters between the extreme points.

[0010] To understand the physical limitation of the maximum length of this type of classic structures, it is most important to take into account that the percentage of the effort to support it, is 91% for its own weight and only the remaining 9% is reserved for vehicle traffic.

[0011] It is clearly observed that the useful bearing capacity of the longest suspension bridge in the world, the more studied, and the one with the best technology of the moment, is less than 10% of its weight. The fact of using heavy materials, such as concrete and steel, subtracted more than 90% of the bearing capacity of the main cables only for supporting gravitational loads. In addition, this complex bridge with the latest technology, although brilliantly resolved, precisely because of the complexity of the work and the variety of materials needed, requires permanent maintenance.

[0012] As it is known, on the Akashi-Kaikyō Ohashi Bridge, due to the effect of a category 7.2 earthquake on the Richter scale, the south tower moved 80 cm, and the top of the tower leaned 10 cm. to the south. Because of this, structural recalculations, delays and significant cost overruns were necessary. It should be noted that this bridge was built with the strongest steel in the world, and the extraordinary technology of materials and anti-seismic design known.

[0013] It is also important to remember that, after strong earthquakes, and for strict security reasons, traffic is usually cut off on this type of bridge, until it is verified that its tensioners did not suffer damage, because when vibrating, they loosen and can be cut by violent shaking. When a cable is cut, the other adjoining cables suffer a violent overload, which induces the chain breakage of other cables, this representing a great inconvenience and

potential danger.

[0014] Because of the above, at least two main problems are identified, which usually prevent the construction of bridges with spans higher than 2000 meters using classical methods, they are

- The own weight of the aerial structure, which can exceed the bearing capacity of the main cables and,
- The oscillations and bends of the deck, caused by winds and violent earthquakes, which, being of stochastic valuation, is based on conjecture, and sooner or later can exceed the acceptable practical limits, and endanger the stability of the entire bridge.

[0015] Despite having strong rigid concrete or steel boards, noble and excellent materials widely used in all major works of the world, classic bridges, due to their intrinsic structural design, are problematically swaying, due to their minimal width-to-length ratio. In the case of the Great Bridge of Akashi-Kaikyō Ohashi: you have 36 m / 1991 m = 0.018, a value that resembles its behavior to a waistband, rather than a rigid and solid body.

[0016] Thus, the classic bridge can become impassable in circumstances of strong winds or turbulence, and can flex and oscillate dangerously, both under the action of hurricanes and telluric events.

[0017] Using the best available technology, applying the most advanced state of the art, making use of high-precision electronic calculation systems and large investments, the maximum span achieved on a bridge has not exceeded 1,991 meters. At present it is necessary to build bridges of greater spans for different geographical situations. However, the current state of the art proves conclusively, that it was never possible to build a bridge with a span greater than 1991 m, applying the superlative technology available without economic limitations, as happened in the Akashi-Kaikyō Ohashi Bridge. It is not possible exceed the limestone of 2000 meters span due to purely technical reasons.

BRIEF DESCRIPTION OF THE INVENTION

[0018] It is very important to understand and evaluate at its right level the radical transformation -at the structural level and transmission of loads to the foundations- that this patent poses versus the current construction systems that use steel and reinforced concrete.

[0019] Faced with the problem posed by the weight of reinforced concrete and steel as a limitation of major works, a new material was sought, lighter and more resistant, currently finding ultra-resistant synthetic fibers, 5 to 10 times stronger than steel in the same weight ratio.

[0020] Having textile fibers, no matter how ultra-resistant they are, they do not seem to be suitable for super-structures, since they lack rigidity, ability to withstand compression loads, torsion, cutting and their combinations, and, in addition, they are only extremely resistant to tension, which, a priori, discards them as a construction

material of major works.

[0021] This patent solves the necessary transition: transforming textile fibers into rigid bodies useful for the construction of major works of different typologies.

5 [0022] We can build solid volumetric bodies with ultra-resistant fiber fabrics, by agglutinating them with special resins - a usual process in industry - but we would be in slightly advantageous conditions to the materials normally used.

10 [0023] However, if instead of building solid bodies, we make hollowed out large volume modules, we have a volumetric body much lighter than the classic ones, but with bearing capacity limited to the resistance of the capsule of the same to the different stresses to which it can be subjected, and in that aspect, the ultra-resistant fibers are not exactly adequate.

[0024] This is when the idea of pressurizing them appears: It radically transforms the way of working of the ultra-resistant module and, therefore, the structural order and the way of transfer of loads to the foundations, in such a way that any type of external load that would cause in a module without pressurizing compression, tensile, cutting, and all composite stresses, will only produce tensile stresses in the pressurized module.

25 [0025] The high-range internal pressure exposes the entire volumetric body, in any way, which we call "module", to pure tensile stresses throughout its whole structure. Its contour is exposed in all directions to a uniform internal pressure and does not admit any other type of tension to withstand it than pure tension: **if the internal force generated against its walls by the internal pressure exceeds the external forces applied to its contour**, since fulfilling this premise it does not change neither the external form nor its tensional state.

30 [0026] In this way a relevant consequence is achieved: any resistant structure made with **pressurized modules, always works with pure tension**, which is precisely the superlative quality of ultra-resistant fibers.

35 [0027] The capsule or hermetic structure, made of ultra-resistant fabric, being firmly agglutinated with special resins and in the appropriate thickness, is totally waterproof, which allows the module to be pressurized without further treatment and, on the other hand, this radically changes the limitations of the other materials: **we can withstand the desired load simply by regulating the internal pressure**, since $F = P \times A$. If we only vary the pressure, the force varies linearly, and we only must calculate the thickness of the contour to verify its resistance.

40 [0028] The confined air was transformed into a structural and resistant element.

[0029] Due to its extreme tensile strength, the radial deformation due to the pressurization of a cylinder built with ultra-resistant fibers, similar to a steel cylinder, is imperceptible to the eye.

55 [0030] The transmission of loads is carried out with minimal deformation, given the extreme resistance of the ultra-resistant fibers to pure tension, creating a construction module for major works, ultralight, floating, ultra-re-

sistant and with a large volume, with superlative qualities of surface hardness, resistance to penetration and abrasion, unalterable, indestructible against earthquakes and winds, extremely tenacious, stainless, electrical insulating, with dimensional stability, can be turned and drilled only with special equipment of high hardness, and is automatically moldable with high precision to make exact module joints. All this, using only filaments of ultra-resistant fibers agglutinated with special resins.

[0031] The Ultra-resistant Pneumatic Modules, pressurized at different pressures, which can be very high, are volumetric bodies of the most varied spatial geometry.

[0032] Considered as a simple hollowed volume without pressurizing, it behaves like an extremely rigid, solid and hard solid body, similar to a steel pipe closed at its ends, and with a similar load capacity.

[0033] It is possible to exponentially increase their load capacity by means of a strong pressurization, which causes in all ultra-resistant fibers pure tensile forces in all directions of the hollowed out body. That is precisely the superlative quality of these fibers; **they are ultra-resistant only to pure tension**, and this patent takes full advantage of it.

[0034] Let's consider the unitary module as the hermetic capsule of an air volume strongly compressed, because the force generated by the pressure must be greater than that caused by the acting external loads, $F = P \times A$, changing the pressure, we change the bearing capacity, and that is how simple the structural approach is, since the external loads are absorbed by the confined gases with an increase in the pressure, but without allowing an appreciable deformation of the container element, which we call a module, and this is achieved precisely because they are walls ultra-resistant to pure tension and able to withstand high internal pressures.

[0035] Unpressurized modules have mechanical characteristics closer to metals than to fabrics of ultra-resistant fibers that make them up, because they are built and configured by multiple layers of fabric agglutinated with special resins, being their tensile strength -caused by the pressure of internal gases-directly proportional to the thickness of the structure or capsule that configures the module, which makes it easily calculable and predictable.

[0036] The almost impenetrable Ultra-resistant fiber fabrics used in bulletproof vests, highend automotive bodies, and parts of modern aircrafts are certainly malleable and flexible as a fabric, but they are transformed into a solid ultra-resistant material as they are agglutinated with special resins, and without any possibility of disintegration or brittle breakage, above all, being highly pressurized with purified air, which entails an insignificant cost.

[0037] What at first instance may seem fragile and unsuitable to be applied as a structural element in major works, such as the use of a simple ultra-resistant thread to build them completely, and forming in its multiplicity a fabric of ultra-resistant fibers, is transformed into a solid

of extreme tensile strength being strongly unified with special resins.

[0038] As they are strongly pressurized, they finally form geometric bodies much firmer and indestructible than any other construction system, remaining rigid and elastic in the event of seismic vibrations and winds, and in the presence of static and dynamic loads, as happens with fishing rods (without pressurizing) made with these materials.

[0039] From the purely structural point of view, it is important to understand the methodology of load transfer. As the modules are highly pressurized, the load is absorbed and transmitted exclusively by compressed air, while the entire pressurized module always works and at all its points to pure tension to contain it. ($F = P \times A$)

[0040] The deck modules, comparatively, are bodies finished in a workshop with very high precision for a perfect assembly, from where they come out pressurized and fully finished, similar to the way in which a prestressed bridge span leaves the workshop ready for assembly. In the same way, the tower module would be the equivalent of the steel or reinforced concrete columns used in buildings, but much more resistant and lightweight, without corrosion or galvanic currents, allowing pieces of more than one hundred meters in direct assembly, without the need for paints or coatings, and with variable load capacity.

[0041] As it has been demonstrated, this patent has succeeded in always producing pure tension in the ultra-resistant fibers at any work carried out with pressurized modules made of ultra-resistant fibers, subjected to any type of load, even in the case of pure compression loads. A novel structural shape that resists own and work loads to pure tension. This justifies the use of ultra-resistant fibers and the name of the patent: Ultra-resistant Pneumatic Constructive arrangement.

[0042] Therefore, an object of the present invention is to provide a new constructive arrangement, which we have called "Ultra-resistant Pneumatic", as it uses as support for any type of loads, ultra-resistant fibers and compressed air, instead of steel and reinforced concrete.

[0043] It is still another object of the present invention to provide an Ultra-resistant Pneumatic Constructive arrangement, comprising ultra-resistant fibers and asymmetrical or symmetrical columns arranged on the sides of a deck. (Considering from now on, as a preferential archetype of possible applications, a bridge of extraordinary spans, due to the enormous complexity it involves).

[0044] Another object of the present invention is to provide a constructive arrangement that allows the construction of a bridge with a span greater than 2000 meters, that tends to null the oscillation before strong gusts of wind, hurricanes or any meteorological phenomenon capable of altering the normal loads of the system.

[0045] It is still another object of the present invention, to provide an arrangement that provides a bridge with an aerial structure and towers showing a flexible, stable and self-adjusting configuration of its original state, with suf-

ficient capacity to absorb additional stresses without damage or permanent deformations, in the event of earthquakes considered destructive, despite their rigidity.

[0046] Another object of the present invention, is to provide an arrangement that allows the aerial work to maintain sufficient elastic absorption capacity of the maximum seismic and wind stresses, during and after their occurrence, without altering the normal operation of the bridge, even considering the most unfavorable situation: with maximum service load and simultaneity of hurricane effects and strong earthquakes.

[0047] It is also another object of the present invention to provide an arrangement that allows the construction of an invulnerable bridge, even in the event of georeferenced shifts of several meters in the areas of foundation and anchorage of the towers, without altering the normal operation or the self-adjusting tensional state of the deck.

[0048] It is still another object of the present invention, to provide an ultra-resistant constructive arrangement that operates exclusively under pure tension, thus supporting any compressive effort, flexion, torsion or their combinations.

[0049] It is yet another object of the present invention to provide an Ultra-resistant Pneumatic Arrangement, (DNU) that allows the construction of sections of great length with extraordinary safety, using new material technologies, a simple and effective design, with clean and direct assembly, without formwork or expensive special equipment, and with a prefabricated aerial construction with precision, on a large scale and with fully dry mounting.

[0050] It is also another object of the present invention to provide an Ultra-resistant Pneumatic Constructive arrangement for major works, such as bridges of great spans, comprising: a plurality of deck modules connectable to each other, which form at least one deck, comprising each deck module a plurality of interwoven ultra-resistant fibers; a plurality of symmetrically or asymmetrically arranged pillars on each side of said deck and separated from it, and comprising at least one or more sets of interwoven ultra-resistant fibres, each of which defines a pressurized volumetric body; this deck is floating in space and tensioned laterally by a plurality of ultra-resistant fiber ropes, which are projected at least obliquely from the sides of the deck to at least one upper end of these pillars.

[0051] It is also another object of the present invention, to provide an Ultra-resistant Pneumatic Constructive arrangement for major works, such as a bridge of a great spans, which includes: the possibility of making mixed bridges, or aerial-floating ones, without limit of continuity and using the same ultra-resistant fibers.

NUMERICAL IDENTIFICATION OF EACH INDIVIDUAL ELEMENT

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1. Full bridge. Made with ultra-resistant fibers. FIGURE 1 with two 4 towers on each side. Side view of it.

2. Foundations 2 of reinforced concrete for the towers 4. Its shape, upper dimension level and other parameters are specific to the specific design in each case. They can end up underwater, and recess the cylinders of the tower module 5 in that underwater level which in this case are pressurized with water to at least the oceanic level.

3. Complete Deck 3 of bridge 1. Made with ultra-resistant pressurized fiber modules.

4. Full tower. Made with a plurality of 4PU unitary pile, which, in turn, are made with a plurality of pressurized modules of tower 5 superimposed. Their respective foundation is considered included.

5. Pressurized individual tower module 5. Made with ultra-resistant fibers. Superimposed on top of the other, and linked by their bulging flanges or any other joint system, they make up an individual 4PU unitary pile with the necessary height. The plurality of these 4PU unitary pile, placed in plan in the most convenient way, make up a tower of bridge 1, properly hyperlinked, both in their anchors to foundations 2, as at the top, and at each intermediate level.

6. Oblique tensioners 6 of deck 3. Made with ultra-resistant fibers. They are linked in bundles of tensioners 6 towards the top of the 4PU unitary pile by means of an intermediate element 82 that unifies them with a single tensioner 71 to the winch 20. Intended to support with its vertical component the gravitational forces of deck 3, and together with its horizontal component, they control the lateral movements of deck 3. 4PU unitary pile must be strongly linked at the top and at each vertical joint to consolidate a Tower and distribute its partial loads equally.

7. Horizontal or slightly inclined tensioners 7. Specific for the lateral retention of the deck 3. They are anchored to one of the flanges or anchors in the vertical joints of one of the 4PU unitary pile that make up the integral tower in each section of deck 3, preferably at the level of deck 3.

8. Surface of the ultra-resistant fabric of the module in the interior space. Perfectly hermetic, preferably cylindrical, with extreme terminations with spherical caps, sealed with the same waterproof resins that agglutinate the fabric of ultra-resistant fibers. They make up a net volume of 13 of compressed air from each module. Intended to contain pressurized dry air, to stiffen the modules and give it bearing capacity under any type of load, which is transferred as pure tension in the ultra-resistant fibers of the fabric that makes up the hollow module. A detail of the 8FUR fabric, made with ultra-resistant fibers, is shown.

9. Special reinforcement of tower module 5 at its ends. Made with ultra-resistant fibers. It allows a flat contact surface when overlapping, and the construction of coupling flanges or other types of joint both between modules and in the foundations 2.

10. Surrounding reinforcement of the spherical cap of tower 9 module. They make up the assembly resistant to the stresses of anchoring and mounting of external accessory elements.

11. High-strength steel bolts. For linking between reinforcement 9, which unify the modules in their vertical assembly one on top of the other, to form the 4PU unitary pile, which, in turn, with a plurality of them, form the complete tower of bridge 4.

12. Cylindrical section of the pressurized module for towers 5. Fabric of ultra-resistant fibers.

13. Net volume of pressurized air inside the module, which can preferably be dehumidified air without corrosive impurities and, for special cases, helium.

14. Extreme anchor flange of the towers. Specially reinforced to resist the stresses of attachment to the foundations 2, in the intermediate vertical joints, and at the top, to the tension winches of the tensioners 6, in addition to the necessary equipment.

15. Reinforced washers. In joints with bolts, to distribute their pressure in the mass of ultra-resistant fibers.

16. Specific bolts. For anchoring the first module of each 4PU unitary pile to the foundations 2 of reinforced concrete. They can be replaced by a stainless steel ring embedded in the foundations with their linking elements.

17. External reinforcement of the peripheral 4PU unitary pile. If necessary. It is preferably replaced with hyperlinks 18 at each joint level.

18. Linking network between the heads of the top of each 4PU unitary pile. It strongly unifies the bonds and distributes stresses jointly among all the 4PU unitary piles, working as if they were a solidarity one.

19. Linkage tensors 19. From the top of the 4PU towers to the foundations 2. They counteract the efforts of the straps of deck 3, if they are deemed necessary.

20. Winch on 4PU unitary piles. Preferably hydraulic - electric with extremely slow and powerful drum movement, for the tensioning and regulation of spatial geometry of deck 3, which controls oblique tensioners 6 by means of the unifying cable 25. It can be replaced if deemed convenient and possible by a 20C.H. hydraulic cylinder, which has the same function of automatic tension regulation as the winch. See in fig. 14

21. Reinforcement of cylindrical steel in the form of a 6-pointed star, which serves to horizontally lock one module of towers on another, as well as for the triangulated linking of each individual 4PU pillar with its adjoining one, to achieve a fully unified tower 4.

22. Example of elliptical foundation 2. It can be more suitable in an elongated shape to retain the tensions of the straps 6 of the deck 3. Figure 14

23. Example of circular foundation. With 4PU unitary piles in a semicircumference, and 19 retention tensioners that counteract horizontal forces anchored

to the foundations 2 of reinforced concrete. In Figure 14.

24. Knot of unification of the bundle of oblique tensioners 6, by means of a transition shackle to a cable 71 of ultra-resistant fibers or steel, unifying the stresses to be controlled simultaneously from a single winch for the lateral section of the corresponding deck.

25. Heliport. On each of the 4 towers, to facilitate the control and scheduled maintenance of its facilities. To do this, the upper links between each 4PU unitary pile have their corresponding walkway and safety railing.

26. Installation of the distribution system for dehumidified and purified air or compressed inert gases. Intended to pressurize all the modules of the system that correspond to a certain tower.

27. Compressor equipment. Electronically controlled to autonomously pressurize all the modules that make up each of the 4PU unitary piles of a complete tower. This equipment, one in each tower, includes all the systems necessary for its specific task, as well as the auscultation sensors to control it from the console located in the engine room at each head of bridge 1.

28. Compressor equipment, similar to the previous one, but specific to pressurize the modules of the deck.

29. Example of one of the possible forms of a module. Specially designed for deck 3 of bridges 1, made entirely of ultra-resistant fibers.

30. Safety anchor shackle. Used as a simple and effective example for anchoring the ends of tensioners 6 and other links.

31. Grade and wear layer of the deck 3. On which traffic circulates. It can be of various materials and shapes; designed to be quickly renewed without altering the service, according to a scheduled maintenance, being the only piece that should be changed by design during the useful life of bridge 1. It can be replaced by 72, which is claimed.

32. Distribution interface. Distribute the punctual loads of the tires on the upper surface of the deck module 3. This layer protects the modules of deck 3, made of ultra-resistant fibers, from the weather and from abrasion. It must be lightweight, rigid and preferably shaped like long spans placed at 45° to transmit the loads to different modules simultaneously. The plates of the grade are placed on it, intended for wear and with the possibility of a quick replacement. It can be replaced with 72.

33. Anchor bolts. Placed perimetally on the entire contact edge between the modules of bridge 1. In Figure 16, the linkage at its ends can be seen by means of a metal clamp 34, bolted without limit of continuity on the same edge that the modules present in their perimeter, so that it acts as an anchor to the tensioners 6 and 7, linked by a shackle to the

deck 3.

34. Metal clamp. Anchored at the 4 ends of the pressurized module of bridge deck 3, for anchoring tensioners 6 and 7.

35. Inlet 35. It may be necessary, according to the project, to verify the interior sealing of surface 8 of ultra-resistant fiber fabric that confines volume 13, through waterproofing resins, its control and maintenance. It is preferred with an opening to the inside and including a safety valve for overpressures. In the case of deck modules 3, it is foreseen that they will be placed at one of their lateral ends, and in the case of tower modules 5, on one of their sides, since the flat ends, in this example, are jointly with each other.

