US 20200332464A1

(19) United States
(12) Patent Application Publication
DUGAIN et al.
(10) Pub. No.: US 2020/0332464 A1
(43) Pub. Date: Oct. 22, 2020

(54) DOUBLE-SHEATHED STRUCTURAL CABLE

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(21) Appl. No.: **16/918,884**

(22) Filed: **Jul. 1, 2020**

Related U.S. Application Data

(63) Continuation of application No. 16/320,349, filed on Jan. 24, 2019, filed as application No. PCT/IB2016/001314 on Jul. 27, 2016.

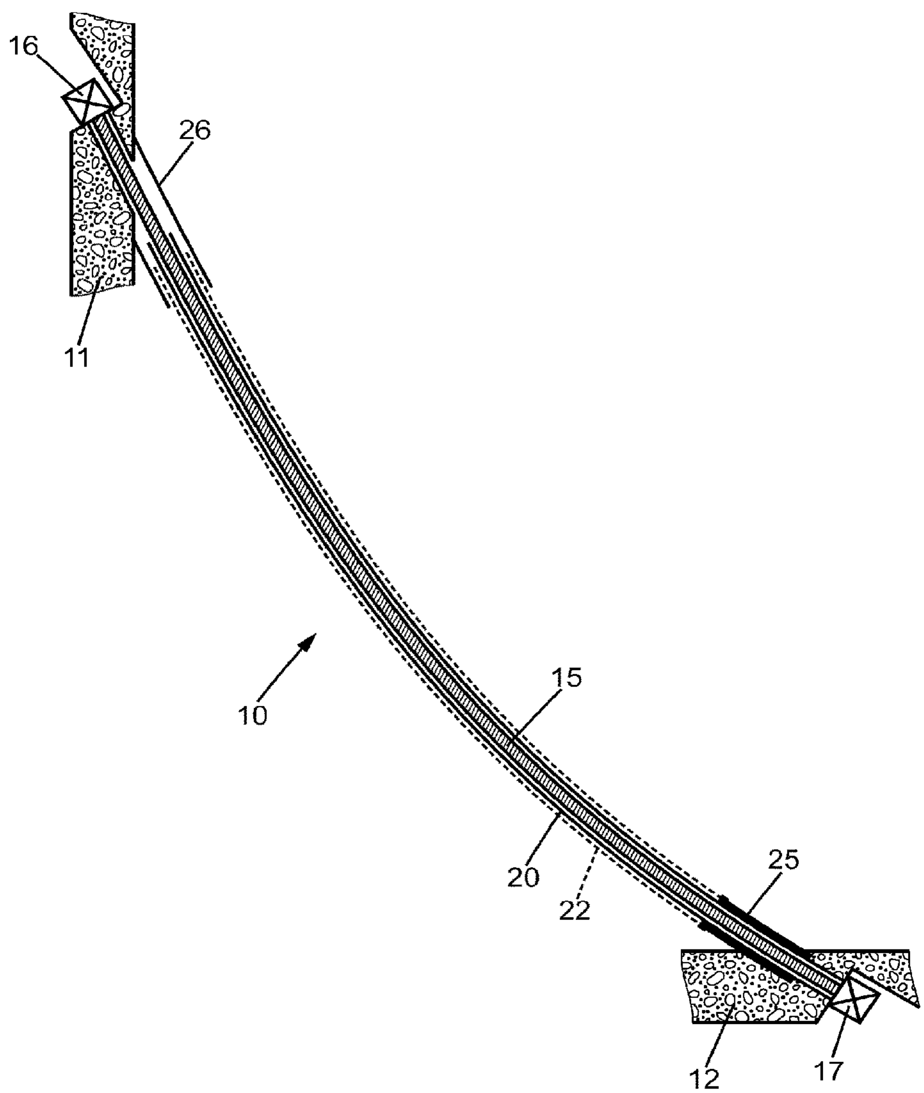
Publication Classification

(51) **Int. Cl.**
D07B 1/16 (2006.01)
D07B 1/14 (2006.01)
E01D 19/16 (2006.01)