36. High-strength steel bolts. Used for the perimeter linking of the modules of deck 3 and the flanges of towers 4. In all cases, they must have a washer of a certain thickness so that they distribute the pressure on the ultra-resistant fiber fabric without injuring it.

37. Anchoring deck of block 3. At each of its ends on solid ground. It was designed in this example as a reinforced concrete block, with sufficient weight and recessed firmness to withstand the tension of the deck 3. It contains an engine room inside, which allows to accommodate a group of winches, the SCADA auscultation and control consoles, the air or gas pressurization system for the modules of deck 3, and boxes for tools and maintenance equipment.

38. Extreme anchors of deck 3 to tension and stress regulation systems. By means of cables linked together with shackles, controlled from a group of winches 46.

39. Reinforcement of the vertical lateral pressurized module at the end of bridge 1. One at each terminal, to firmly secure anchors 38.

40. Detail of a perimetral bulging joint. In the contact area between pressurized modules of deck 3. In Fig. 19.

41. Pressurizer equipment for air or inert gases. Specific for the modules of deck 3, similar in specifications to the one used for tower modules, but with behavior programming determined for bridge 1. See fig. 20-24. It is useful to clarify that, although in this example of embodiment, a mechanical equipment of very simple drive and common in heavy industry is used, they can also be made by hydraulic cylinders, preferably telescopic to have a longer travel, in which case they are embedded in the same place where the winches were embedded, and directly connect to the anchor plate that should have the vertical side of the last module of deck 3.

42. Compressed air distribution pipe. To pressurize modules of the deck 3. One from each end.

43. Inflation and deflation nozzles system of bridge module 1. Especially suitable for high pressures, with flow and pressure control.

44. Reinforcement in the extreme areas of the spher-

ical cap of the module of deck 3. To allow the perimeter ribbing 45 in the contact zones between modules and leave its geometry with the rim on the edge, where the units can be bulged together. Fig. 21

45. Perimeter ribbing. Symmetrical on the two contact faces of each module, leaving during its manufacture a gutter that, without interfering with any relief on the surfaces of the module, allow to place the perimetral bolts and nuts. This is one of the multiple models that can be designed to perform this linkage between modules of deck 3. This perimeter gutter works as such to discharge rainwater from both ends more efficiently than the flat surface.

46. Set of bridge tensioning hydraulic - electric winches. Strongly embedded in the reinforced concrete floor of the engine room, from where the tension of deck 3 and its geometry are controlled. Each of them works by securing a cross-section of the final module of deck 3, in identical sequence to the other end. They must be perfectly synchronized in the tension levels, to work as a single mechanism. Alternatively, they can be replaced by a set of hydraulic cylinders.

47. Engine room. In this example, located on the same interior of the reinforced concrete anchor block at each end of bridge 1. Its function is the anchoring of the longitudinal tensions of deck 3, which is carried out by means of winches 20 with movement of its very slow drag cylinder, or 20C.H. hydraulic cylinders, preferably telescopic to achieve more range of movement, embedded in its floor. Each winch tenses a cable, in such a way that, as there is a plurality of them, if any of them were in maintenance, it will not alter the normal operation of bridge 1.

48. Reinforced concrete block of anchorage. At each end of deck 3, which houses engine room 47.

49. Electronic auscultation control consoles, and another of the SCADA systems -Supervisory Control And Data Acquisition. This way, it concentrates its control and maintenance in the same work. It also includes the air pressurizer equipment 41, specific for the modules of deck 3.

50. Self-slip deck system 3. It is a pair of rigidized triangular steel plates, which absorb the differential movements that the pressurized deck 3 may have during changes in tension or load. One of the triangles is mounted in an articulated way on the final part of the pressurized bridge 1, and is embedded in another complementary triangle in the reinforced concrete block.

51. Special boxes. They protect scheduled maintenance equipment and tools.

52. Tension regulation cables. From the hydraulic-electric winch, synchronized at its rpm.

53. Cable system for stress transmission. They start from deck 3 of bridge 1, complementary to cable 52, by means of 4 cables anchored to a section of it, which are unified at a certain distance, forming the

edges of a pyramid of 4 sides, at whose apex they are unified with a shackle, to start the group of cables 52. Fig. 24

54. Spherical cap of the modules of the pressurized modules of bridge 1, one at each end, reinforced to include inlet 35, the perimeter anchors and the pressurizing system. Fig. 24

55. Reinforcement of the extreme vertical side of the final module at each end of bridge 1. To be able to anchor on it the tension and regulation systems of the spatial geometry. Fig. 24

56. Longitudinal steel plate. Formed in an open L-shape to be able to firmly link the upper and lower edges of the vertical face of the bridge module 1, with the anchor shackles of the regulation cables from the winch. Fig. 24.

57. Combined Bridge floating-aerial. Example of a combined bridge 1 that solves some cases where, even with the technology of this patent can not be realized. Especially indicated when there are long ocean distances with sea trenches that may turn the construction of foundations 2 and towers 4 unfeasible due to costs or insecurity. In this case, a floating deck 3 can be built on the deep water section, perfectly linked to the aerial one without limit of continuity or materials, forming a composite of -bridge 1-marine highway-bridge, which solves in an efficient and practical way critical situations.

58. Profile of the seabed. That makes another type of solution critical when the span between the ends of the sea trenches is excessive.

59. Sea surface line. Navigation is resolved by leaving enough span on each section of air bridge 1. Naturally, the depth of the water and the draft of the vessels must be taken into account.

60. Flotation module. It must be designed to withstand, in addition to supporting the load of the floating bridge 1, all the stresses of the sea, surface currents, waves and tides. The longitudinal difference of the aerial bridge 1 connected to the floating bridge 1 in the case of change of height by the action of the tides, is automatically absorbed with the tensioners 52 of the winches or the hydraulic cylinders located in the extreme engine rooms, always maintaining the perfect conditions of the deck 3.

61. Anchor log located in the foundations, where the 62 tensioners from the top of pillar 4 are fastened, to compensate for the horizontal stresses of the 6 cables from the deck.

62. Ultra-resistant tensioners that join the top of the towers with the anchors in the foundations.

63. The 4 short tensioners anchored in the extreme eyebolts of the deck modules 29, serve for the lifting of the modules and then for the coupling of the tensioner 6 of each deck module.

64. Longitudinal U profiles that serve as an interface between bolts and ultra-resistant fibres at the transverse linear joint of modules 29

65. Perimeter circulation platform of the modules of towers 5 at the top, with safety railing. It serves for assembly, maintenance and circulation at the different levels of the tower.

66. Three plain bolts that serve as a guide for the perfect calibration of the centering of each module when overlapping vertically with the other. They are embedded in the upper plane of the module, leaving half its length protruding, to be embedded in the perfectly centered holes of the base of the next module, and thus align them perfectly.

67. Support structure linked to the perimeter flange in each 4PU unitary pile, strong and rigid to anchor the top of the winch, corresponding to the bundles of tensioners 6 of each one.

68. Automatic oleohydraulic power plant, oil pressure generator for doubleacting hydraulic cylinders or hydraulic-electric winches.

69. High-pressure oleohydraulic telescopic cylinders, firmly mounted on the cross-shaped steel structure with six 67 arms at the top of the 4PU unitary pile. The starry cross is also embedded between the two contact planes of all tower 5 modules.

70. Hydraulic cylinders on the 4PU unitary pile.

71. Cable of greater section than the tensioners 6, which unifies the stresses of the corresponding bundle in a transition plate 82, to transmit them to the winch anchored on the top of one of the 4PU unitary pile that corresponds to it due to its relative position.

72. Layer of high resistance to abrasion, which always maintains an abrasive surface similar to a coarse-grained sandpaper, which provides excellent grip to the tires, but which, due to its extreme hardness, is practically indestructible during the bridge lifetime, and that, in the extreme event of breakage, can be easily repaired simply with a spatula and leveling rule. This simpler, more functional, lasting and efficient solution replaces the two layers of the distribution and wear interface of the deck, also possible as an example of construction. This novel solution of the grade is a reason for a claim. It consists of a single layer, of a thickness to be determined, which is applied in the manufacturing workshop on the upper face of the ultra-resistant fiber modules of deck 29, preferably with the consistency of a viscous paste easily applicable in a single operation, composed of ultra-resistant fibers mixed with specific epoxy resin and blast of metals or ultrahard compounds, with live edges, which compose the inert aggregate similar to coarse sand obtained by quartziferous crushing, whether synthetic diamonds, with hardness $H > 20 - 70 \text{ GPa}$, (20 - 70 gigapascals), new composite materials of ceramic matrix, ceramic-metal nanocomposites consisting of oxydic ceramic matrix and Nanoparticles of Tungsten, Molybdenum, Nickel, with a hardness comparable to diamond, or other ultrahard material immune to traffic abrasion. To obtain the perfect non-slip surface, the desired particles of

granulometry can be additionally distributed on the surface of the paste before it frays, crushing them properly to give a very thick sandpaper finish, which prevents slippage and protects the ultra-resistant fiber fabric from the pressurized module. With this surface treatment, the pressurized modules serve as a rigid direct highway, as long as their pressure comfortably exceeds the maximum of the tires that circulate, which is easily obtainable.

73. Unit part of the bridge: Set of fig. 37 that unifies a unit part of the bridge, a pair of 4PU unitary piles, a pair of tensioning bundles 6. A pair of winches on every 4PU, a pair of winch cables for regulation and tensioning 71.

74. Section of the deck corresponding to a section of unitary deck, which can have various shapes, both with a plurality of modules with a single cylinder, and a single module with multiplicity of pressurized cylinders. This system is preferential. It can have an important saving of materials and weight with the design such as 3 - TUTUR in fig. 40

75. Linking plate, preferably titanium, where the bundle of tensioners 6 is collected and unified in the tensioner 71 that is anchored to the winch.

76. Unitary section of board: set of fig. 37 that unifies a unit section of deck, a pair of bundles of tensioners 6 and a pair of linking plates 82. When the sections of the deck are thrown into the water for assembly, they include everything included in the unitary section of the deck.

77. In Fig. 40 - SGB - STRAIT OF GIBRALTAR BRIDGE

2 - SGB - Section of Gibraltar Strait Airlift Bridge

3 - SGB - Section of Gibraltar Strait Floating Bridge

TUPNU - Unitary Section Ultra-resistant Pneumatic Bridge.

BRIEF DESCRIPTION OF THE DRAWINGS

[0053] All figures are illustrative, lacking scale.

[0054] We will consider the terms "towers" and "pillars" as synonymous in this patent.

[0055] For the sake of a better clarity and understanding of the object of the present invention, it has been illustrated in several figures, in which the invention has been represented in one of the preferred embodiments, all of them being illustrative embodiments and where: figures 1 and 25 are lateral views to identify the elements that compose it, fig. 1 with the airlift, and fig. 25 with the mixed air-floating bridge.

Figure 1 shows a longitudinal cut of a complete bridge 1, entirely aerial. For clarity, only 2 towers have been placed, on each side of the deck and at each end of it.

Figures 2 to 7 show different views and embodiments

of a bridge 1 of extraordinary span, obtained by the present invention; different possible positions of the towers 4, the oblique tensioners 6 and the possible horizontal tensioners 7 that secure the deck 3 in the spatial geometry of the bridge 1 can be observed. In this case, the bundles of tensioners originating in a section of the deck, converge directly and in a unified way, on the cable of the winch located at the top of the tower.

Figures have been made with two different examples of linkage between modules, in order to visualize some of the multiple possibilities presented by the Ultra-resistant Pneumatic constructive arrangement. Linking systems are not claimed and are freely applicable.

Figures 8 to 15 show an example of the construction of the towers and the deck with tower modules linked by bulging flanges, bundles of tensioning cables 6 support a section of the deck and are unified at a certain distance, to continue with a single collector cable 25 to the tensioning regulation system 20. It is a possible variant in the way of placing the tensors presented in figures 2 to 7. Tensioning system by means of a hydraulic-electric winch 20, and pressurization systems 27 and compressed air distribution 26 for different tower modules 5 from a plant, all this with different forms of foundations 2 and towers 4 formed by a plurality of tower modules 5 that make up each unitary pillar. Also, the anchor block is shown at the ends of the deck with an engine room and its equipment inside.

Figure 8 shows a view of a possible configuration of foundations 2 and towers 4 executed with modules of Ultra-resistant Pneumatic towers 5 made entirely with ultra-resistant fibers. Visualizes an example of anchors of the modules to the foundations 2 of reinforced concrete 2, and of the vertical links of each module between them, made with bulging flanges 9; Figure 9 shows an axial cut of a possible termination form for the 5-end modules, intended for the construction of the Ultra-resistant Pneumatic Towers 4, with a flat reinforcement 10 at one of its ends 14, which can be used both for anchoring to foundations 2, and for anchoring all the elements that are fastened at its top. It also shows a possible lateral position of the inlet 35 for inspection and maintenance. It is foreseen in this case, to install on the inlet 35 the safety valve to protect it from excessive pressures. A normal axial cut of tower module 5 is detailed, exemplifying a tower module model 5 of those used at the ends, both for anchoring to the foundation and at the top. In this illustrative but not limitative embodiment, the flexible pneumatic module of towers 5, is formed by a cylindrical model on the outside, with a pair of flanges at its ends, of the same ultra-resistant material and perfectly supportive of the cylinder. The ends that make up the linkage flange between modules can be identical at both ends, using

the normal flanges 9, or can have one of them reinforced, flange 14, for anchoring uses in the foundations or for the equipment at the top. Inside we have a free space or volume 13, formed in this example by a cylinder 8 in the central part, unified to two spherical caps at its ends, which make up space 13 where pressurized gases are injected under pressure, whether air, helium, even water. The 35 inlet is a standard element in all modules 5 and 29. In this case it is placed included in the cylindrical shaft, since the upper and lower part, used as support and unification by flanges 9, are unified and inaccessible. Also bolts 11 of unification of the intermediate flanges 9 and superior ones 14 are shown, and the reinforcement 10 around the spherical cap, made with the same ultra-resistant fibers 8FUR jointly with the module of tower 5.

Figure 10 shows the shape of a flange for bulging linkage, both for anchoring module 5 to foundations 2 and for joining the modules together, and also for anchoring all the necessary elements at the top of the tower. Anchor bolts 11 between modules differ from special anchoring systems that can be used in foundations 2, preferably by means of special expansive bolts 16 and epoxy resins, etc. We have a horizontal cut in the central section of the cylinder of module 5, where you can see from another angle the free internal volume and ready to be pressurized, and the flange 9 joined by the bolts 11. It is important that washers 15 are placed along with bolts 11, or even better a continuous metal ring of stainless steel 9Al on each side of the flange, to prevent damage to the ultra-resistant fibers with the adjustment of the 11 bolts.

Figure 11 shows a possible arrangement with circular foundation of reinforced concrete, of the pressurized modules built with ultra-resistant fibers 8FUR. It can be clearly seen that, although modules 5 are separated in the horizontal plane one from the other, forming groups of independent 4PU unitary piles, even with a larger diameter in the center, all of them meet at the top and in the foundations 2 perfectly linked to each other, to work harmoniously as a single block and to be able to withstand any failure in one of the 4PU unitary piles without resenting the general behavior of the system. A possible way of assembling the 4PU unitary piles is detailed, made up of tower modules 5 vertically mounted one on top of the other, on a circular foundation 2. It can be seen that the plurality of 4PU unitary piles, at its top level, has a linking pattern 18 that unifies individual 4PU unitary piles to form a complete 4 tower or bridge pillar 1. These links, anchored in bolts 15 of its reinforced upper flanges 14, make up a network of reinforcements 18 that in turn supports safety walkways between the different 4PU unitary piles, for service and maintenance. As an example, a larger diameter 4PU unitary tower was installed in the center, which

works jointly with all the others to consolidate a tower or pile of bridge 1 complete 4.

Figure 12 shows a variant of Figure 11, in order to demonstrate the design flexibility of the constructive arrangement, where only modules 5 are placed in a sector of the circular foundation 2, to form a free semicircle that allows the anchoring of tensioners 19 from the top, in this case from the center of the central tower, linked with all the others to the perimeter of said semicircle at the base, thus holding the overturning stress that could produce the tensions of the bridge sector 1 that corresponds to the complete tower 4;

Figure 13 shows another variant, with an elliptical shape, both of the shape of the foundations and the position of those within it, a shape that better corresponds with the forces generated in this type of work. At the top, all 4PU unitary piles share the efforts among the others through their upper links 18;

Figure 14 is very important to understand the essence of this Ultra-resistant Pneumatic bridge 1 of large spans, made entirely with ultra-resistant 8FUR fibers, except in the points of links and anchors, which naturally, if they are bolts 11, must be made of steel. It is observed in the center of a section of the deck 3 of the bridge 1, from where it radiates several bundles of tensioners 6, which are unified by a shackle 24 at a certain distance, to stop being a bundle and become a single tensioner 25, which is controlled by an automatic hydraulic-electric winch 20, which can keep constant the pretensioned tension for that sector of tensioners 6. Winch 20 is firmly anchored at the top of one of the best oriented 4PU unitary piles, and all of them, in this case, located on the outer perimeter. By means of the upper links 18 between each of them, even those that do not have direct load, tensions resulting from the corresponding bridge section 1 are unified, being distributed in the complete pressurized Ultra-resistant Pneumatic Tower 4, which makes up the whole. Different forms of foundations 2 and assembly of the 4PU unitary piles are also shown, indicating the sector furthest from the section that corresponds to it, will be anchored from the 4PU unitary pile located at the end of the axial axis of tower 4, one on each side. All this represents just an example among a number of possible prototypes;

Figure 15 intends to give a detail about the possibilities of use the tops of some of the 4PU unitary piles, which make up the assembly that we call tower 4. In this case it can be seen that on the central tower of greater diameter, the following have been installed: a heliport, the integral and automatic pressurization system with air or helium, used for pressurizing, pressure regulation, safety controls, and everything that a work of these characteristics may require. The distribution network of dry compressed air or pressurized noble gas is also observed, with a high-pres-

sure industrial compressed air intake system inside the volume of the module located on the sides of the cylinder, as the ends become inaccessible in the assembly. There are also anchor slings 19 that link the top of the 4PU towers with the reinforced concrete foundations 2, and the linking network 18 between each of the 4PU unitary pile;

Figures 16 to 24 refer to the deck modules, and their linking systems, always using in this example the linear sets of bolts as linking elements. Each linking system entails a special design for the shape of the module, which turns it easy and efficient. Naturally, in the actual work, the solution for each type of joint can be much more complex than those indicated, which are elementary, but efficient, and using strong and simple standardized elements. In this case, the deck is designed with a load distribution interface and a wear grade.

It is very important to bear in mind that tower and deck modules, pressurized and ultra-resistant, have an extreme hardness, and although they are relatively elastic and with a certain degree of flexibility, when pressurized they tend to be tenacious and rigid bodies, with surfaces very difficult to penetrate, cut, drill, etc. so it is necessary to leave everything necessary for assembly planned during manufacturing, such as drillings, recesses, etc. with extreme precision, as is normally done with the machining of industrial parts before assembly. The ultra-resistant fibers have optimal characteristics to be used in the structures of major works, among which we can synthesize: High modules of elasticity and low elongation at breakage, great toughness which means low fragility, high impact resistance and high energy absorption capacity, fire resistance. They do not melt or ignite, and char only at very high temperatures. High abrasion resistance. Exceptional rigidity. Extraordinary tensile strength. High elongation at breakage. Low electrical conductivity. High chemical resistance. Excellent dimensional stability.

In Figure 16, the details of the modules of bridge 1 deck 3 begin. In this case, the side view of a normal axial cut of one of the modules of deck 3 can be observed. Module 29 is apparently similar to that of towers 4, but lacks the flange ring, and instead, in order to make a solid and firm link between them, they were designed in this example with a square section, containing a hermetic cylinder 8 included inside, ending with spherical caps at each end. To achieve a perimeter linkage throughout the contact perimeter, a recess without material 45 is made in the square section during manufacturing, which allows to create a rectangular rim where to mount the row of bolts 33 that unifies the modules 29 with each other. One of the possibilities of linking the modules with the oblique 6 or the horizontal 7 tensioners is also observed, through the use of simple elements, but of proven effectiveness, such as safety shackles

30, secured to steel fittings 34, strongly anchored in the extreme edge of the modules, which can be placed both in the anchorage of the upper and lower shackles, or both simultaneously. At one end, you can see inlet 35, preferably with an interior opening, which includes the safety valve of each module. Since this figure makes an axial vertical cut, it allows to observe the load distribution elements 32 and the wear layer 31;

Figure 17 allows to see a horizontal axial cut, with upper view, of the same previous module, where one of the lateral edges of the module with the set of corresponding bolts 36 is observed from the zenith, to be unified with another adjoining one, also, the extreme steel fittings 34 used to anchor the shackles 30, the inlet 35 at one end, and how to attach a 6 or 7 tensioner to the shackle; with identical anchoring possibilities at the 4 points of each junction between modules, two at the top and 2 at the bottom;

Figure 18 shows a cut of 4 modules 29 unified in the axis line of deck 3. On them the load distribution interface 32 is appreciated and on this the wear grade 31. As it can be appreciated, the entire contact contour has the same anchoring system, through a sequence of 36 steel bolts, preferably with a large steel washer that protects the fabric of ultra-resistant fibers of the module.