(52) **U.S. Cl.**
CPC ***D07B 1/162*** (2013.01); ***D07B 1/148*** (2013.01); ***E01D 19/16*** (2013.01); *D07B 2201/1092* (2013.01); *D07B 2201/2086* (2013.01); *D07B 2201/2088* (2013.01); *E01D 11/04* (2013.01); *D07B 2401/202* (2013.01); *D07B 2501/203* (2013.01); *D07B 2201/2091* (2013.01); *D07B 2201/2087* (2013.01); *D07B 2201/2044* (2013.01); *D07B 2201/2094* (2013.01)

(57) **ABSTRACT**

The structural cable comprises a bundle of load-bearing tendons extending between upper and lower anchoring devices, a first sheath containing the bundle of tendons, and a second sheath arranged around the first sheath, with a gap between the first and second sheaths.



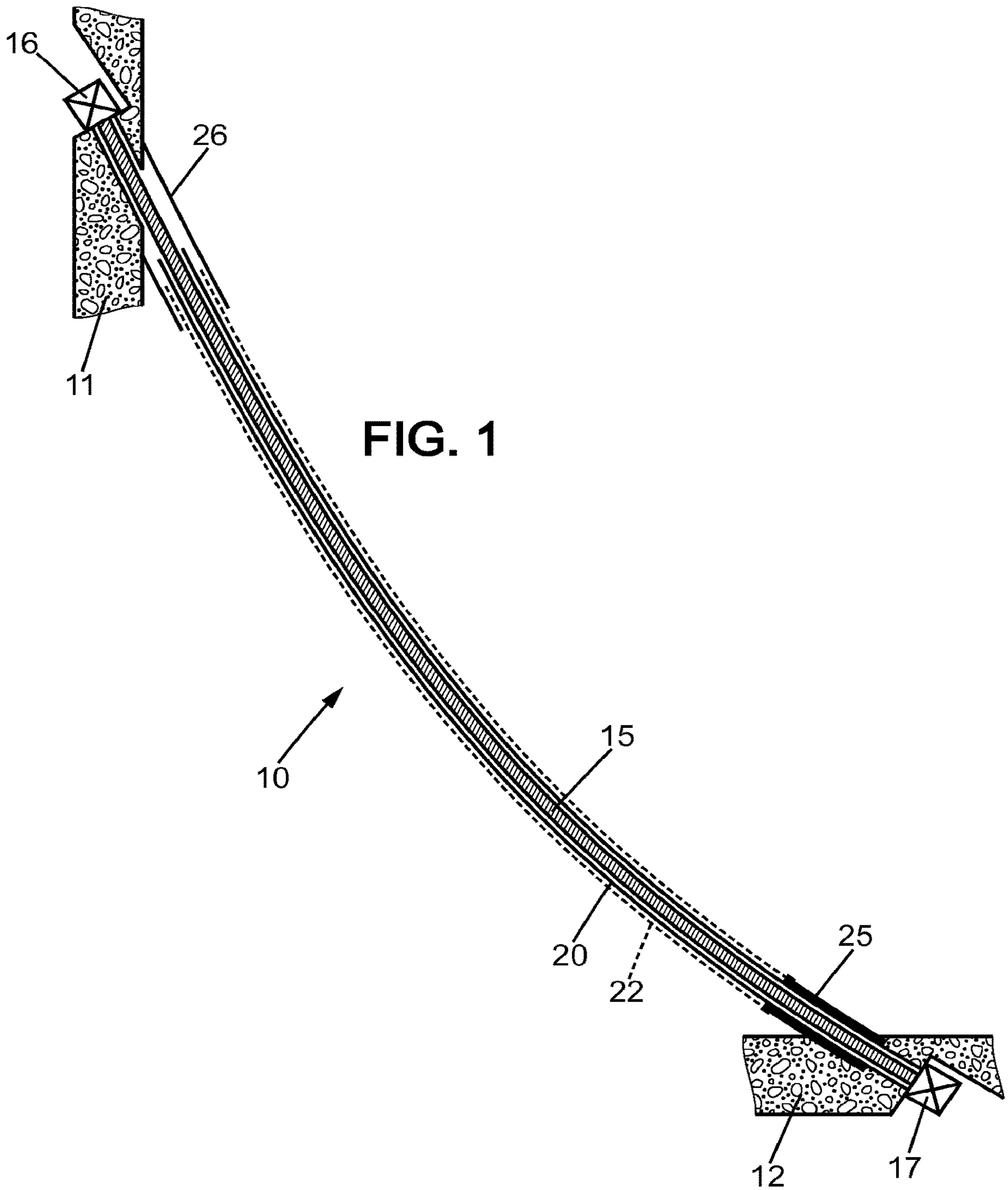
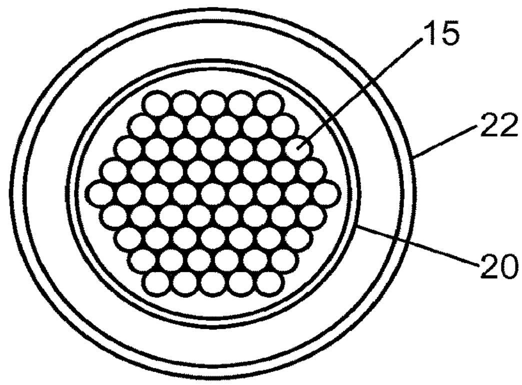