Figure 19 shows a set of 8 unified simple deck 3 modules with a simplified sketch of their linkage to the anchor block needed at each end of deck 3 for their embedding and tensioning, as well as some amplified details of the joints; - modules can be single or have multiple modules, in which case joints are reduced during assembly.

Figure 20 shows a front exterior view of two deck 3 modules joined by steel bolts, indicating the position of the inlet 35 with the pressure valve 35, and a diagram of the dry air or noble gases pressurization system, showing a complete automatic compressed gas processing plant 41, located at each end of bridge 1, a distribution pipe 42 along deck 3 and its inflation points with high pressure industrial nozzles 43.

Figure 21 is an axial cut with normal view of the module of deck 3; it details the way in which the pressurized gas pipe 42 is linked in its unitary derivation 43, with the inner volume 13 of the cylinder, also shows the inlet 35, as well as the ribbed sections without perimeter material 45, for the placement of the perimeter bolts 36. It also highlights the reinforcement in the extreme heads of the pressurized cylinder 44, necessary to protect module 29;

Figure 22 is an axial cut of the module of deck 3 with side view. The inlet 35 opened inwards, the relative position of the pressure pipe 42, and the relative position of the bolts 36 in the perimeter anchors of union between modules of the deck 3 29 can be observed; Figure 23 is a synthetic detail of a possible way to

link deck 3 with tensioning and tension regulation equipment. We consider that engine room 47, is located inside the reinforced concrete anchor block 48 at each end of the deck 3 2, containing a series of 46 hydraulic-electric winches, each of them being independent, but hydraulically unified with the others at identical pressures, to retain a transverse section of bridge 1, which reduces its size, its power, and increases the safety in the event some of them is damaged, as the others absorb their tension to keep bridge 1 operational during maintenance. In the engine room we also find the electronic auscultation control console and the integral control console 49, in addition to the automatic compression center 27 of dry air or noble gases. A coupling model can be seen between deck 3 and each of the winches or hydraulic jacks, using a simple system of cables and shackles, which allows a wide range of motion of the end of the deck 3 to regulate its tensioning. As deck 3 must maintain a free clearance in contact with the mainland, or otherwise with the anchor concrete block, a section of self-sliding variable width 50 is necessary, which maintains the continuity of deck 3, but not its extreme recess. Deck 3 of Bridge 1 is thus integrated into the mainland without a limit of continuity, like a normal highway, although towers 4 are hundreds of meters into water.

Figure 24 is a synthetic illustration of a mode of linkage between pneumatic deck 3 with the extreme anchor block of bridge 1. It was designed as a reinforced concrete anchor block, including an engine room in its interior, which contains a group of winches that regulate the tension of deck 3, linked to it by cables of a certain length that allow the tensioning and relaxation of deck 3 as necessary. It was made by simple and firm joints, such as the safety shackles, taking each winch a cable that is linked to the 4 cables that are joined in the corresponding section of deck 3, 2 at the top and 2 at the bottom of deck 3 for a better distribution of loads. All winches work synchronously as one, so that the tension is perfectly uniform throughout the width of the deck 3. The engine room includes a dry air or inert gas compression equipment, such as helium, for pressurizing the bridge 1 modules, as well as the consoles that control the auscultation sensors and all SCADA commands used in bridge 1. Likewise, a space is reserved for the tools and maintenance equipment in boxes according to their functions.

Figures 25 to 27 refer to a mixed bridge, part of it is aerial, and part is floating.

This design is especially suitable for situations of spans so large that turn the complete aerial solution impossible.

Figure 25 shows a very significant design variant in bridges of extraordinary spans with problems of great depths in some of its sections -the very large routethat prevent foundations and towers from being

made with total safety. In this case, the possibility of using the Ultra-resistant Pneumatic constructive arrangement is raised to make in that section a floating bridge perfectly linked to two sections of air bridge, under which maritime traffic moves. This variant would be especially suitable in a case such as the bridge of the Strait of Gibraltar, with about 10 km wide in its central trench, leaving 2000 m on each side for the air bridge 1 and marine traffic. As appreciated, the modules of the air bridge can continue over the floating section supported by other modules designed with hydrodynamic technology, similar to the bow of ships, which reduce their effects on waves and surface currents by letting them pass freely between the modules, as if it was a catamaran with multiple arcs, it can also be manufactured from ultra-resistant fibers.

Figure 26 depicts a cross-section of a possible solution of the floating bridge over the waters, which is resolved using the pressurized modules.

Figure 27 shows a cross-section of the set of modules in deck 3 with flotation modules 60, in a non-hydrodynamic example, for illustrative purposes.

For a more detailed illustration of another possibility of linking, as well as to give a clear idea of the complete manufacturing process of the modules, how the linking points are designed and how they are assembled in a different way, we have figures 28 to 32

In this case, the anchoring of the tower and deck modules were solved more cleanly, that is, without the need for flanges, which somehow alters the simplicity of the design of the modules.

Figure 28 shows an axial cut of the top of a 4PU unitary pile. A number of possible solutions to support a hydraulic cylinder or a winch, perfectly anchored to the upper end of the unitary tower can be appreciated. You can also see the perimeter reinforcements that allow a better embedding of the support structure.

Figure 29 gives an idea of how the unitary tower modules 5 are linked together, to form a 4PU unitary pillar, also, the way in which with a multiplicity of 4PU, a tower or pillar of the bridge is built, which will support a section of it from one of its sides.

Figure 30 shows details of the embedding between modules without using flanges, by means of special criss-cross embedding bolts, and with the possibility of reinforcing them perimetrically by means of a bolted metal ring in both tower 5 modules.

Figure 31 shows the preferential way to unify the 4PU unitary pile, using a hexagonal lattice 67, which is embedded in semi-cylinders drilled on both sides in contact, to be perfectly recessed and useful for making hyperlinks in all directions with the other unitary pillars, to unify a tower 4. Plain bolts 66 semi-embedded in three holes made with extreme precision in each of the faces are also shown, to serve

as a precise guide in the assembly of the upper one. This same framework supports the assembly and maintenance walkways, as well as any necessary equipment, such as the air pressurizing plant for the entire set of 4PU unitary piles.

Figure 32 suggests a preferential way of placing the 4PU unitary pile in an elliptical foundation; a more appropriate form than circular one for these cases. It is planned to use the outer rows to support with each of the 4PU a unitary section of the deck. The interior unitary towers will serve where necessary, as a unified structural element through the hexagonal network of hyperlinks at each level of contact of the tower modules 5. They can also be used in the back part, to join the tops of the unitary towers with the anchoring of the tensioners that counteract the horizontal tension of the bridge.

Figure 33 summarizes the work of the bridge. We can visualize one of the two large anchor blocks at each end of the bridge, with its engine room included, where the set of winches is aligned, its control and tension tensioners, the auscultation and control consoles, the compressed air pressurization equipment, and the maintenance room. From that point the bridge is born to the left, composed of a multiplicity of unitary sections of bridge, each of which is integrated by the unitary section of deck 3, the two bundles of tensioners 6, the transition plate of the bundle of tensioners to a single tensioner, embedded in the ribbed reel of the winch, from where the system is tensioned and regulated from a 4PU unitary pile on each side, with all the oil-electro-mechanical equipment.

The sequence of 9 unitary sections of bridge, identical to each other, except in the length of each tensioner due to the inclination of the distance, integrate a section of bridge corresponding to a pair of towers. There are also three successive bridge sections of equal modules, which can be repeated indefinitely. It is important to note that the entire bridge is made with identical segments, with a small size, easily interchangeable and highly resistant, which results in an economic construction and maintenance.

Figure 34 describes in detail one side of a bridge section corresponding to a tower 4, composed of a multiplicity of 4PU unitary piles, embedded in the foundation 2. You can see the deck, the bundles of tensioners 6, the transition plate from bundle 6 to cable 71, the bundle of cables 78 that counteract horizontal stresses, and a diagram of the hexagonal star 65 of hyperlink between each tower module 5. Figure 35 shows some unitary bridge sections, with a system of joints based on shackles and eyebolts, where the oil-hydraulic-electric control unit that controls the oil pressure of the hydraulic piston or winch is also observed.

Figure 36 shows a different way of embedding between simple deck modules, with a single pressu-

rized cylinder, with its reinforcement plates and anchor bolts. In this case, shackles and eyebolts are used for the coupling of the tensioners.

Figure 37 shows a section of unit deck 80, a section of tower 83, details of the coupling of the bundle of tensioners 6 with the tensor 71 by means of the transition element 82, preferably of titanium. There is also a detail of the deck, with the 6-lane highway and central railway. The section of 18 simple modules that make up sector 81, can be replaced by a single piece more elaborated and with simpler joints, as can be seen in:

Figure 38. shows a design of the unitary section of the one piece bridge, made in the workshop with precision robotic instruments, with a design that reduces the amount of material and relieves the weight, without considerable loss of resistance, since they are always considered highly pressurized. Figure 39 presents a cross-sectional view of the bridge, with its most important features. The possibility of making 1A foundations that protrude from the sea level, or that remain submerged 1B, is also observed, as well as the possibility of placing the optional stabilizing tensioners of the deck in different positions, 7A and 7B. The position and function of the retention tensioners 62 behind the towers 4, fixed in anchor 61, are also clearly visible.

Figure 40 - SGB, specific to the Bridge over the Strait of Gibraltar, synthetically shows a design with a very high possibility of technically solving the problem generated by the enormous span of the strait. It is also possible to evaluate it with a completely aerial bridge, with the only change in the magnitude of the 4 towers near the edge of the abyss, which must support 5500 m. each pair, from a side without a symmetry of loads, which requires placing them at a great distance from the axis of the deck, but using the procedure of the unitary towers 4PU and unitary bridge sections, it is a matter of advancing in a sum of identical elements, where only the length of the tensor 71 changes and slightly the length of the tensors 6 to adapt to the smaller angle of coupling.

[0056] When in any of the figures, elements with equal functions are drawn, even if they are somewhat different in form, as is the case of the foundations in figure 39, they are identified with the same number, with the addition of a letter, A, B, etc., the same happens with the tensors 7A and 7B.

BASIS OF PRACTICAL APPLICATIONS

[0057] This specification explains one of the ways to make a bridge of extreme spans from the beginning, that is, receiving from the factory the materials of tensioners, fabrics of ultra-resistant fibers and special resins, how to proceed for the construction of each type of modules, and the details that must be taken into account during

manufacturing both for transport and assembly, the possibility of having eyebolts included for direct hoisting, the shape of the couplings between each face of the modules, both in towers and on the deck, the construction process and the inclusion of hydraulic cylinders instead of the hydraulic-electric winches, if convenient.

[0058] In the detailed description of the construction procedure, included in this document, each step of design, construction, assembly and completion is explained. As shown, it includes simple and similar solutions that can be safely applied to most extreme-span bridges.

[0059] The great advantage of using the same elements in a multiplicity of segments, makes that no part of the work is monumental, but it is all distributed in modular fragments identical for each function, which support in small scale a fraction of the total support capacity. This makes the work very safe, because the failure of any of these parts, does not involve the total structure, but causes the adjoining parts to absorb their load until the problem is solved. Assembly and maintenance is favored, as well as costs are reduced, by having more manipulable and repetitive elements.

[0060] According to what is known so far, funicular structures are those made up of ropes, cables or cords that, due to their nature, do not have rigidity, so they can only absorb tensile forces. The ropes or cables have an extremely reduced moment of inertia in relation to the length, so we could assimilate their behavior to pieces of "infinite slenderness" and, therefore, of "zero rigidity".

[0061] On the other hand, and this is very important in this patent, tension causes the opposite effect, that is, it tends to stretch the piece, and not to curve it, as happens with flexion or compression in very slender pieces, therefore, its resistance does not depend on rigidity; it is independent of it. The cables behave inversely to the arcs, in which, due to their curvature, the shear and tensile stresses can become null, and the compression stresses become the support of the structure. In the case of a cable, the geometry it acquires when applying the loads is such that it ensures compliance with the law of equilibrium with the only tension work of the element.

[0062] The type of geometry that a cable acquires depends on the type of acting loads. Cables subjected to uniform loads horizontally, acquire the parabolic shape, following the shape of the moment diagram of the simple beam. Cables subjected to punctual loads acquire a discontinuous shape at each point where loads are applied, and cables subjected to their own weight form a curve called a catenary. In this case we have a uniform static load, and another variable due to traffic and external events as earthquakes and winds.

[0063] For the analysis of the aerial structure of bridge 1 obtained by the invention, all the elements that make up the aerial structure, made with ultra-resistant fibers, are considered totally flexible and inextensible, in such a way that in all its length the stresses will only be axial tension, and always tangential of the cable.

[0064] The shape that always acquires a tension structure is the one that corresponds to the funicular of the acting loads. The funicular are the shapes that correspond to the applied loads so that the resulting internal forces are compression or pure tension. Therefore, the analysis of the aerial structure of the Ultra-resistant Pneumatic Bridge, fully complies with the shape of a load funicular.

[0065] When a force system is applied to an aerial structure in a network of flexible cables, placed in any spatial position, each cable is automatically located in such a way that only pure tensile axial stresses occur in its internal structure; this necessarily implies that it will do so in exact geometric coincidence with the funicular of the loads. You can find a very important property, in: https://es.wikipedia.org/wiki/Pol%C3%ADgono_funicular

[0066] It should be noted that the funicular polygon is not unique, but many funicular polygons that meet the above conditions can be drawn for a group of forces. Intuitively, this can be justified from the idea that the funicular polygon would be the shape adopted by an ideal, massless, inextensible string subjected to such forces. Initially it can be placed according to an arbitrary direction in the plane, and as the forces are allowed to act on it, the funicular polygon is generated. Two identical strings, but in different original orientations will generate different funicular polygons, although geometrically related. The funicular polygon is closed being the first and last side coincident, in that case, the resulting force and the resulting moment are null and therefore the original system of forces is in mechanical equilibrium.

[0067] In this way a fundamental property applied in the present invention is obtained, since it invariably and biunivocally links two concepts: spatial geometry with intensity and direction of tensions.

[0068] In the case of a classic suspension bridge, the funicular form is usually considered a second-degree parabola due to its similarity to the catenary of the cable, and can be represented in its entirety in the plane.

[0069] In the case of the present invention, with closed and three-dimensional funicular polygon, the spatial geometry of the superstructure is very different as it is in a perfect balance, both in the position of the straps and in the shape of the funicular, because it is a structure of free spatial design and always three-dimensional, subject to the biunivocal relationship mentioned above.

[0070] Depending on the load system, in this case the stresses are applied to the tensioners, the assembly takes a single shape: the one that is perfect for working with pure tension. If any of the loads change, the shape of the funicular varies, but it automatically rearranges its shape to achieve pure tension.

[0071] In this way, it allows an aerial structure with different possibilities of spatial geometry for the basic engineering project, from an elementary bridge 1 to the most complex spatial configurations, such as elevated urban highways, with intersections and roundabouts in the same plane, with the great possibility of varying it in the

future in an instant and without additional works, with the simple change of tensions at the right points.

[0072] Since the aerial structure of this type of bridge 1 is a freight funicular with three-dimensional spatial geometry, its regulation in terms of achieving the desired shape, essentially depends on a parameter: the stress tension that is applied to each of the tensioners 6 or 7, according to their directions, since there is direct reciprocity between tension and form. We can modify the shape up to the design level, without any limitations, simply by changing the tensions of some cables.

[0073] It is important to note that throughout the structure which is an object of the present invention, and respecting the main quality of the ultra-resistant material, the automatically achieved funicular, and infallibly, makes the ultra-resistant fibers always work with pure tension in all its parts, even when they constitute the structure of the pillars or "ultra-resistant pneumatic towers" subjected to compression or flexocompression.

[0074] One of the essential aspects of the project, and of the present constructive arrangement, is that the entire aerial structure can be executed entirely with a single type of material and, in case of taking it to an extreme simplicity, it can be executed with a single section of the thread or ultra-resistant cord, identical for the entire work, this being the optimal possible limit to economize materials, reduce the administration, logistics, infrastructure of the workshop and its construction equipment, assembly and, logically, optimize costs.

[0075] To understand more clearly this concept of a single material and a single section of the cable, the following is proposed: the construction similarity of this system is comparable to the spider web. In some areas with a single thread, in others, reinforcing the same thread with several cords to form more resistant linear cords, or, flat or curved interwoven surfaces to make the construction modules flat or volumetric, but always using the same and identical structural element: a single ultra-resistant fiber. If we pull any of the threads, we can see that the entire fabric is immediately rearranged to a new funicular, to verify the pure tension in all its cables.

[0076] If in addition to the above, the type of material for the entire work is a simple cord of ultra-resistant material, the work must be obviously simplified and have stability and security to the extreme. It becomes independent of the weather and few relatively simple and light equipment is needed to execute it, being, as in the spider's web, the same complex system of tensioned and interlocking ropes of the final structure, a sufficient self-supporting aerial scaffolding to safely perform all spatial work definitively and in a single step, as explained in this example when detailing the construction process.

[0077] Due to its extremely flexible spatial geometry, the ideal shape is achieved naturally by the flexibility of the cables, whose funicular automatically varies with the type of stresses. In this case, where deck 3 can resemble a large tensioner, because it really shares the flexibility of the other lateral tensioners that support it, an arrange-

ment of spatial tensioners absolutely homogeneous in their physical qualities is configured, which allows the most varied combinations of spatial geometry. In addition, the shape of bridge 1 can be adapted to the present and the future, just by changing the individual stresses in the funicular system.

[0078] The gravitational forces of bridge 1, plus the possible cyclones and earthquakes, generate in space and at every moment, a precise funicular: the indefectible and unique one so that exclusively pure tension forces occurs in the axes of all the tensioners. This implies that the spatial shape taken by each tensioned cable must necessarily coincide with the line generated by the trajectory of one of the various compositions of the three-dimensional system of forces that can be generated. Therefore, it is possible to act inversely: by means of the previous and precise regulation of these tensions applied from the anchors, we can modify the spatial form of perfect design that the cables will necessarily take. This principle is the basis of the spatial geometry of bridge 1 obtained through the invention: to achieve the most varied predetermined and functional three-dimensional shapes, of the most diverse forms, both present and future, by simply controlling the tensions at the anchor points of the structure, always of pure tension. In addition, once preset, it can easily be automated and preserved, with real-time responses.

[0079] Given the posed challenge: to ensure that a single type of effort is manifested throughout the structure - pure tension - and to execute it with a single construction material, in order to maintain absolute homogeneity in its physical qualities, it is essential in this patent, to face the design engineering of the new great works from an absolutely different perspective in all aspects to the existing one, even in constructions as standardized as the suspension bridges 1 of extreme spans, which in this case serves as a preferred example of application of this novel Pneumatic-Ultra-resistant Constructive arrangement, of generalized use.

[0080] Pneumatic pressure has been considered as an excellent solution to stiffen any part of the hollow load-bearing structures made with ultra-resistant fibers, due to its simplicity, ability to vary its pressure level, or what directly corresponds to it, as its load, in addition to economy, lightness, low environmental impact, durability and low maintenance. If helium is used for pressurization and being it an inert gas lighter than air, it even lightens the aerial structure. It also has the advantage of keeping the entire structure perfectly elastic, with identical longitudinal elastic modulus of the material throughout the structure and being able to withstand any type of external stresses with tensions on its ultra-resistant fibers exclusively of pure tension.

[0081] The resulting superstructure initially tensioned in a precise and controlled way in all its segments, presents an instantaneous response to random efforts, always of pure tension, with perfect flexibility due to the cables and structural rigidity due to the tensioning. Spe-

cifically, a rigid structure due to tension and pressurization, but highly elastic and reactive in real time, which acts before any impact or stochastic stresses, like a vibrating rope.

[0082] Since the entire structure is highly tensioned, and the deck 3 is held laterally by the tensioning cables or straps 6, the degree of freedom for the lateral and vertical movements of the deck 3 is inversely proportional to the tension exerted by the strap and their lateral cables. The possible regulation is perfect, and the full bridge 1 is ultralight and ultra-resistant. This geometry allows to absorb the maximum lateral stresses produced by wind and earthquakes with vibrations or minimum controllable and bounded lateral displacements, and without any risk of breakage, of fundamental relevance in bridges 1 of extraordinary spans.

[0083] It is noted that, in an aerial structure that is tensed and built entirely with ultra-resistant fibers, there is no risk of fragile breakage under both static and intensely dynamic gravitational loads. The behavior of the tensed structure is always the same, excellent and immune to strong earthquakes, since, being entirely made by a three-dimensional interlacing of ultra-resistant cords or cables, it does not have rigid or fragile parts that can be broken by horizontal and vertical shaking, which it absorbs elastically; it is also not affected by resonance or plastic deformations. It is never affected by torsional or bending efforts, which do not exist in the structure. The absorption of the most intense seismic vibrations or hurricanes, translates into vibrations of tense strings, similar to those produced by the strong winds on the shroud, irrelevant to their resistance.

[0084] A georeferenced shift or rotation in the bases due to the effect of earthquakes, would generate an automatic order in automatic hydraulic equipment or cylinders for readjustment of the tensioning of the cables, with active-reactive control through a SCADA system or similar, to return immediately and without human intervention to the work situation and spatial positioning of each point of deck 3 originally established, simply lengthening or shortening some tensioners 6, without further consequences, without altering the normal operation and in real time. In the case of not having this automatic reactive system, it simply stresses more a sector of deck 3 and the upper end of the tower, or its axis can be slightly deviated, which, being flexible, occurs without further consequences, until the original tensions are manually corrected and returned to their normal state. When using the ultra-resistant pneumatic pillars or towers 4, the effect is greatly dampened by the elasticity of the towers themselves, which compensates for the displacement with slight inclinations, easily correctable by their own elastic tendency to maintain the vertical, with absolute softness, without fissures or major catastrophic consequences.

DETAILED DESCRIPTION OF THE INVENTION

APPLIED TO A BRIDGE OF EXTRAORDINARY SPAN BY WAY OF EXAMPLE

[0085] Referring now to the figures, it is seen that the invention consists of a novel Ultra-resistant Pneumatic Constructive arrangement for major works, suitable for the construction of bridges of extraordinary spans, greater than 2000 meters, thanks to the use of a versatile ultra-resistant material for the construction, both of pillars, as well as of deck and straps, thus providing shorter execution times of the work, easy maintenance and lower related costs, in addition to allowing the construction of bridges with spans greater than 2000 meters.

[0086] Thus, the Ultra-resistant Pneumatic Constructive arrangement of the invention, allows the construction of a bridge of extraordinary spans of general reference, as best illustrated in figures 1 to 7. In general, it can be seen that the invention comprises at least a deck 3, arranged in an aerial floating form and bi tensioned or three-dimensionally tensioned by means of straps 6 and / or 7, which extend obliquely and / or horizontally from its sides to respective pillars 4, arranged both symmetrically and asymmetrically on each side of deck 3. By means of this arrangement of bi- or three-dimensionally tensioned floating 3 deck and using an ultra-resistant material totally new in relation to its application in industry and the way in which it is designed, built, adapted and used for the present invention, it is achieved the construction of bridges of extraordinary spans, with spans greater than 2000 meters.

[0087] It is again noted that although in the present invention reference will be made to one of the great works, such as a bridge of extraordinary spans, obtained through the arrangement of the invention, this does not imply that it is limited to them, but that the invention can be considered, adapted and used for any type of construction without any inconvenience, either independently or jointly with respective devices or related arrangements.

[0088] Those construction parts of the invention will be later described in detail.

[0089] For the construction of a bridge of the planned characteristics, two types of pressurized pneumatic modules were designed, which will be the only structural elements, one specific for the construction of the towers, and another specific for the construction of the deck. In the case of having floating sections, another flotation module must be made. They are the only necessary pieces. (In addition, of course, to the foundations and anchoring accessories that are necessary, and that are not claimed).

[0090] The two modules have an internal volume necessary for the storage of pressurized air, basically in a cylinder of diameter and length to be determined in the calculation, being able to be greater than one hundred meters, finished at its ends with hemispherical caps of

the same diameter.

[0091] It is known that, structurally, pressurized receptacles work as elastic membranes. The stresses depend on the radius of curvature and the thickness of the membrane containing the fluid. The selected shape is obviously the optimal one for pressurizing gases and widely used placed horizontally in the storage of liquefied gases.

[0092] We consider that, to manufacture these modules, due to their enormous possible volume, it is convenient that they be carried out on site, in a plant specially designed for the construction of the same, with the maximum robotic terminology and automatic laser controls, because to make a really efficient and perfect work, especially in consideration of the safety and quality of their assemblies, its form, controls and measures must be absolutely precise. This issue is not currently problematic. A hightech workshop-factory would have a small number of automatic robots, since the work they must do is always the same, and with the possibility of being transported to other works and anywhere to build any type of modules in the future.

[0093] For the two necessary modules, the tower module and the deck module, the manufacturing process can be broadly speaking as follows:

1. Make the full-scale interior mold of the cylindrical section without the hemispherical caps, with any type of material that is considered suitable, with a linear coupling of quick opening and closing along a generatrix, to link it and leave it circular, or to separate it and reduce the diameter to allow the demolding of the finished cylinder.
2. Make the inner mold of a hemispherical cap.
3. Place the cylindrical mold on a horizontal axis of rotation, so that it can roll smoothly without moving its spatial geometry.
4. The cylindrical mold is slowly rotated, while the robotic equipment places the bandage of the fabric made with the ultra-resistant fibers, after homogeneous impregnation with the specific resin for its perfect adhesion, until the thickness determined in the calculation is achieved. The thickness is controlled on the entire surface with precision instruments, as well as the total absence of bubbles. With this procedure, the semi-rigid cylindrical part of ultra-resistant fibers of the pressurized tower unit module is manufactured.
5. The ends of the module, which are identical, are simultaneously manufactured, unless an inlet must be placed in one of them, and therefore the corresponding access space must be projected. Due to its special shape for assembly and anchors, it requires a specific robot for giving it the predetermined shape and fittings with pinpoint precision. It is solved by automatic instructions: <https://www.tdx.cat/bitstream/handle/10803/6837/07/Jcb07de16.pdf?sequence=7&isAllowed=y> To support the vast majority of design activities there is a commercial offer of soft-

ware, widely recognized and accepted for its contribution and benefits demonstrated in practice. For example, there are many options of CAD type packages, some of which offer specialized versions for different types of applications in engineering, which give very important support in the area of detail design, particularly in relation to the drawing of parts, assembly of assemblies, dimensional verification, calculation of the volume of materials, etc. We can also mention the finite element analysis (FEA) programs that have given agility to the process of calculating the mechanical elements, for example, allowing to effectively incorporate optimization processes. This type of software is complemented by the concept generically called "computer-aided manufacturing" (CAM), so that it has been possible to integrate a chain within the process of design and production of elements. To this can be added the most recent research that has led to new proposals such as the evaluation of designs using virtual reality and extended reality techniques.

6. Just as the straight cylindrical section is left intact and finished with the construction of the tube, so as not to weaken or alter it at all, the ends, considerably reinforced, have a series of elements that must be incorporated in the workshop before assembly at the tube terminals. First, it is necessary that the assembly is fast and of extreme precision to achieve a unitary tower 4PU, composed of a plurality of modules of tower 5 placed one on top of the other to form a single vertical cylindrical section, (unitary pillar) 4PU, which is embedded in the foundations and linked to all other unitary towers by ligature elements that must be placed during assembly. A 4PU unitary tower supports a section of "unitary length" of "n" meters on one of the two sides of the bridge, and a plurality of unified unitary towers, (tower or pillar), supports a greater length of the bridge, by adding new unitary sections of deck on each side of the bridge.

7. In the construction of the two cylinder heads, which include the hemispherical caps, at least the following elements must be taken into account:

- I. Three holes in the flat circular plate. Close to the edges. In perfect coincidence on all the faces of the modules. During assembly, the perfectly coupled guide bolts 66 will be placed in those three holes, on the upper face of the installed module and near the edge. They are required to locate the exact coupling position of one module on top of another during assembly, and to vertically align all identical elements. Inside these three asymmetrical holes and to avoid confusion, a cylindrical segment of smooth and lubricated stainless steel is introduced, with a reduced diameter, but robust, such as 5 cm. and with a length of about 30 cm., which penetrates up to half, or about 15 cm., and leaves the other

end of the three bolts protruding vertically to be embedded on the plate of the tower module that is mounted on the already installed. At their ends there are spherical caps of the same diameter as the bolt, to allow easy sliding on the edge of the hole when trying to align module 5 to be coupled on the installed one. Note: the total length of the two holes should be slightly greater than the bolt, to avoid stop effects that prevent full contact of the plates.

II. On both sides of the module there will be a channel with radial plan of 6 or 12 radii, in hexagonal form, with a central circle, it must have a semicircular section, of a diameter identical to that of the module, up to the edge. The hemispherical channel allows to embed in the workshop a network of stainless steel 67 semi-embedded in it, (on the top 67sch, to support the oil-electromechanical equipment) with such a diameter that externally forms a hexagon big enough to allow the creation of a circulation walkway in its environment, as can be seen in figures 30 and 31, strongly installed in the workshop on the flat surface of only one of its faces, which corresponds to the upper horizontal plane of junction with other modules. It has the double function of providing 6 anchor points for its hoisting as a tower module by means of helicopters or the assembly towers of the workshop, from the 6 robust eyebolts that it has at its 6 ends, and that once mounted, will serve as a support to link horizontally on each level a unitary tower with the adjoining one, in a triangulated form, to unify the whole as a single solidarity tower.

III. To secure the radial plant 67 to the top of the module, a stainless steel plate strongly welded to it in a radial shape is used, which is fixed with special anchor bolts on the vertical side of the module, in the workshop. The ends of the bars that make up the steel hexagon, also serve to anchor a perimeter stainless steel bar to the cylinder, to hold the safety harnesses, a perimeter walkway with safety railing, for circulation during assembly, and subsequent maintenance controls. It is necessary to provide all these elements in the workshop, and any others considered necessary, to have them placed and firm before lifting and assembly, such as for instance the lateral staircase.

IV. During assembly, the bottom part of the module to be placed, suspended in the air by the helicopter or crane on the already installed one, is manually aligned with the 3 plain bolts described in 9- I manually by rotating the body of the module, and once aligned, it descends and the 3 guide bolts are embedded. When totally laying, it is linked to the inverted channel on the steel hexagon already mounted, which prevents

transverse movements in the contact zone. Anchor bolts 75 and 75 A and B are placed, both on the perimeter steel ring 78 and on the solid body at the end of the module. The holes must be planned in the workshop with total precision, because making them in situ, due to the extreme hardness of the material, would be inconvenient, as detailed below.

V. The procedure continues in the manufacturing workshop, drilling with millimeter precision the perimeter holes at 45° that alternately cross both spherical caps to be tightly coupled by special anchor bolts 75 A and B, which are identical, but one goes up and the other goes down, they are anchored with special resin and its expansive system, half of the bolts rise from the edge of the lower module and the other half descend inclined from the edge of the upper module, crossing in both cases a solid sector of the coupled module, with a length to be determined in the calculation. The matching of the anchor holes between the modules must be ensured by robotic precision. Note: any error detected that prevents the assembly of any of the bolts, is solved by filling the failed perforations with epoxy, and making new ones, taking into account that drilling the aramid fibers with resins or any other ultra-resistant fiber is very complicated because it is ultrahard.

VI. To finish the basic details of the hemispheric head before being assembled into the cylinder, the inlet is mounted from inside if it is considered necessary, (it is not essential), for which, the corresponding hole must be provided at one end during manufacturing. It is planned with an opening to the interior so that the same pressure helps the sealing, and can contain on the inlet's particularly wide frame, both the inflation peak and the safety valve and any other auscultation control instrument. It is recommended, for security at the entrance, to access with a nearby interior floor, and to do so on the lower head of each tower module.

VII. If any reinforcement is necessary in the vertical plane of the link of the towers, being additional to the oblique bolts in the optimal position of embedding and determined quantity, it can be executed with stainless steel plates of vertical external link between both tower modules, with special anchor bolts. It is determined by the calculator.

8. Having finished the construction of the extreme heads that contain the spherical caps of the tower modules with all their equipment, we proceed to their assembly with the cylindrical section, taking into account that both the length and the square of the extreme flat faces must be perfect, for this the use of

a control matrix is recommended. The joints of these three pieces are made according to the state of the art in that special file, in a very robust way, always having available, if necessary, the interior access from the inlet.

9. Once the tower module is finished, it is necessary to control its tightness and resistance, pressurizing at a higher pressure than the working pressure. A tightness test pressure for 15 days is considered reasonable, exceeding the pressure corresponding to the safety coefficient, but not approaching the breaking pressure. Subsequently, it is decompressed to the working level, and the integrity of the tested element is verified. Protect the exterior from UV radiation if necessary, and paint them with polyurethane paints or similar if defined in the project.

10. In relation to the deck modules, which we set with a simple model in this example, 36 m. long x 3 m. wide x 3 m. high, exterior measurements, all identical. The construction procedure is very similar to the previous one: a central section of square section, which includes a cylinder inside, which we set at 2.90 m in diameter. It is linked with two hemispherical ends with special external terminations on a solid body of ultra-resistant fibers of 3 m x 3 m, at one end of the deck module is included the inlet, (if necessary), identical to that installed in the tower modules. The pressurized cylinder and the hemispherical heads are in this example embedded within a massif of square cross section of 3 m x 3 m, and rectangular longitudinal section, of 36 m x 3 m. For this reason, after finishing the placement of the coating on the mold cylinder, with the ultra-resistant fiber fabrics embedded in the special resins, in a real thickness to be determined by the calculation, which in this example we consider 5 cm., the placement of the missing material must be completed at the 4 angles to form a square, always with the same materials. It is very important to have 4 sides reinforced, because two of them, those of contact with the adjoining modules, are linked to each other with oblique bolts similar to those used in the heads of the tower modules, in an alternating linear and perimeter way, in the two contact faces, both at the upper and lower level. The upper face of the module, protected by an ultra-resistant layer to abrasion, works directly as a circulation grade of the practically indestructible bridge.

11. As in the previous case, the details of anchoring, placement of inlet and other elements of use and control, are made smaller module, that is, in the hemispherical caps of the central section that can be manufactured separately.

I. Drill horizontal holes in the workshop at the lateral ends of each module, one on top of the other at each end and on both contact faces, 20 cm. deep. They are intended for the alignment of the modules to make a perfect fit in all the

longitudinal perforations that link them with anchor bolts.

II. Like the guide bolts of the tower modules, a bolt of about 40 cm. with rounded heads is placed in each side hole of the placed module, and on the guide bolts the new module is embedded as a first step during assembly. This helps to hold it and also places it in its exact place for longitudinal and transverse alignment while being held by side tensioners or a crane for mounting that slides over the newly finished deck.

III. To anchor a new one with the adjoining one, the anchor bolts are placed with special resins, identically to the towers. The adjustment of the nuts of the protruding end, both upper and lower, tighten it with the previous module. To finish the assembly of this module, the hollows where the adjustment nuts are located are sealed with resins.

PREFERENTIAL PRACTICAL EXAMPLE OF EXECUTION:

[0094] A bridge of a 14 km. span over the water is designed, over the Strait of Gibraltar, which would link through a 6-lane motorway and railway Europe with Africa; the most extraordinary necessary work in the world as regards to span.

[0095] The actual schedule of the calculation and execution processes can be very variable, since they are extremely complex works, with multiple critical points that must be addressed simultaneously, but as an example, we will try to simplify them in large sectors of work with structural and sequential logic suitable for a feasible construction, from the work to the assembly.

[0096] The following objectives are proposed: Take advantage of the exclusive physical characteristics of the Ultra-Resistant Pneumatic Constructive arrangement, such as:

Buoyancy of ultra-resistant modules.

[0097] The extreme hardness and tensile and penetration resistance of the material used.

[0098] The extreme lightness of the ultra-resistant pressurized modules, compared to classic materials.

[0099] The current availability of extremely precise construction technology through the use of electromechanical robots.

[0100] An assembly with minimum equipment of common use, in a very safe way and taking advantage of the buoyancy of the bridge and the pillars.

[0101] The possibility of mounting the towers and the entire deck of the bridge and its tensioners with extreme speed, safety and economy, directly floating and from the water.

[0102] To achieve these objectives and in addition to those specified above, we will subdivide the entire bridge into unitary sections with very similar characteris-

tics.

[0103] A unitary section of ultra-resistant pneumatic bridge: (TUPNU) Figure 40 - SGB, includes the following:

A unitary section of ultra-resistant deck. FIG 40 - SGB (Strait of Gibraltar Bridge), detail (3 - TUTUR) of identical length to that which will be supported by a pair of 4PU unitary piles in each tower opposite the axis of the same.

[0104] A unit pillar (4PU) on each side of the deck, (Composed of a multiplicity of 5 individual ultra-resistant pressurized tower modules, with everything necessary to secure, tension and calibrate the tensioners corresponding to its section: winch, pressurizing equipment etc. placed one on top of the other to achieve the desired height. The unitary pillar PU, is affirmed and anchored on a foundation 2, suitable for a multiplicity of unitary pillars perfectly hyperlinked, working as a single unit, which we will call Pillar or Tower 4.

[0105] A pair of bundles of multiple tensioners 6, identical quantity for each section, (which will support the unit section on both sides of the deck, unified at a certain distance by a plate, 82, preferably titanium, which collects the load distributed by the tensioners 6 and discharges it by means of a single tensioner 71, of greater section, to the calibration and tensioning winches.

[0106] This criterion allows us to manufacture only two types of elements exactly alike in the module factory, one for the tower module, and one for the deck module. Obviously, they can be matrixed and built perfectly, since they will be repeated a significant number of times, reducing costs considerably. Eventually, you may have a different flotation module, when the bridge, as in this case, has floating spans.

Summary of the design of a bridge over the Strait of Gibraltar, which we consider **appropriate for the ultra-resistant pneumatic constructive arrangement**:

[0107] A section of air bridge at each end, with a slope of 6.5% towards the water, from the height + 130 m. until we reach, 2000 m. later to the progressive ones corresponding to the sea trenches, one on the marine platform on the European side, and another almost identical on the marine platform on the African side. We estimate each section of about 2000 m. of length, 1500 m. of which would be on the marine platform, and the other 500 m on the mainland, to achieve the exit height that allows free marine traffic below these two sections.

[0108] A central section of 11,000 m. of floating bridge directly over the water, supported by floats made with the same ultra-resistant material, pressurized and hydrodynamically shaped at its ends, to have the least influence of waves and marine currents. The unit section of ultra-resistant deck (3 - TUTUR) is only needed, joined in sequence to reach the necessary length, they form the deck, including the factory-finished circulation track. See FIG. 40 - SGB - (Strait of Gibraltar Bridge)

[0109] The synthesis of the construction procedure of

the elements necessary to build the entire bridge would be as follows:

Build the workshop and modules factory. It should be at a certain distance from the bridge, where the land is more level, with few meters above sea level and adjacent to the coast. We believe from logistics that the European coast would be appropriate.

[0110] Build reinforced concrete foundations without position limitations.

[0111] Build access highways to the bridge, extreme anchorage blocks on solid ground, and auxiliary services.

[0112] During this process, in the ultra-resistant fiber factories, fabrics for the execution of the modules and the cables for the execution of the tensioners are manufactured. Ultra-resistant fibers can be pure or combined with different types, but they must arrive woven when they enter the module manufacturing plant, integrated into the workshop. The first modules that are manufactured are those of the towers, until all the necessary ones are finished. It is estimated that, if they were 7 m. in diameter by 100 m. in height, with complete towers 4 containing 15 4PU pressurized ultra-resistant unitary pillars of about 400 m in height and strongly linked in each knot of coupling, it would require: 4 modules per unitary pillar x 15 unitary pillars per tower x 8 towers = 480 identical tower modules, pressurized in this case to 10Kg/cm2., which results in a payload of about 4,000 tn. supported by the air pressure of each unitary pillar, as an illustrative example of the bearing capacity. (With a pressure of 50 kg/cm2 the load capacity amounts to more than 190,000 tons in each unitary tower).)