FIG. 1

FIG. 2



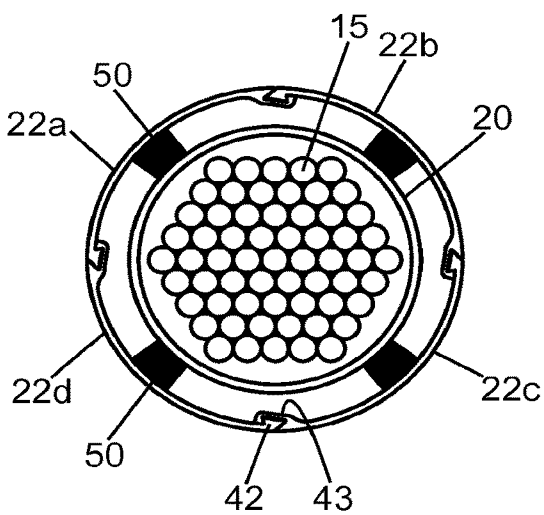


FIG. 3

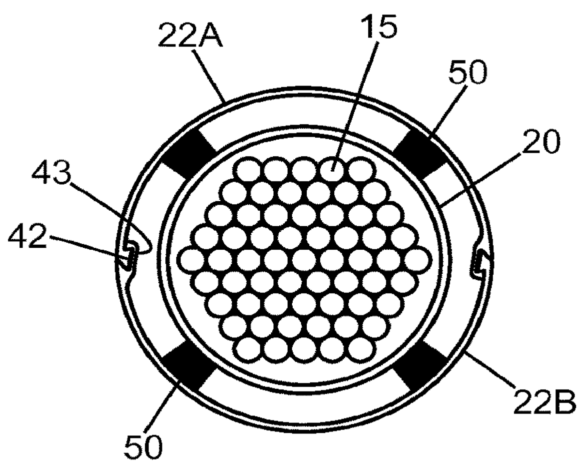


FIG. 4

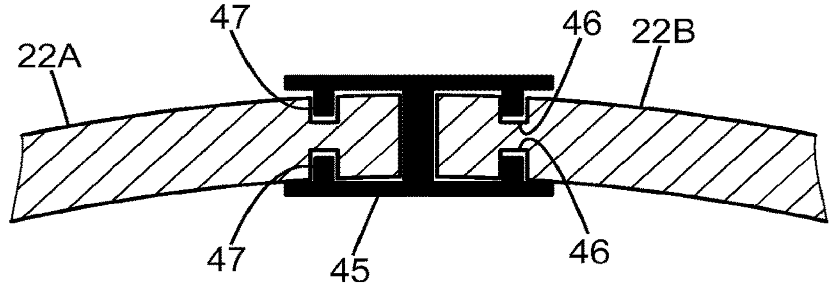


FIG. 5

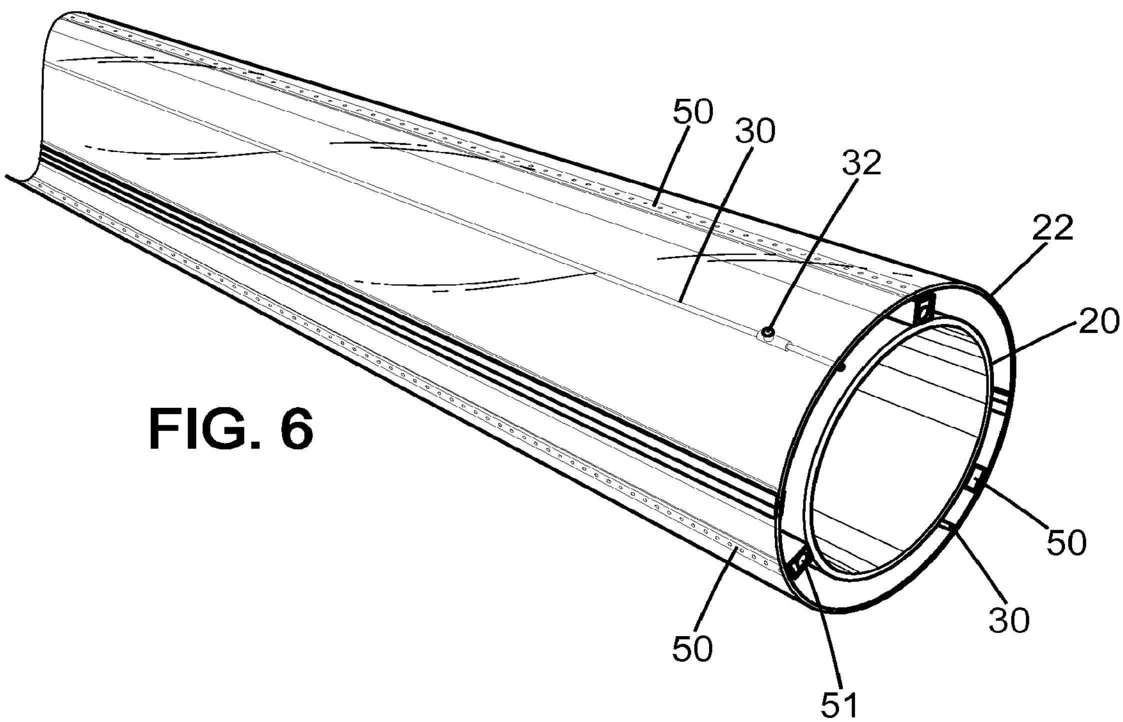


FIG. 6

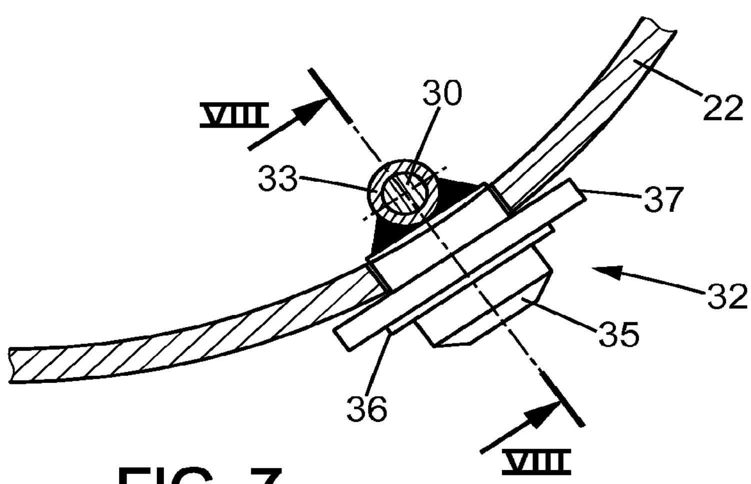


FIG. 7

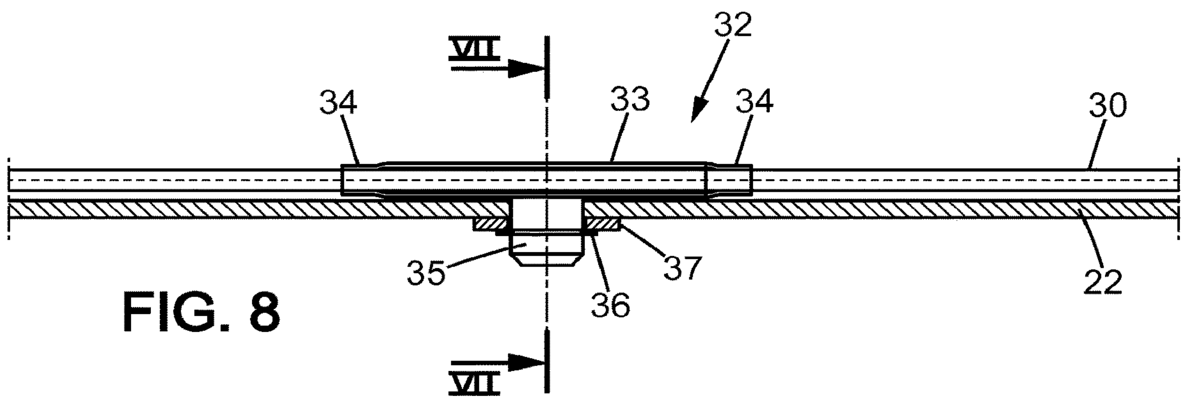


FIG. 8

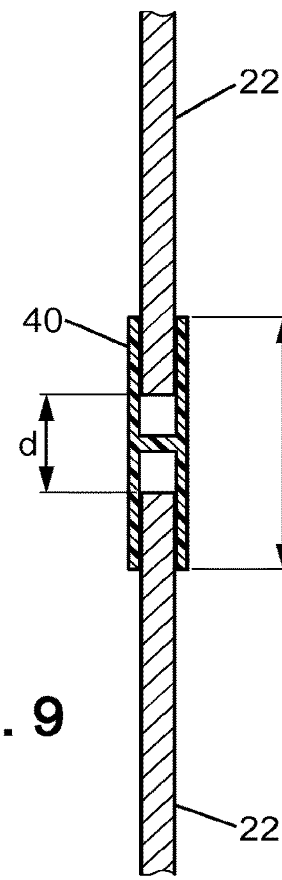


FIG. 9

DOUBLE-SHEATHED STRUCTURAL CABLE

[0001] The present invention relates to structural cables used in the construction industry. It is applicable, in particular, to stay cables used for supporting, stiffening or stabilizing structures.

BACKGROUND

[0002] Stay cables are widely used to support suspended structures such as bridge decks or roofs. They can also be used to stabilize erected structures such as towers or masts.

[0003] A typical structure of a stay cable includes a bundle of tendons, for example wires or strands, housed in a collective plastic sheath. The sheath protects the metallic tendons of the bundle and provides a smooth appearance of the stay cable.