[0113] As they are manufactured, resistance, tightness and quality control tests are carried out, being delivered to the assembly with the corresponding working pressure. It is assembled on the 4 platforms of the foundations built on the marine platform of each continent, in total 8 towers or pillars.

[0114] An issue of great economic and practical interest is given through this Ultra-resistant Pneumatic Arrangement, which is extremely strong and can be placed directly on a submerged platform, which considerably reduces the amount of concrete.

[0115] If the modules are 100 m. and the depth is greater, they are joined in the workshop to make them 200 m. in length. They are launched attached to the water, and floating they reach the georeferenced point of the anchoring vertical. There the lower section is filled with water by the inlet, pressuring it to the same degree as the upper modules will be, and in part the upper module is also filled with water, in such a way that it remains afloat, but vertically.

[0116] With this position, water is completed inside the upper module to the level necessary for it to sink slowly and settle on the anchor ring provided and recessed in the foundations, there it is perfectly secured, and the free volume of the upper module is pressurized with purified air, continuing the assembly with the third module, preferably hoisted by helicopter, normally already pressu-

rized in the workshop.

[0117] On each of the unit pillars intended to directly support the tensioners, the winch, the electrical-oleohydraulic systems of the equipment, and the 62 tensioners anchored at the top and at the other end of the foundation, in the steel anchor mooring 61, are placed to balance the horizontal forces of the deck.

[0118] On some platform formed by the linking framework, an automatic pressurization and air purification plant is mounted, which will serve the entire tower during its useful life. They can be redundant equipment, for safety purposes.

[0119] Naturally, towers need around each joint of modules, walkways for assembly and safety railings, described above. At the same level of union between modules, all the 4PU are hyperlinked radially in a firm and rigid way.

[0120] With these operations, we have finished the 8 complete towers, the service roads and the access highways, which end on the anchor block of the ends of the deck on each continent, containing in their inside the engine, control, auscultation and maintenance room.

[0121] All the deck modules can be manufactured simultaneously, which we estimate in 100 m long, 36 m wide and 3 m high.

[0122] Its interior shape can be very varied. The optimum will be the lightest one with the maximum resistance to pressurization and crushing on its upper face. We propose the one in Figure 38, which in addition to having the inner hollowed cylinders, has other cylinders semi-embedded among the previous ones, maintaining resistant arches on their faces and relieving the ultra-resistant material without removing resistance from the module.

[0123] Once all the deck modules are manufactured, we calculate (15.000 m / 100 m.) 150 modules, follows the assembly of all the tensioners corresponding to the aerial sections above them, and their unification on the intermediate titanium piece 82. They are properly accommodated on the upper face of the deck, which has already been reinforced against the abrasion of traffic with the layer intended for the grade and circulation plane.

[0124] Subsequently, we proceed to the mooring of one module after the other, perfectly joint on land before being thrown into the water, and in this way we have a first section of 20 modules, that is, 2000 m of deck floating on the water. The navigation maneuvers are carried out by the specific tugboats for these purposes.

[0125] One end approaches towards the starting point of the bridge, and the deck is secured and aligned on its final trace, while it is kept floating and stabilized with tugs near the mainland, while tensioners 71 are launched from the towers, anchoring it firmly at the opposite end of the titanium plate that has all the tensioners 6 anchored 6 on a unitary bridge module, with identical quantity in each section.

[0126] Once all the joints are finished and verified, which presupposes very little time, since it should be necessary to secure 40 shackles on the titanium plates, the

deck is slowly hoisted simultaneously from all the towers, bearing in mind that, being one of the ends on the sea 500 m. from its anchorage point on land, it must be fastened with the tugs, and leaving the last sections of the bridge without elevation, until it slowly advances through the air the 500 m. until its anchorage in the reinforced concrete block, where the set of winches that will tighten it properly are waiting.

[0127] Once anchored, each deck module is positioned at its exact point, with the sole automatic control of the winches located on the 4PU unitary pile. One end is embedded in land, and the other raised to a level of about 15 m above the water, at the edge of the sea trenches.

[0128] As the procedure is identical and symmetrical at each end, we have finished the 4000 m bridge in its two aerial sections.

[0129] In the same way we proceed with the section of 11,000 m. of the floating bridge, which, in the same way as the other modules, enters the water through a ramp with rollers from the manufacturing shed, and perfectly joined before being thrown into the water, they make up a train with 110 bridge modules without any type of tensioner, mounted in the same workshop on the floating modules of nautical design, preferably similar to a sequential catamaran. See 3 - SGB in Figure 40

[0130] The perfect joint of its ends with the modules of the floating bridge is carried out, and possibly also with some tensioners 6 specially arranged for it. The lighting systems, signage, etc. are placed and the bridge is fully finished and ready for its inauguration. Note: in the case of preferring to reduce the slope of the aerial sections, it is possible to advance with the air bridge tensioners over the sea trenches, for example, 500 m. on each side, which reduces the slope of entry and exit to a value of about 5.2% instead of 6.5%, with 130 m. of elevation at the entrance and exit of the bridge, to allow the navigation of large ships.

DESIGN PROCESS WITH FULLY AERIAL VARIANT:

[0131] With respect to the procedure, a novel prototype has been designed, which is possible to build due to the possibilities and versatility offered by the Ultra-resistant Pneumatic Arrangement of the present invention, as it serves to have the representation of a specific archetype, which allows to visualize in a synthetic way the potential solutions in all phases of this work, and of the other great works in which it can be used.

[0132] All data contained in this example are approximate, but they were chosen based on possible ones and those close to the reality existing in the Planialtimetry of the Strait of Gibraltar, and are only given as a demonstrative example.

[0133] Planning sequence, prior to construction:

- Determine the ideal place of linkage between Africa and Europe.

- Determine the optimal starting and ending point of the causeway, both in Europe and in Africa, within the mainland, preferably at an appropriate altitude to allow maritime traffic throughout the strait. (100 m. minimum height on the coastlines)
- Plot the axis of the deck joining those two points.
- This longitudinal axis of deck 3 can be straight or curved. We will assume it straight, shaped like an anti-tenanaria with a minimum arrow, of only 50 m. for the following reason: given the enormous span, doing it in the form of an appreciable arrow anti-candlestick would increase its height in the center by hundreds of meters, would imply simultaneously raising the height of the towers that support that section in the same proportion.
- As extensive studies have been carried out in detail of the Planialtimetry, geotechnics and geology of the seabed and the mainland, select and demarcate all suitable sites to build bases and towers. Among that selection, determine the most convenient to optimize the work both in safety and cost.
- The span over the strait of 14 km. from coast to coast is adopted, plus 0.5 Km. on each side on the mainland for its entry into the continent at a level of about 100 meters above sea level, sufficient to allow free navigation throughout the width of the strait of large cruise ships and cargo ships of great draft, which do not usually require more than 16 m. draft or have more than about 80 m depth.
- In the central transverse axis we will raise the deck to 150 meters above sea level to be covered in the future.
- A total deck span equal to 15 km is planned without contact with the multiple and asymmetrical towers, selected in position and number by the resistance of their foundations 2 and economic convenience, all being separated from their axis at a different distance, determined by Geotechnics and Planialtimetry.
- To minimize the span of the central section located over the sea trenches of the center of the channel, a section that would rest on the towers located near the terminal edge of the continental shelf of both continents, it would be ideal to locate some of the foundations of the towers on the shallow parts with greater support of soils, located on the marine shelves, which really exist on both coasts of the strait, entering offshore up to about 1,500 m. from the coast, with depths of about 100-150 m., without reaching depths such as those existing in the deep channels of the center.
- The central section would have a span of 11,000 m, and would be supported by 4 towers away from the deck, 2 on each edge of the marine shelves of Europe and Africa, so that 5,500 m. would correspond to each pair of towers.
- With these parameters, the height and separation of towers 4 can be planned so that their tensioners 6

and 71 are efficient, both for gravitational vertical loads, and the horizontal fastening of the deck before winds and earthquakes.

- The marine traffic of great draft and with greater depth, currently circulates through the central 6 km of the strait, and the maximum depth of large ships from the water to the end of the mast does not currently exceed 100 m. We consider this height as the minimum starting point for deck 3 at the edge of the coasts.
- The position of the piles on the sea bank does not affect the normality of the traffic of large ships. Nor would it be affected at any time during the process of the works.

[0134] To make bridge 1, the following will be used:

- Multiple pillars or ultra-resistant asymmetrical pneumatic towers.
- Ultra-resistant Pneumatic Deck 3 of longitudinal section equal to a vertical parabola that opens downwards, with minimum height over the sea of 100 m. on both coasts and central height of 150 m.
- Ultra-resistant Pneumatic Deck identical to the previous case, with 6 lanes and a central railway.
- Define the design of deck 3
- Define the position of the foundations and towers
- Do the project and the structural calculation.
- Make a perfect model of a scaled down model: 1:100, about 170 m. long to include 1 km. of land accesses in each edge, practicing during the assembly of the model the proposed construction system, with all its construction details and those of the surrounding habitat.
- Perform load, seismic, wind tests, both partial and simultaneous, and if desired, those of overload and deformations until breakage.
- Readjust project and calculation.
- Metric computation and budget.
- Detailed engineering.

[0135] Constructive process of the bridge:

- Build on the mainland the infrastructure works necessary for the operation and construction of the bridge. Extreme anchor blocks, engine room, access and service roads.
- Build the foundation structures of the towers: We consider it convenient 2 towers of about 500 m. high placed about 700 m from the coasts and about 200 m. from the axis of the deck approximately, to support the first section of 1,500 m on each coast.
- 2 foundations 2 will follow for the towers near the abyssal edge of the continental slope, at about 1,500 m. from each coast, of about 1,300 to 1,500 m high, and if economically viable, even greater, to allow to

obtain relevant vertical components of the tensioners at a distance of 5,500 m. towards the central axis of the bridge. The shape of the foundations and the placement of the 4PU unitary piles should be specially studied. Their tensional state suggests placing them slightly transverse to the axis of the deck, and almost parallel to the edge of the abyss, to be able to separate the tensioners properly at the great distances of 5.5 km. It is also necessary to place anchored tensioners from the top of the unitary towers to the foundations, to counteract the horizontal tension of the section.

- The enormous loads involved in the span of 5500 m. to be supported from one end and obliquely, can be safely supported by distributing the load of each unit section of the bridge in each unitary pile 4PU, and, in this case, at least 55 unitary piles are necessary on each foundation on the side of the marine abyss, the further away from the axis of the deck, much better. By changing the internal pressure of the tower modules and reinforcing the walls of their cylinder, it is possible to achieve very high unit loads, without buckling problems, as they are hyperlinked to each other. With a pressure of 30 kg/cm² the load capacity amounts to more than 110,000 tons in each unitary tower.
- The distance from the central bases to the axis of the deck is estimated at about 800 m., to have a horizontal component of the tensioners 6 appropriate to stabilize oscillations of the deck at a distance of 5,500 m., equivalent to a lateral slope of 14.5% at the furthest point, which requires greater efforts to support the section. For this reason, the floating bridge section has been developed, which effectively solves all these problems.

[0136] The assembly of the towers and the deck would be the same as in the previous example. In this way, it is possible, fast and safe, to build the deck without formwork or special equipment for assembly, with total safety throughout the process, even when they are thousands of meters from the beginning, over the sea, more than one hundred meters high and with any type of climate or seismic movement.

[0137] In this case, it is important to carry out the assembly of the central section of 11,000 m simultaneously from both margins, to compensate for the tension caused by the asymmetry of the towers, which are at one end, and not in the center of each section. This tensile effort should be taken into account in the calculation in the towers and in the deck modules and their joints.

[0138] As it has been made explicit, there is no necessary element for the assembly that is not included and remaining at the finalization of the work.

[0139] In this way, a construction method that does not use a single element to support large loads is developed,

as in the case of classic bridges, but, on the contrary, the loads are distributed in small portions among a network of tensioners, resulting in a much safer construction and in an efficient eventual maintenance, because if everything is well built and joined, it can be said that it is almost free of preservation and surveillance. The expressed above in relation to construction and assembly methodology, is hereby claimed.

10 SPECIAL SITUATIONS OF LOAD OR SPATIAL GEOMETRY

[0140] During the final stages of construction, the necessary sensors for automatic auscultation and the perfect control of georeferential points of spatial geometry, lighting, signaling, etc. will be included.

[0141] The bridge is finished, logically and technically efficiently, without interruptions of vessel traffic, without formwork or special equipment, with total safety, with a simple and perfectly controllable methodology, and in a short term.

[0142] The project integrates an automatic tensions control system in each anchorage of the 4PU unitary towers, which acts in real time to keep the optimal design tension constant under any circumstances, pre-setting the hydraulic pressure of each of the oleohydraulic systems, as a constant to be kept stable over time, which is electronically self-regulated to do so, achieving the designed spatial geometry, and which sends its data to the Auscultation Center for knowledge of the human team. This serves both to stabilize the spatial geometry under different loads, and to automatically correct tower shifts due to strong earthquakes or by intentionally provoked harmful effects. At this point the bridge that is entirely over air is finished and ready for service.

[0143] If there is an emergency due to some unexpected event, the tensions of all or part of the whole can be reduced, until it is repaired, and then revert back to normal without further inconvenience. If considered advantageous, the spatial geometry considered ideal can be automatically maintained permanent and accurate in three-dimensional space, under any dynamic and variable action of permanent and transient workloads. In the event that a super vessel with excessive depth requires greater elevation of the deck, it can easily be achieved by changing the stresses of some tensioners, which will alter the spatial geometry to achieve this end, and then, it is simply returned to the normal state.

[0144] Each point of deck 3 in space can be automatically stabilized by means of automatic compensatory tension changes at the end of deck 3, when spatial variations in the position of georeferenced points are detected, caused by circumstantial loads of traffic, thermal reasons, earthquakes or winds.

[0145] To do this, being without service load, deck 3 can be initially tensioned, until achieving the descent corresponding to the maximum traffic load considered in the design, and the tensioning can be reduced automatically

in the same proportion that the deformation caused by the normal real circulating load. It is not necessary to act on the 6 tensors to achieve this instantaneous adjustment effect. It can be achieved by electronically pre-setting a certain value for the battery oil pressure of the hydraulic winches that control the longitudinal tension of the deck 3, with instant automatic compensation to keep it constant.

[0146] This optional regulation means that the stresses in all the cables that make up the flexible structure are practically uniform over time, being bridge 1 loaded or unloaded, reducing the dynamic fatigue of the materials and maintaining constant and invariable the stability of bridge 1 in response to dynamic loads, earthquakes and winds. Naturally, the constant increase in tension can increase static fatigue. On the other hand, the cables always work at the maximum design load.

[0147] This proposes a construction arrangement that provides an intelligent tension system that self-regulates and allows simple, safe and automatic control, preservation and repair in real time. In turn, given the extreme flexibility of the aerial structure, interwoven and firmly embedded in the towers, the only expected result in the event of natural disasters, such as earthquakes or extreme tornadoes, is the physical effect known as vibrations of tense strings, even on deck 3, which due to its width-length ratio behaves relatively like a rope. In a similar way to piano strings, tressed cords are immune to sudden external blows, without alteration of their integrity or functioning. The calculation of a structure tensed with identical ultra-resistant multifilaments, which can work alone or grouped in interwoven cables of the most diverse forms, whose uniformity in quality, elastic modulus, breaking stress, Young's modulus, and other qualities, is perfectly known by factory tests, is determinant to know with absolute precision the safety coefficient of the finished structure.

[0148] It is really a guarantee for calculating engineers. A calculation with the actual safety coefficient for the entire structure can be achieved. The same does not happen when a multitude of different materials and joints of special parts must be taken into account, as if it were a complex mechanism with so many random unknowns that it is necessary to estimate them. The safety coefficient in this case is approximate.

[0149] The possibility of a total catastrophic rupture is almost zero, due to the characteristics of the design itself, because even destroying a tower abruptly, bridge 1 will lose the temporary possibility of circulation, but will remain in space by drawing another funicular of the loads, suitable for the resulting new system, due to its low comparative weight and without the working stress, thus allowing its repair and return to normal operation. Naturally, the 4PU unitary pile, whose multiplicity compose a complete tower or pillar, unified at the base and at the top and as long as it has modules with air, will continue anchored and afloat, with almost no possibility of sinking; the same applies to deck 3. We can estimate that it is a

design with very high resistance to its total destruction, and to prove it nothing better than doing resistance tests and breaking strength on scale models.

[0150] The effect of each type of cataclysm on the real structure can be observed in a relatively simple way by means of a special layout for these studies, prepared in detail and in such a way as to simulate each possible catastrophic effect; in the same way by a dynamic calculation program that allows to graph the instantaneous and reactive tension states from the winches, and of any possible violent partial destruction due to explosives of some towers or of the same deck 3.

[0151] It is evident that this space system is immune by its own attributes to the most violent earthquakes and winds. These advantages simply make it extremely advantageous compared to current systems for any type of civil works, which suffer the consequences with loss of human lives and enormous costs. In any situation, it is possible to achieve the desired safety by making the project according to the specific needs and real environmental possibilities, since the flexibility and freedom of action are almost unlimited.

[0152] The variation in tidal height on the floating bridge, by shortening or lengthening the deck 3, are absorbed with the movement allowed at the ends of bridge 1. Reiterating, the lateral displacement of the axis by marine currents is considered irrelevant, especially if the flotation modules have an adequate design, since it does not affect the normal operation of bridge 1 and is visually not seen.

[0153] Likewise, deck 3 is floating on flotation modules, arranged at sea level, each of which also includes this plurality of interwoven ultra-resistant fibers that form volumetric bodies pressurized by compressed air. Rigidized flotation cylinders can be made with a shape similar to the bow of a ship at their ends, leaving free spaces between modules, as in a catamaran, to reduce the impact of waves and currents. If they are made longer than the width of deck 3, the surface serenity of the deck increases. In any case, the existence of some ascending and descending movement is irrelevant for traffic, as they are very smooth and result imperceptible from the car.

[0154] The objectives proposed by the invention are achieved through the conception of a new constructive arrangement, in this case developed as a practical example for a bridge of extreme span, selected for being one of the most complex and unresolved works, but also useful for any work.

[0155] It is extremely safe for people and vehicles that are on deck 3 in the event of large earthquakes or violent gusts. Even in extreme situations, such as tornadoes and major storms; it is very resistant because it does not have large surfaces on which extreme pressures can be exerted, and because its spatial movements are restricted. To reduce these effects, the sides of the aerial deck 3 can be designed with an aerodynamic shape, similar to the mirror cut of the wing of an airplane. This construction detail, valuable for the final project of the deck, efficiently

and jointly corrects the wind pressure and the discharge of rainwater, as is usual in highways, having a slight slope towards its sides. Like this, a plurality of details must be taken into account in the final project, since this documentation only raises possibilities.

[0156] To increase safety drilled wind deflectors can be placed at the edges of the deck 3 together with the normal safety railing, which, without closing the full vision effectively protects from its direct influence.

[0157] The current technology allows the instantaneous control of the tensions in each anchor knot, so it is expected an active and reactive control of this structure, being able to exactly regulate the tensions and the spatial forms, by means of an automated SCADA system or similar, that works maintaining the spatial geometry of design. The maintenance is comparatively lower compared to the classic suspension bridge, for having minimal uneven control elements, without hidden parts and easily interchangeable.

[0158] Another strong point of the design is the significant cost reduction that can be achieved by reducing the weight, quantity and variety of materials used, with almost no residual debris, as well as having ultra-resistant threads as the only essential element of construction. Naturally, an industry capable of producing them on a large scale and thus at competitive prices is needed at the moment, which is currently underway. The lower cost of the assembly process is really extraordinary, using the same equipment of tensioning and control of the bridge, added to the possibility of doing a dry construction, in extreme climates and in extremely short time, without expensive construction equipment that must be amortized in a single work.

[0159] In summary, there is a Pneumatic-Ultra-resistant Constructive arrangement for major works that is made with modular elements built with ultra-resistant fibers, pressurized according to need, or what is the same, with resistance to loads and variable work tensions according to need, which make up construction elements of the most varied forms, which are suitable for the constructions of civil works, naval, aerospace, architecture, etc. due to its conditions of low weight, high resistance, cohesion, flexibility, without being despicable or corrosive, and being immune to strong winds and earthquakes. Likewise, it is suitable for making totally dry and prefabricated structures with extreme precision and maintenance of the forms, where the material used are the ultra-resistant fibers interwoven and strongly joined with special resins, working exclusively to pure tension freely regulated by the designer, even when withstanding compression loads, torsional bending and their combinations.

[0160] The arrangement of the invention basically uses two construction elements for the construction of any structure: cables or cords of ultra-resistant fibers, and surfaces interwoven with the same material, whether flat or curved, closed or open, being able to use these ultra-resistant surfaces for the generation of flat bodies or

closed volumes of any form, which in this case must be strongly pressurized to transform the modules, tenacious and of extreme hardness, in volumetric, rigid and ultra-resistant bodies, capable of pneumatically withstanding very high compression loads, which are transmitted as an increase in internal pressure on the air used for pressurization, and pure tensile stresses in the ultra-resistant material that makes up the solid body of the pressurized volumetric figure, in any way, hollowed out and hermetically sealed by its own fibers and resin, to work constantly without loss of pneumatic pressure.

[0161] With these two elements, ropes and volumes woven with the same cable, which tenaciously maintain their shape by being strongly glued with epoxy resins, it is possible to dry build bridges of extreme span; the closing wall of reservoir dams; build resistant structures, side closures and horizontal floors in skyscrapers of heights greater than 1.000 m.; build elevated urban highways; manufacture lighter and sink-proof large ships of all kinds, modules containing oil, bulk grains, and other products; modules for expeditions, camps or permanent housing, etc.

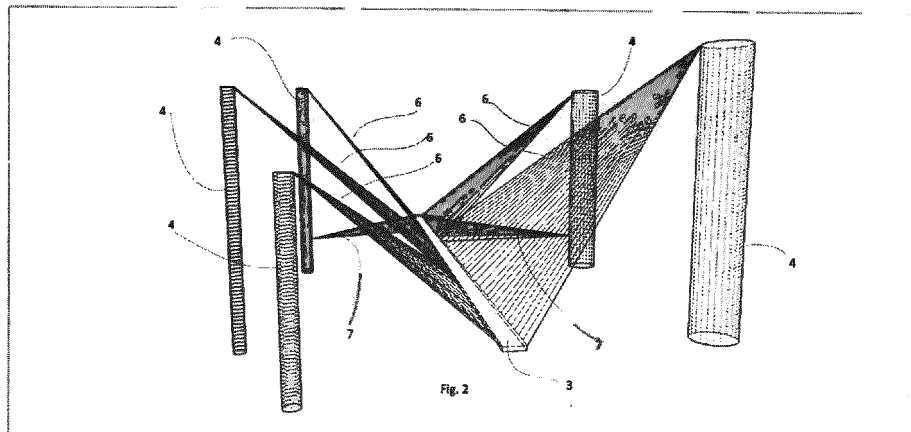
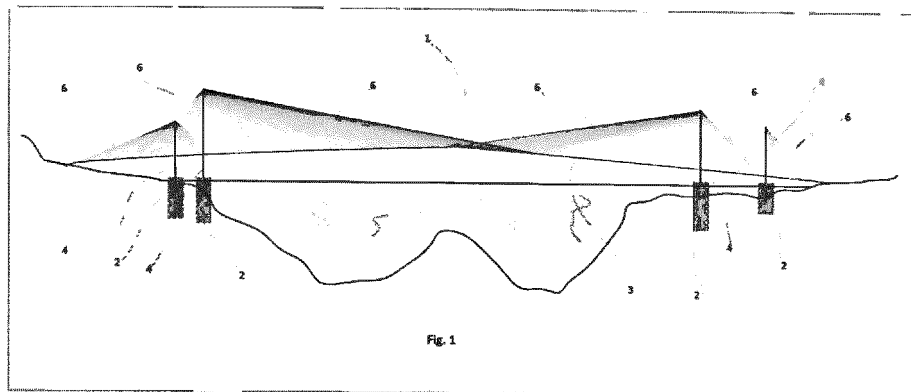
[0162] Thus, any type of work made with the arrangement of the invention, presents very high resistance to earthquakes, without the minimum risk of breakage by shocks and vibrations due to hurricane winds and any type of terrestrial meteor, withstanding varied efforts in any direction, through pure tensile stresses in the ultra-resistant fibers, without detachments or risk of fragile breakage. In the same way it would be useful for buildings with autonomous flotation capacity as they are unanchored from the ground in a programmed way in case of tsunamis, floating cities, etc.

Claims

1. A Pneumatic-Ultra-resistant Constructive arrangement for major works, such as bridges 1 of large spans, **characterized in that** it comprises:

a plurality of interconnectable deck modules 3 forming at least one Ultra-resistant Pneumatic deck 3, each deck module 3 comprising a plurality of interwoven ultra-resistant fibers;
a plurality of pillars symmetrically or asymmetrically arranged on each side of said deck 3, and comprising at least one or more sets of ultra-resistant fibers interwoven and strongly agglutinated with special epoxy resins, each of which defines a hollowed volumetric body, both pressurized and at atmospheric pressure;
being said Ultra-resistant Pneumatic deck 3 laterally tensioned by means of a plurality of ultra-resistant fiber ropes, which are projected at least obliquely from the sides of the deck 3 to at least one upper end of said pillars.

2. A Pneumatic-ultra-resistant Constructive arrangement for major works according to claim 1, wherein each deck module 3 comprises one or more sets of ultra-resistant fibers interwoven and strongly agglutinated with special epoxy resins, each of which defines a pressurized volumetric body. 5
3. A Pneumatic-Ultra-Resistant Constructive arrangement for major works, according to the foregoing claims, wherein such ultra-resistant fibres are selected from the group consisting of aramid fibres, carbon fibres, UHMWPE fibre, or any other ultra-resistant fibre, or a combination thereof. 10
4. A pneumatic-ultra-resistant constructive arrangement for major works according to the above claims, wherein each pressurized volumetric body formed by these ultra-resistant fibers interwoven and strongly agglutinated with special epoxy resins that form pillars and deck modules 3, is preferably pressurized by purified compressed air. 15 20
5. A Pneumatic-Ultra-resistant Constructive arrangement for major works according to any of the preceding claims, wherein each module of deck 3 defines a lower layer of deck 3, being said modules of deck 3 embeddable by means of unified flanges with bolts aligned in their contact perimeter, or other arrangement of free choice. 25 30
6. A Pneumatic-Ultra-resistant Constructive arrangement for major works according to claim 5, wherein said deck 3 can also include a renewable top layer of wear grade, an intermediate layer of load distribution and said lower layer formed by the modules of deck 3. 35
7. A pneumatic-ultra-resistant constructive arrangement for major works according to any of the preceding claims, wherein each pillar is mounted on a respective foundation and comprises a plurality of these pressurized volumetric bodies, arranged together in various forms, heights, volumes and diameters. 40 45
8. A Pneumatic-Ultra-resistant Constructive arrangement for major works, according to claim 7, wherein this plurality of pressurized volumetric bodies that make up each pillar, is closed in its upper and lower interior preferably by hemispherical caps at both ends, and finished at both ends with a flat surface that includes the coupling flanges of greater diameter or another mean of free coupling. 50
9. A Pneumatic-Ultra-resistant Constructive arrangement for major works, according to any of the previous claims, wherein said deck 3, in addition, is tensioned by horizontal cables of ultra-resistant fibers that extend horizontally from the sides of the same to an intermediate part of the pillars. 55
10. A Pneumatic-Ultra-resistant Constructive arrangement for major works, according to claim 9, wherein said deck 3 is floating on air, water or a combination thereof, its ends being on coastal land.
11. A Pneumatic-Ultra-resistant Constructive arrangement for major works, according to claim 1 or 9, wherein these oblique and horizontal cables of ultra-resistant fibers converge towards a respective point of the pillars while diverging towards the sides of deck 3.
12. A Pneumatic-Ultra-resistant Constructive arrangement for major works, according to any of the preceding claims, wherein these pressurized volumetric bodies are connected to respective pressurization equipment, while each bundle of cables is connected to an hydraulic-electric automatic tension regulator equipment.
13. A Pneumatic-Ultra-resistant Constructive arrangement for major works, according to any of the previous claims, wherein said deck 3 is floating on rigidized flotation cylinders arranged at sea level, each of which also includes said plurality of interwoven ultra-resistant fibers that form pressurized volumetric bodies.



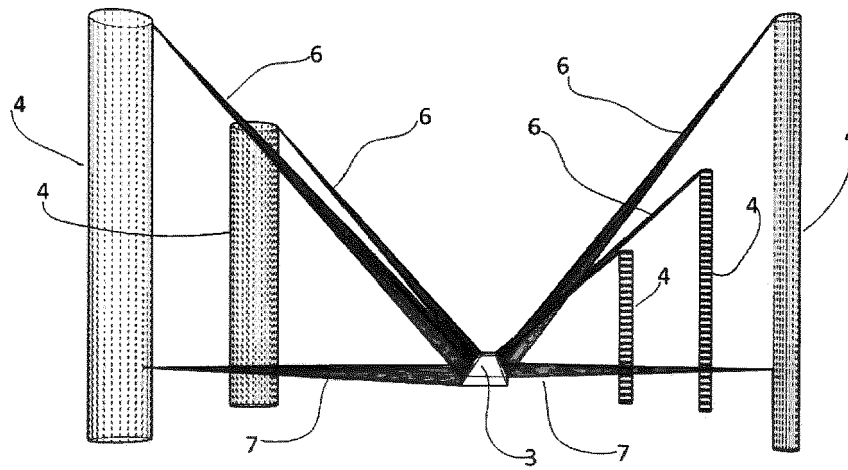


Fig. 3

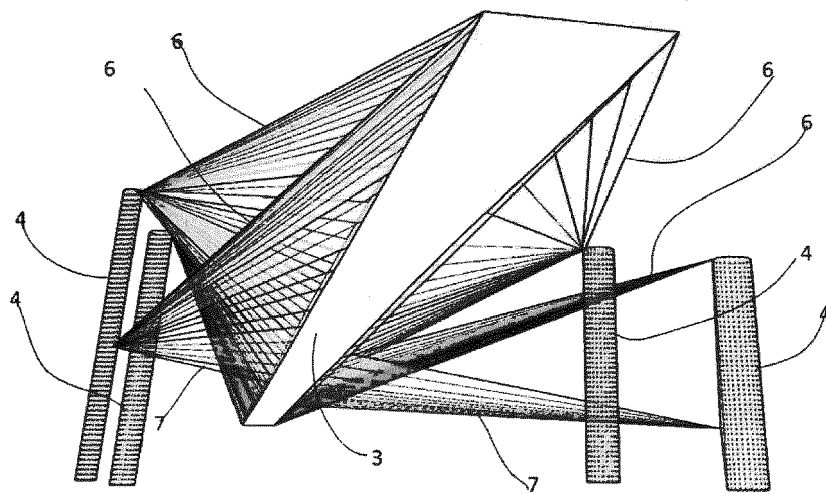
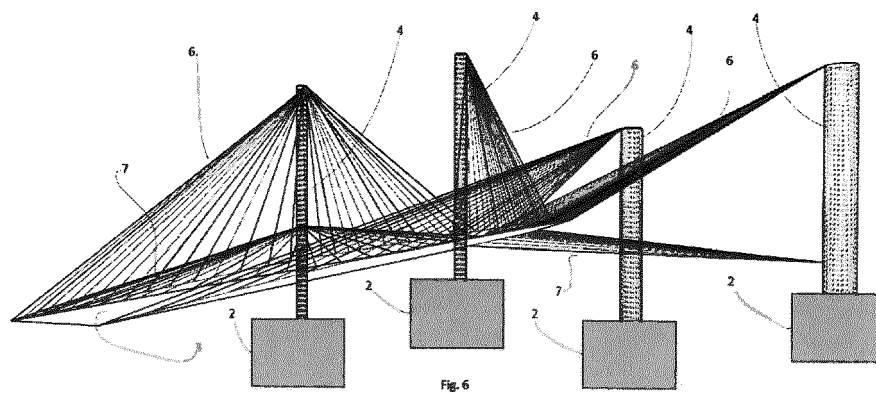
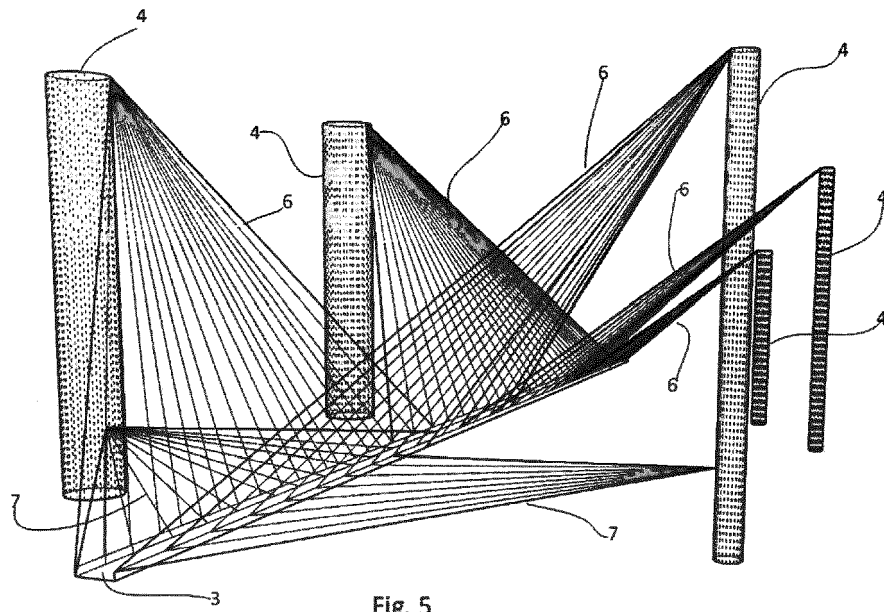
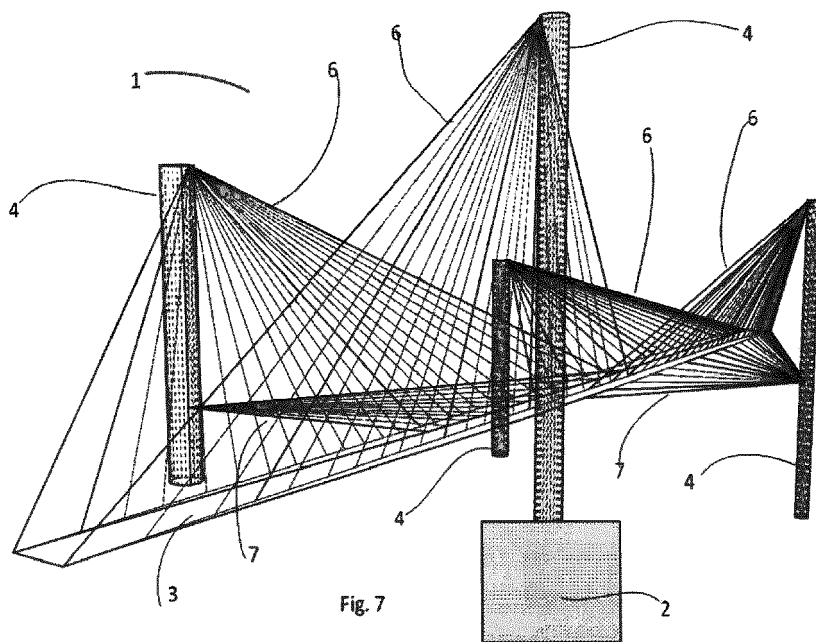


Fig. 4





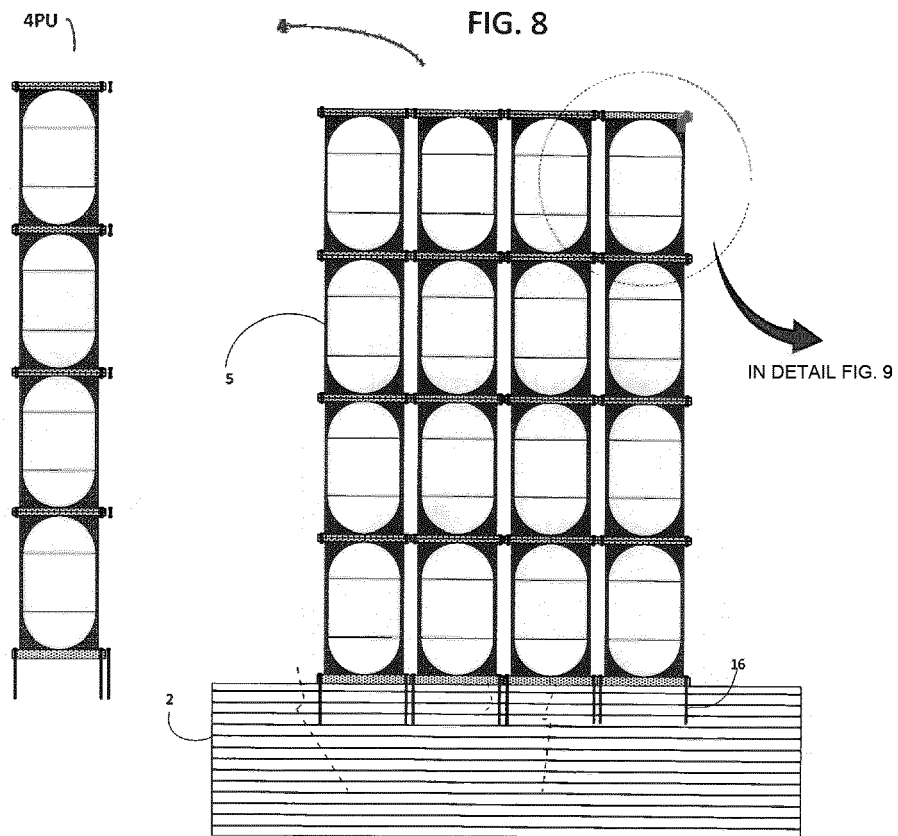


FIG. 9

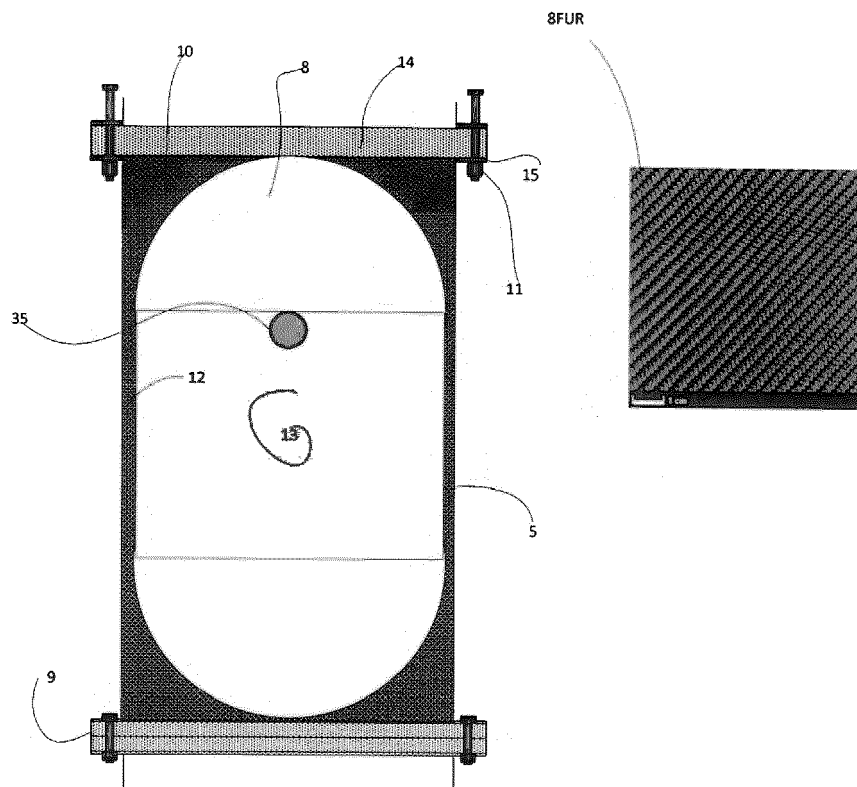
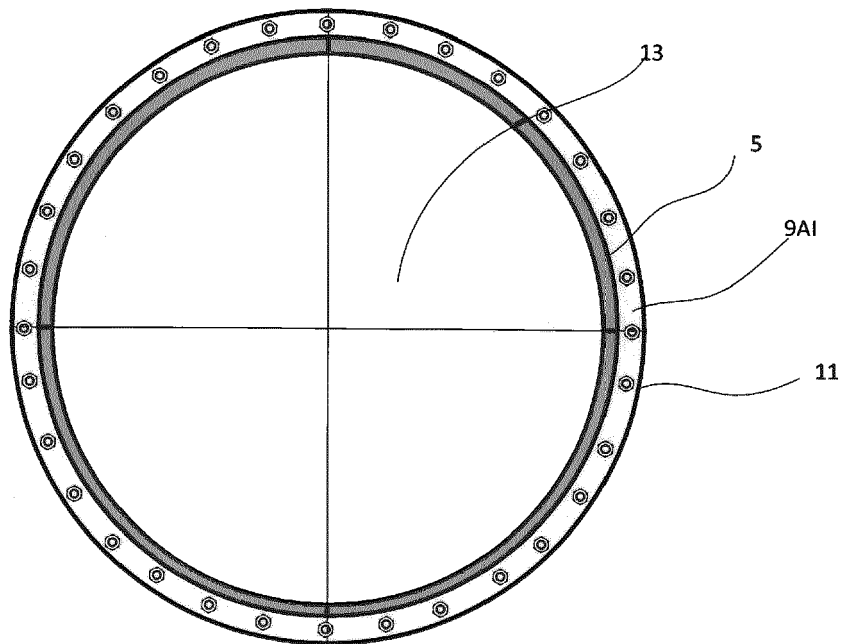