[0004] In certain cases, the sheath is in the form of an integral tube which extends from the lower anchoring point to the upper anchoring point of the stay cable. The tendons are threaded, usually one by one or small groups by small groups, into the sheath before anchoring them at both ends. Examples illustrating such technology are described in U.S. Pat. Nos. 5,461,743 and 7,779,499.

[0005] In other cases, the sheath is made of segments following each other along the cable. Each segment can be made of several sectors assembled around the bundle of tendons. See, for example, U.S. Pat. No. 5,479,671.

[0006] An object of the present invention is to propose another kind of sheath design for structural cables.

SUMMARY

[0007] The present document discloses a structural cable of a construction work. The structural cable comprises:

[0008] a bundle of load-bearing tendons extending between upper and lower anchoring devices;

[0009] a first sheath containing the bundle of tendons; and

[0010] a second sheath arranged around the first sheath, with a gap between the first and second sheaths.

[0011] The gap between the two concentric sheaths can be advantageously used to insert some equipment, for example wiring, piping or various kinds of devices to provide more functionality in the structural cable, beyond its primary load-bearing function. Visual effects, lightning protection, fire protection can be cited as potential functionality which may be added thanks to the gap between the first and second sheaths.

[0012] In one application, light sources are arranged in the gap between the first and second sheaths, the second sheath being at least in part light-transmissive.

[0013] Typically, the second sheath extends over more than 80% of a length of the bundle of tendons between the upper and lower anchoring devices.

[0014] In an embodiment, the first sheath extends as an integral tubular member between a first end adjacent to the lower anchoring device and a second end adjacent to the upper anchoring device.

[0015] The second sheath can be configured to transmit substantially no longitudinal effort to the first sheath. Thus, addition of the second sheath does not alter significantly the mechanical behavior of the structural cable.