FIG. 10



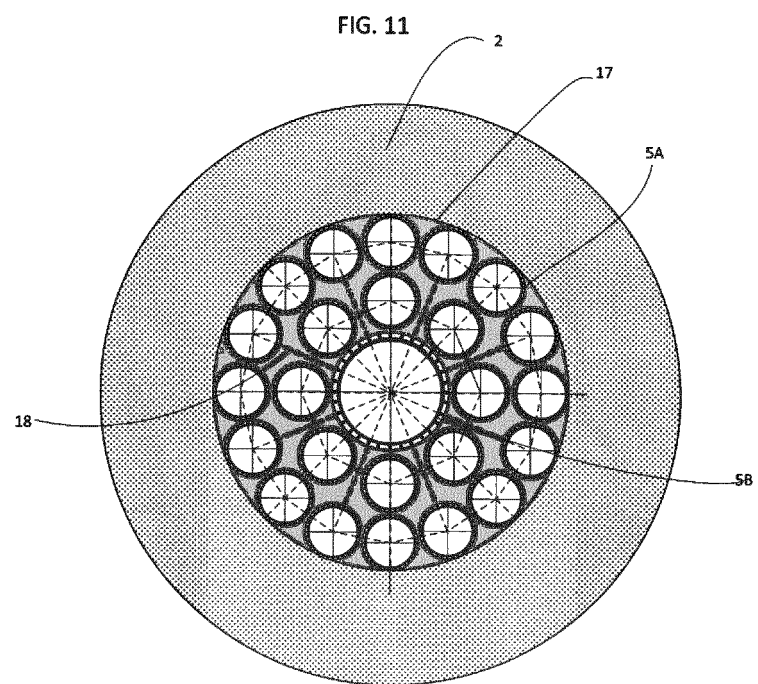


FIG. 12

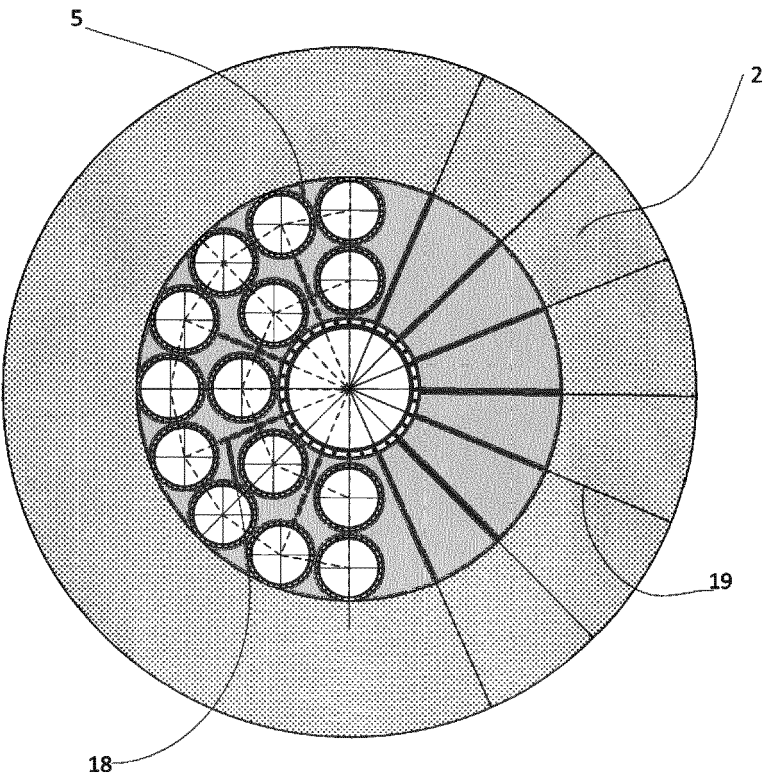


FIG. 13

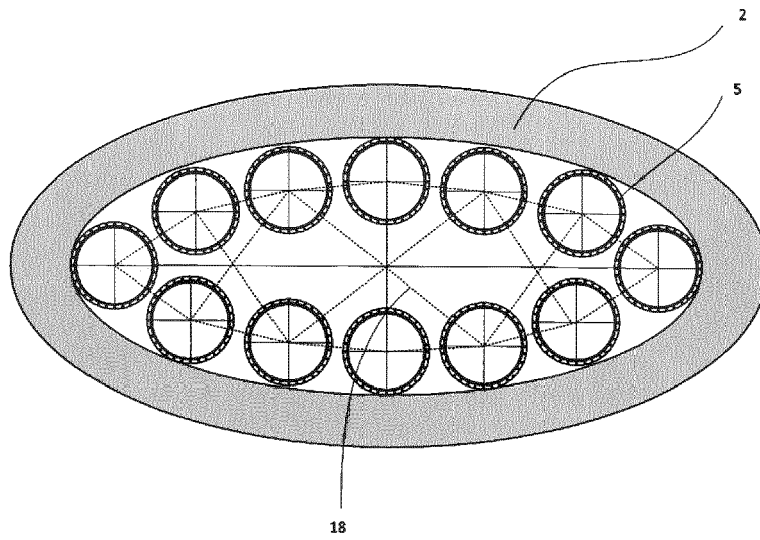


FIG. 14

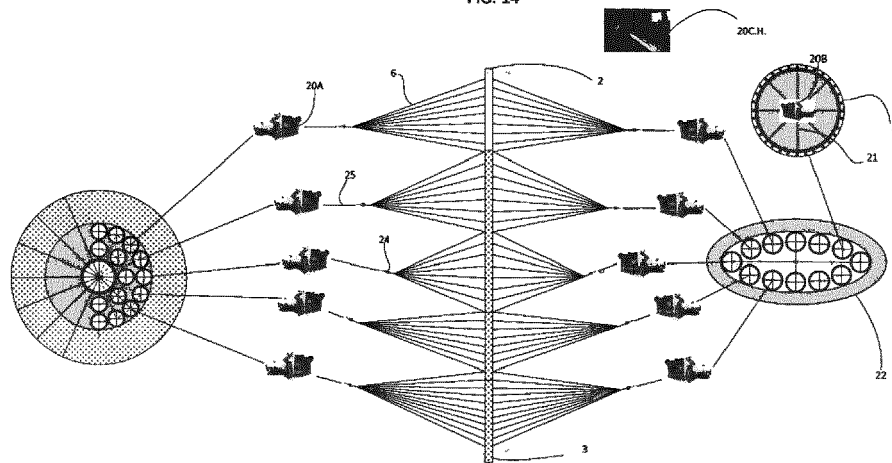


FIG. 15

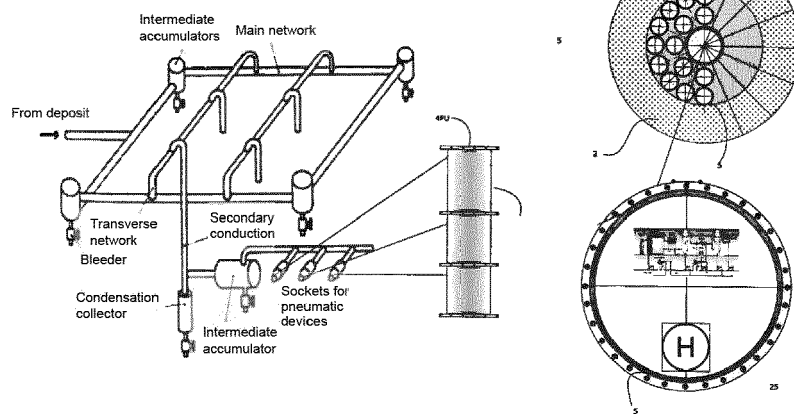
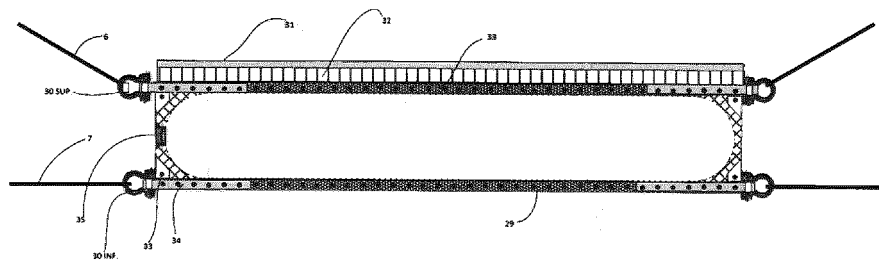
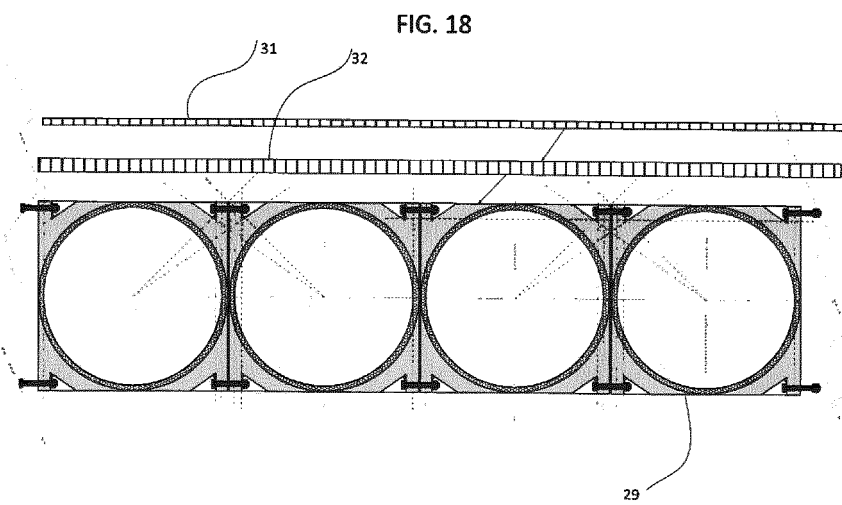
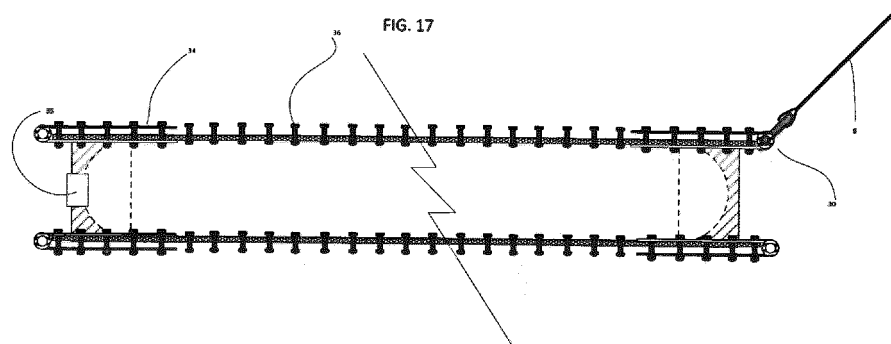


FIG. 16





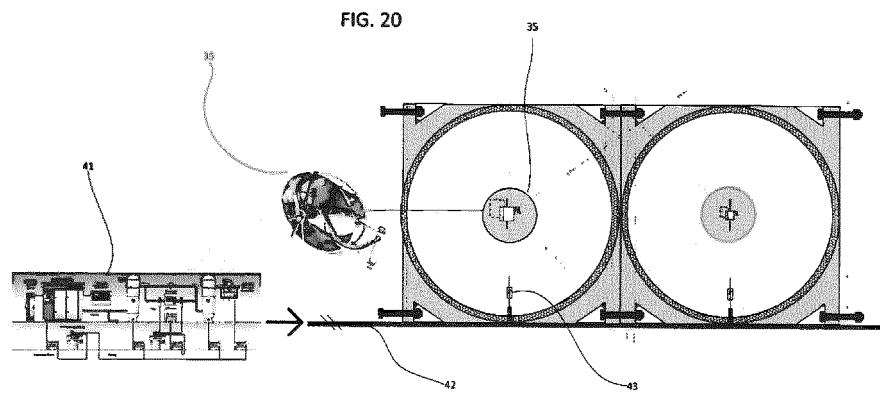
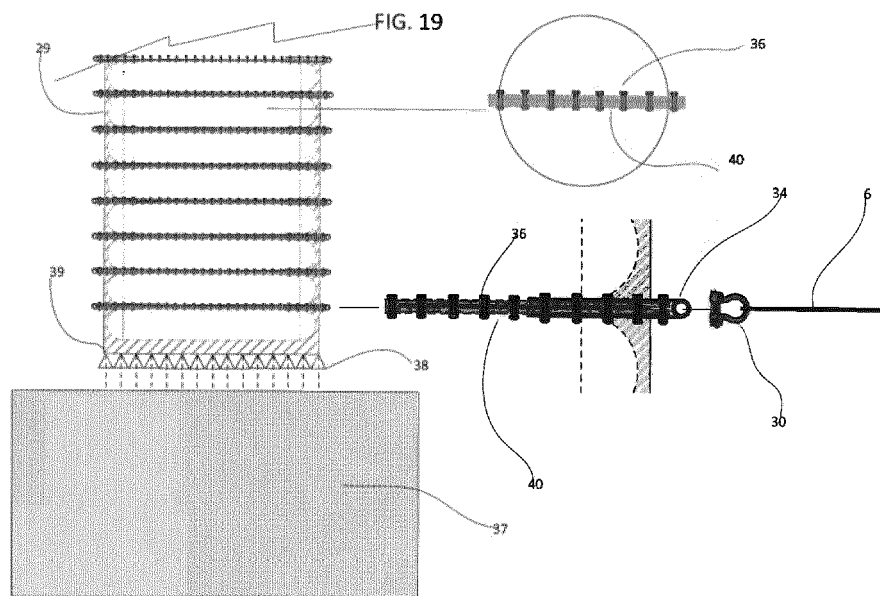


FIG. 21

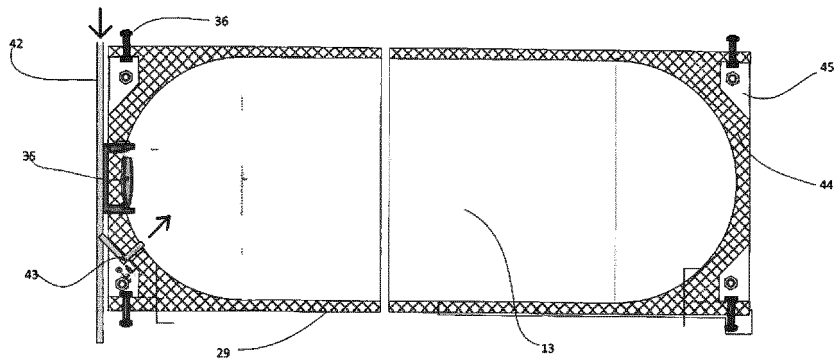
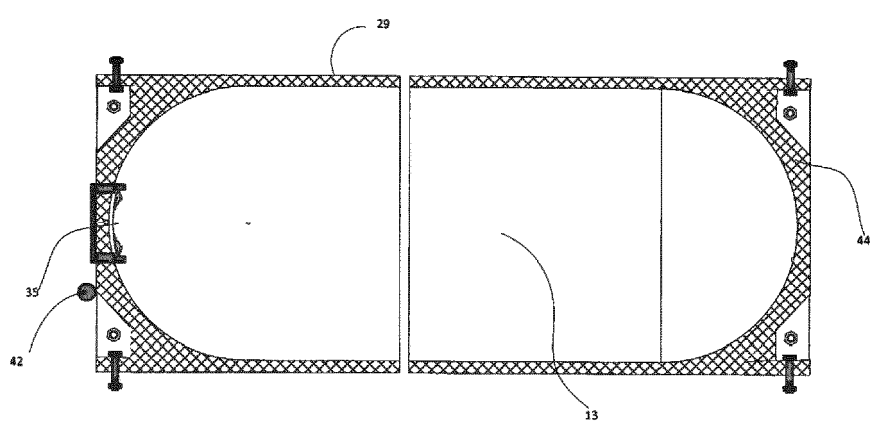


FIG. 22



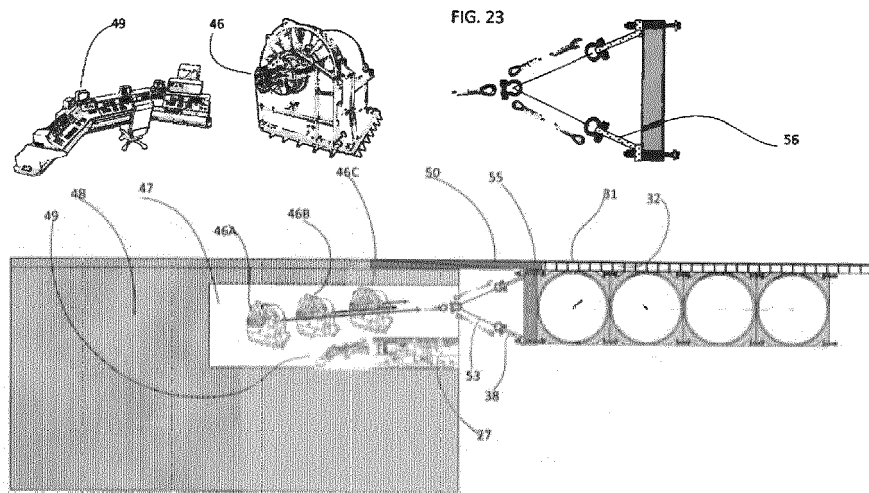
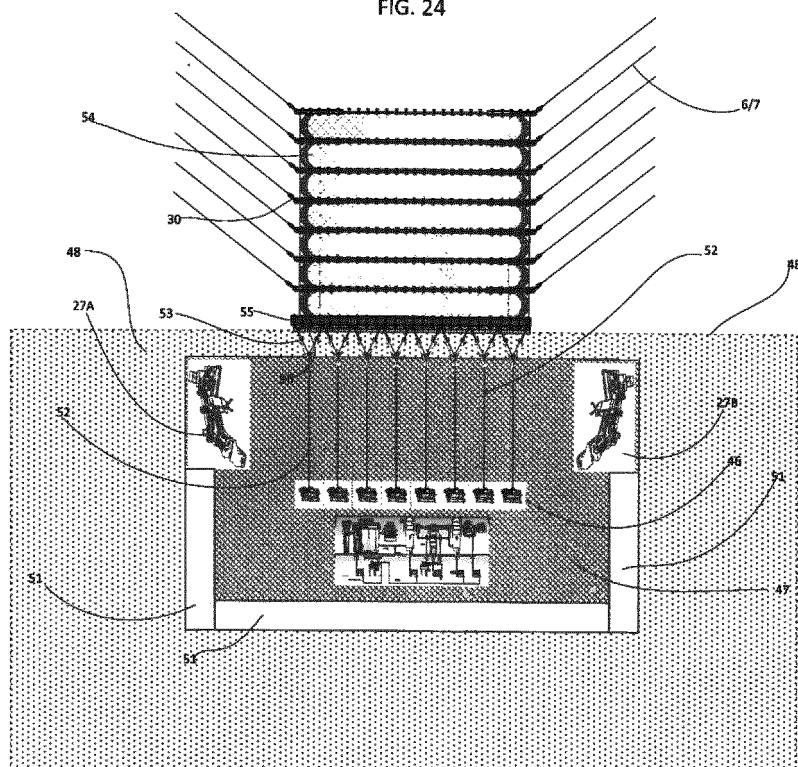
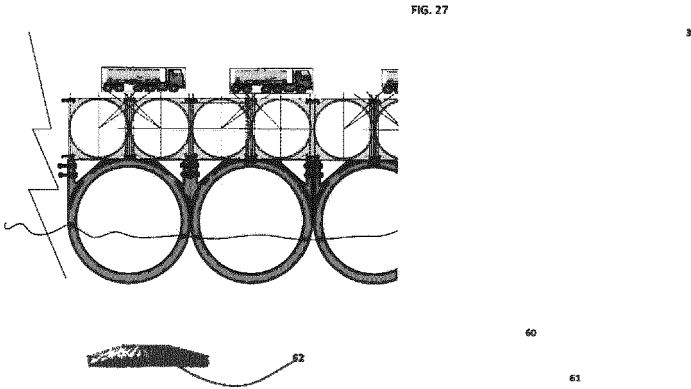
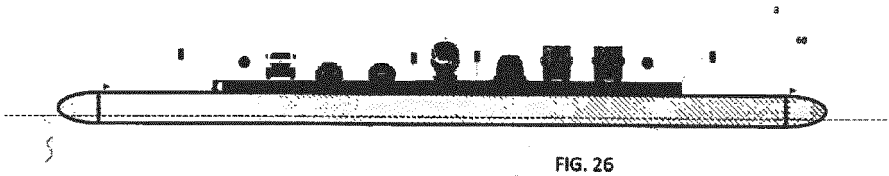
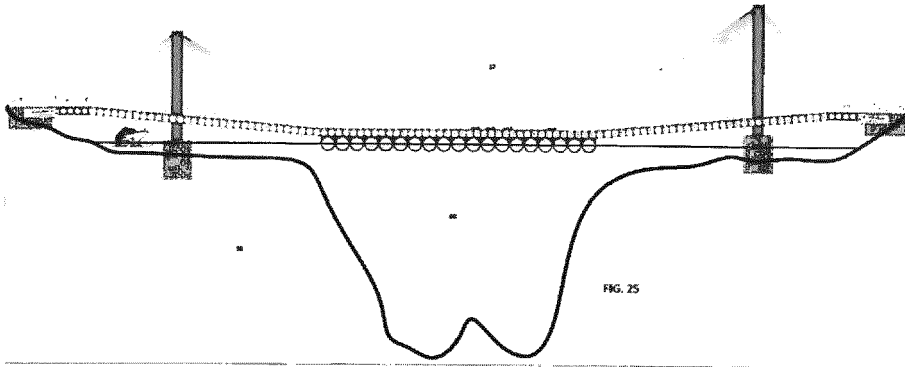