[0016] In addition, each segment of the second sheath can be configured to transmit substantially no longitudinal effort to an adjacent segment of the second sheath.

[0017] An embodiment of the structural cable further comprises at least one rope extending along the bundle of tendons in the gap between the first and second sheaths, the second sheath being attached to the at least one rope. The rope(s) support(s) the second sheath along the direction of the structural cable, such that the efforts between the first and second sheath are essentially transverse to the direction of the structural cable.

[0018] The second sheath may be attached to the at least one rope using fasteners each having a first part fixed to a rope and a second part protruding transversely to the rope and through a wall of the second sheath, the second part having an end outside the second sheath for receiving a removable connector.

[0019] In an embodiment, the second sheath comprises a plurality of segments assembled along the bundle of tendons, each segment being connected to the at least one rope. A joint member may be disposed between an upper end of a first segment of the second sheath and a lower end of a second segment of the second sheath adjacent to the first segment, the joint member being configured to accommodate a longitudinal displacement of the upper end of the first segment relatively to the lower of the second segment. For example, the joint member may have an H-shaped cross-section.

[0020] Each segment of the second sheath may comprise a plurality of elements assembled together around the first sheath. For example, the elements of a segment of the second sheath are assembled together by fitting a male edge of an element in a female edge of an adjacent element. Alternatively, they can be assembled together using clips holding opposing edges of adjacent elements.

[0021] Advantageously, each segment of the second sheath is at least in part removable to provide access to the gap between the first and second sheaths.

[0022] In order to minimize transversal movements of the second sheath with respect to the first sheath, spacing members may be disposed in the gap between the first and second sheaths.

BRIEF DESCRIPTION THE DRAWINGS

[0023] Other features and advantages of the structural cable disclosed herein will become apparent from the following description of non-limiting embodiments, with reference to the appended drawings, in which:

[0024] FIG. **1** is a schematic side view of a stay cable;

[0025] FIGS. **2-4** are cross-sectional schematic views of structural cables according to embodiments as disclosed herein;

[0026] FIG. **5** is an axial sectional view illustrating the assembly of two adjacent elements of a cable sheath;

[0027] FIG. **6** is a perspective view of a double sheath which may be used in embodiments as disclosed herein;

[0028] FIGS. **7** and **8** are cross-sectional views of fasteners used to hold a sheath on ropes in embodiments as disclosed herein, FIG. **7** being an axial section along direction VII-VII shown in FIG. **8**, and FIG. **8** being a radial section along direction VIII-VIII shown in FIG. **7**; and

[0029] FIG. **9** is an longitudinal sectional view illustrating the assembly of two adjacent segments of a cable sheath.

DESCRIPTION OF EMBODIMENTS

[0030] FIG. **1** shows a stay cable **10** which is a structural cable extending between two parts **11**, **12** of a construction work. The first part **11** is at a higher position than the second part **12**. For example, the first part **11** belongs to a tower, while the second part **12** belongs to a foundation to stabilize the tower. Alternatively, the first part **11** may belong to a pylon, while the second part **12** belongs to some structure suspended from the pylon **11**.

[0031] The construction work typically includes a number of stay cables **10**, only one of them being shown in FIG. **1**.

[0032] The structural cable **10** has a load-bearing part **15** which consists of a bundle of tendons disposed parallel to each other (see FIGS. **2-4**). For example, the bundled tendons may be strands of the same type as used to pre-stress concrete structures. Each strand may optionally be protected by a substance such as grease or wax and individually contained in a respective plastic sheath (not shown).

[0033] Each stay cable **10** may have a length of up to several hundred meters, and include a few tens of tendons, as illustrated in FIGS. **2-4**.

[0034] The load-bearing tendons arc anchored at both ends of the bundle **15** using an upper anchoring device **16** mounted on the first part **11** of the construction work and a lower anchoring device **17** mounted on the second part **12** of the construction work. Between the two anchoring devices **16**, **17**, the bundle of tendons **15** follows a catenary curve due to its own weight and the tensile force maintained by the anchoring devices. The anchoring devices **16**, **17** are positioned on the first and second parts **11**, **12** by taking into account the pre-calculated catenary curve of each stay cable **10**.