FIG. 24





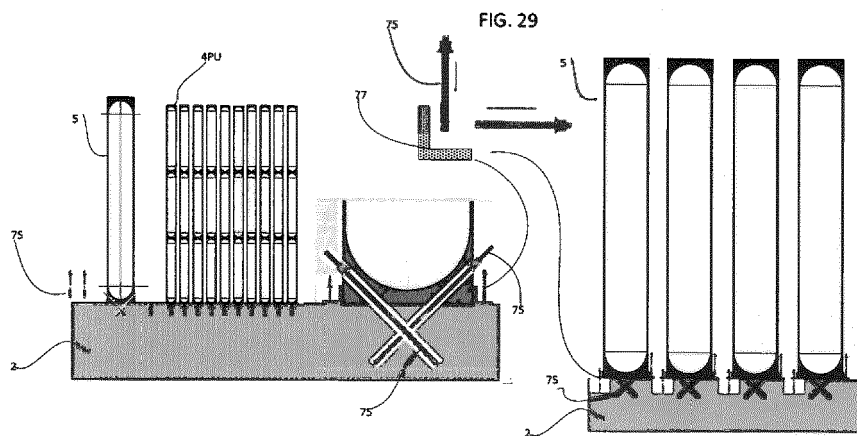
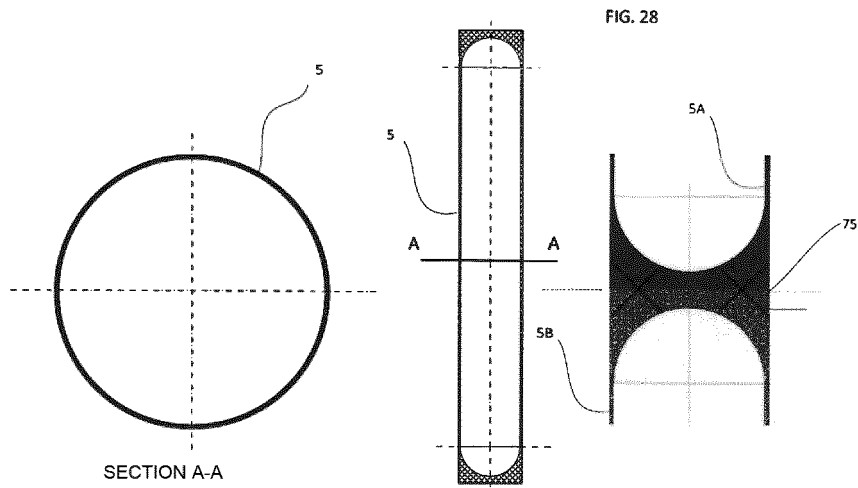


FIG. 30

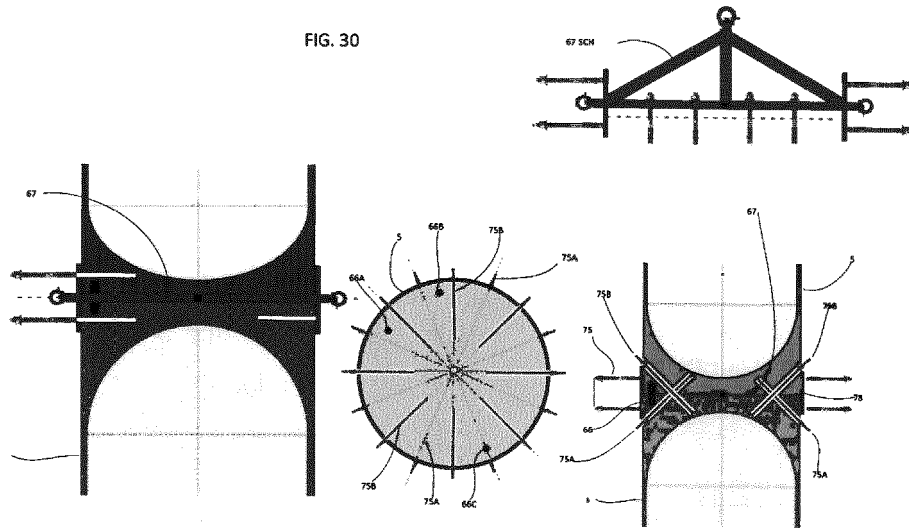
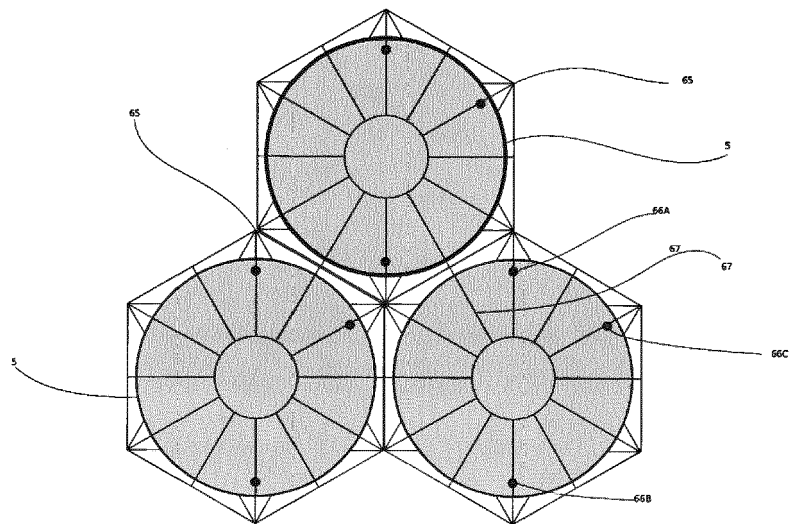
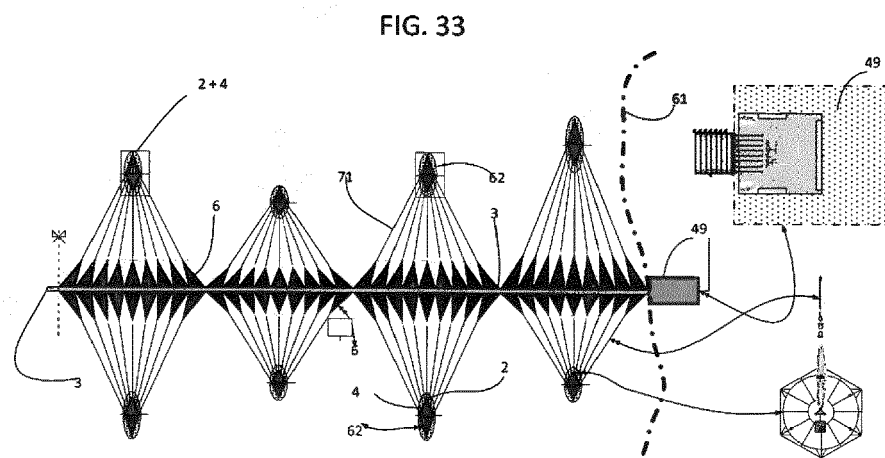
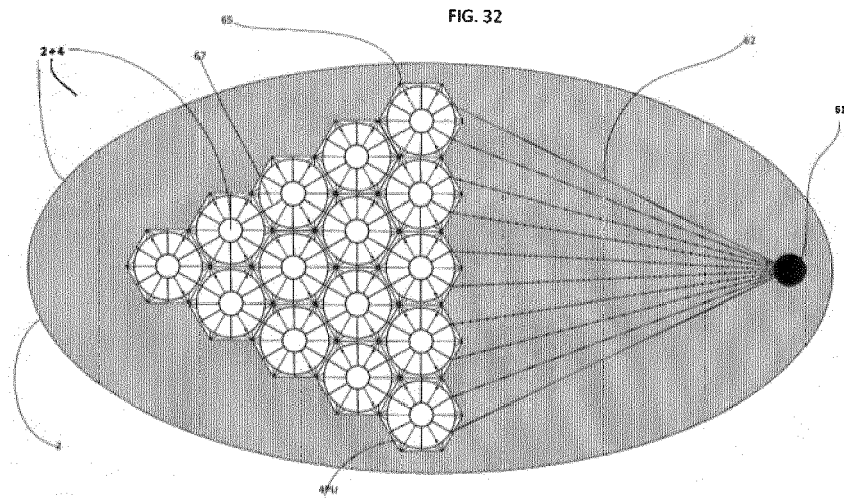
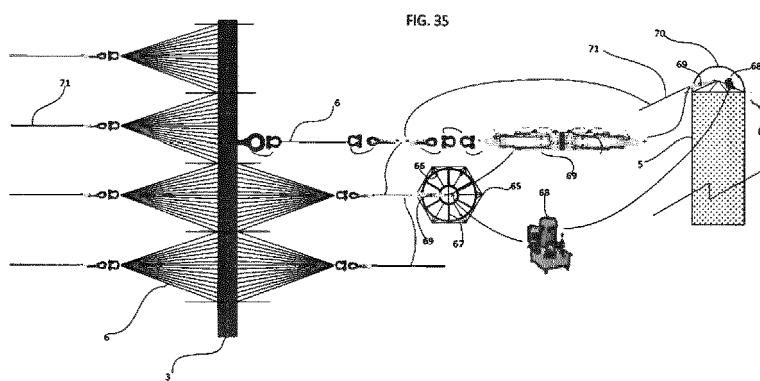
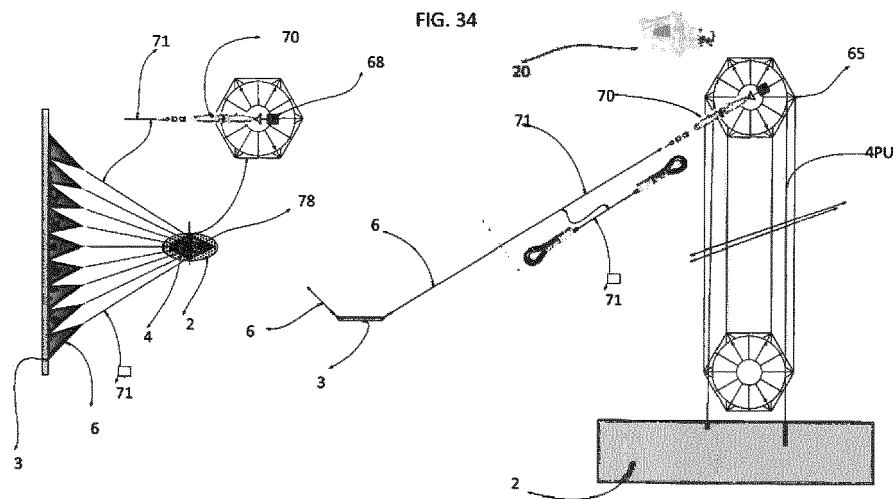


FIG. 31







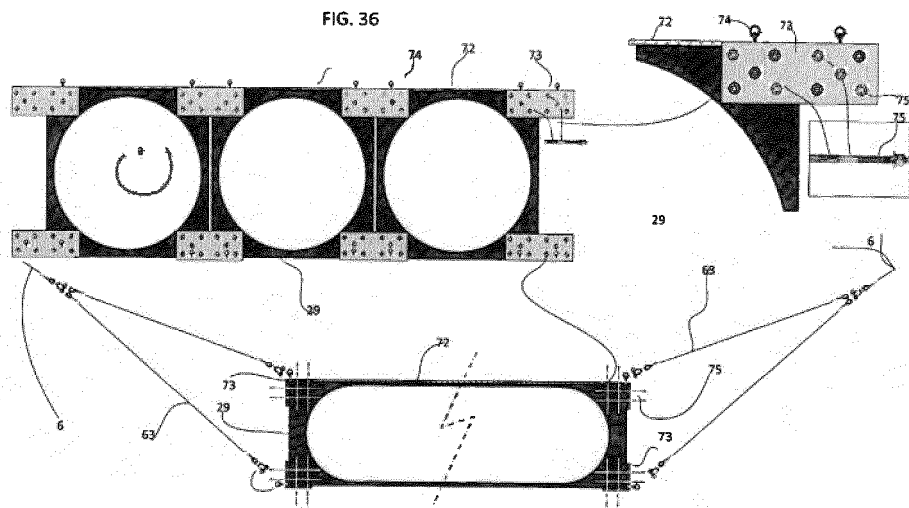


FIG. 37

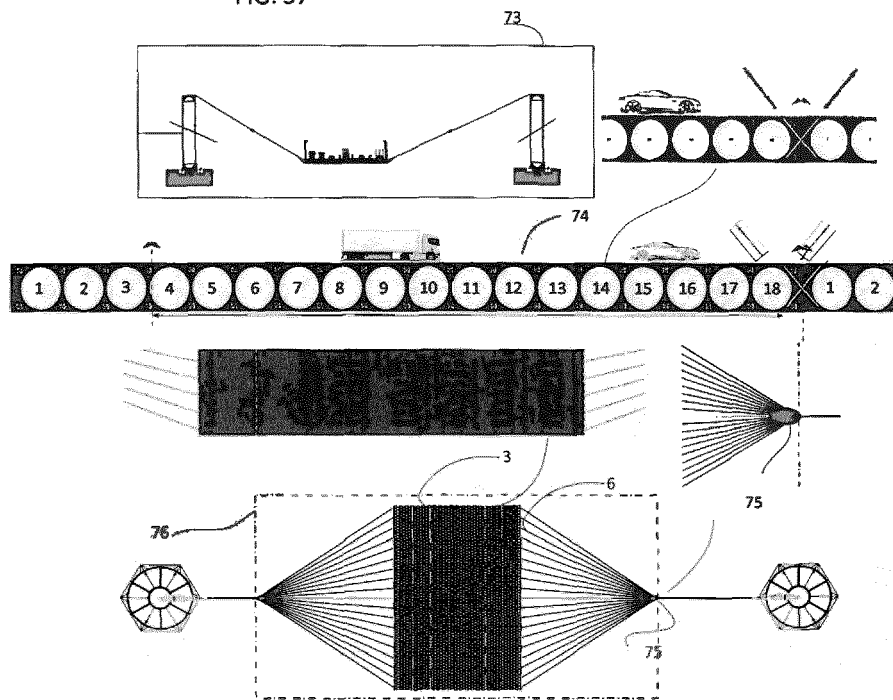
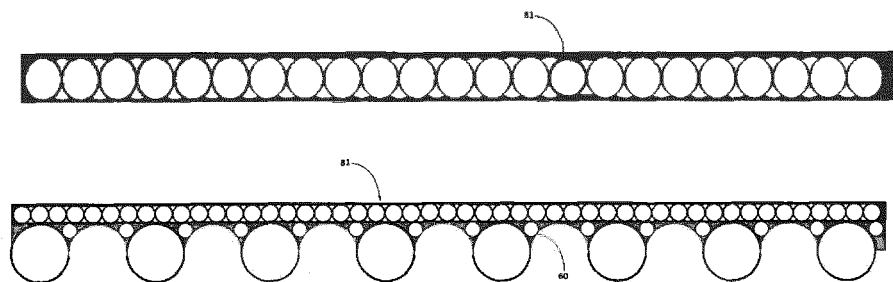


FIGURE 38



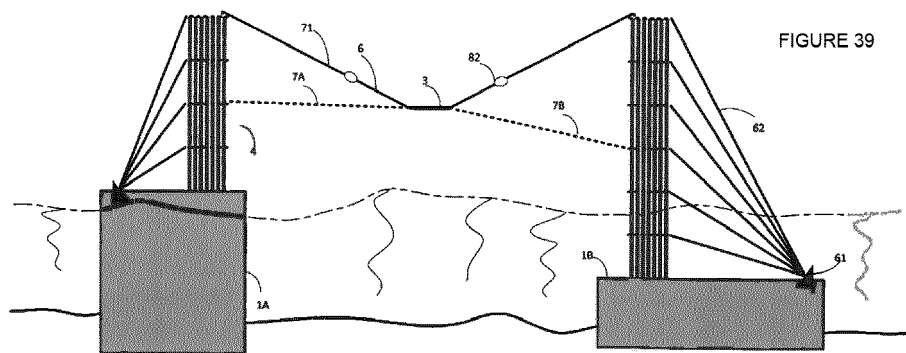
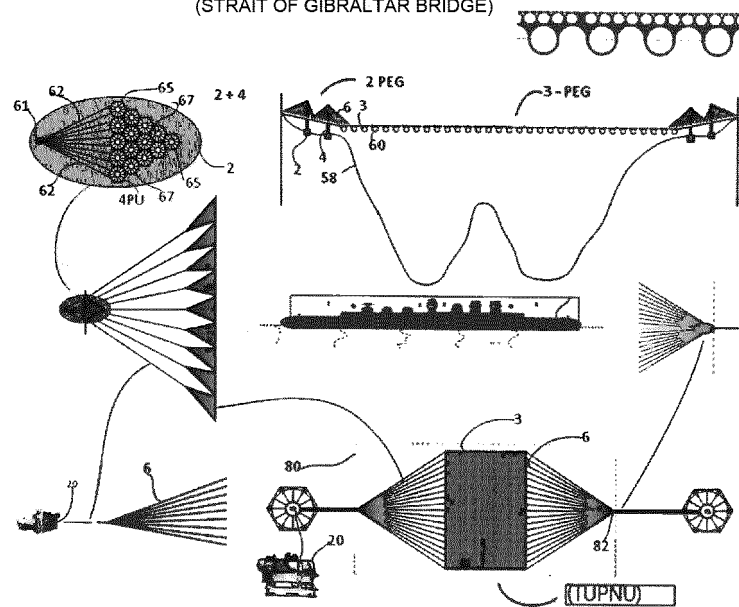


FIG. 40 - SGB
(STRAIT OF GIBRALTAR BRIDGE)





EUROPEAN SEARCH REPORT

Application Number

EP 22 02 0102

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			E01D
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 19 July 2022	Examiner Beucher, Stefan
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