[0035] The bundle of tendons **15** is contained in a first protective sheath **20** which is surrounded by a second sheath **22**. Both sheaths **20**, **22** are typically made of plastic material. The materials of the two sheaths may be different from each other.

[0036] The first and second sheaths **20**, **22** are spaced apart from each other, so that there is a gap between them. In the example shown, both sheaths **20**, **22** have a circular cross-section and are arranged substantially concentric to each other along the bundle of tendons **15**. Therefore, the cross-section of the gap has an annular shape.

[0037] In order to facilitate the design and the mounting of the structural cable **10**, the first sheath **20** may consist of an integral tubular member extending between a first end adjacent to the lower anchoring device **17** and a second end adjacent to the upper anchoring device **16**. The bundle of tendons **15** and the first sheath **20** can then be installed according to a conventional method, for example as described in U.S. Pat. Nos. 5,461,743 or 7,779,499.

[0038] In the example illustrated in FIG. **1**, the first end of the first sheath **20** bears on a guide tube **25** through which the bundle of tendons **15** passes near the lower anchoring device **17**, while the second end of the first sheath **20** penetrates into another tube **26** disposed on the first part **11** of the construction work, through which the upper end of the bundle of tendons **15** passes to reach the upper anchoring device **16**. The second end of the first sheath **20** is not connected to the tube **26**, so that it can slide therein when the tendons **15** and the sheath **20** undergo different expansion or contraction on account of the thermal expansion coefficients of their materials. The arrangement prevents run off water from flowing inside the first sheath **20**.

[0039] The weight of the plastic sheath **20** is taken up by some transverse effort on the bundle of tendons **15**, and mainly by an axial effort on the guide tube **25**. Alternatively, the first sheath **20** may be suspended from the first part **11** of the construction work near the upper anchoring device **16**, with a buffering arrangement near the lower end of the stay cable to accommodate for the different thermal expansion behaviors.

[0040] The second sheath **22** is mounted around the first sheath **20** so as to be, to a large extent, mechanically independent from the first sheath **20**. In other words, the second sheath **22** is configured to transmit substantially no longitudinal effort to the first sheath **20**.

[0041] Such independence of the second sheath **22** can be achieved by attaching the second sheath **22** to one or more ropes **30** extending along the bundle of tendons **15** in the gap between the first and second sheaths **20**, **22**, using an arrangement as illustrated in FIGS. **6-8**.

[0042] FIG. **6** shows the two concentric sheaths **20**, **22** with a pair of ropes **30** arranged in the gap at diametrically opposed positions. It will be appreciated that there can be only one rope, or more than two ropes. Each rope **30** can be made of metallic wires and have its two ends connected to the first and second parts **11**, **12** of the construction work using respective anchoring devices (not shown).

[0043] The wire ropes **30** are arranged near the inner surface of the outer sheath **22**, to which they are attached via fasteners **32** distributed along the length of the stay cable. Each fastener **32** (FIGS. **7-8**) has a sleeve part **33** in which the wire rope **30** is threaded and having swaged ends **34** for fixing the sleeve part **33** to the rope **30**. The fastener **32** also includes a rod part **35** protruding transversely from the sleeve part **33** and the rope **30**. To attach the second sheath **22** to the wire rope **30**, the rod part **35** is inserted in a hole formed in the wall of the second sheath **22**, and a removable connector **36** is received at the end of the rod part **35** outside the sheath **22**. In the example shown, the removable connector **36** is a circlip engaging an annular groove of the rod part **35**, a washer **37** being placed between the wall of the second sheath **22** and the circlip **36**. Other connectors such as locking pins can be used.

[0044] The wire ropes **30** and the fasteners **32** hold each segment of the second sheath **22** such that the weight of each segment of the second sheath **22** does not translate into longitudinal efforts applied on the first sheath **20** or the bundle of tendons **15**, and is not applied on an adjacent segment of the second sheath **22**.

[0045] FIG. **6** shows one segment of the second sheath **22**. In an embodiment, a plurality of such segments are assembled along the structural cable **10**. Each segment, having a length of 3 to 10 m, for example, is connected to the wire ropes **30** stretched between the two sheaths **20**, **22** by means of fasteners **32**.

[0046] Joint members **40** are disposed between the segments of the second sheath **22** to ensure their proper alignment while allowing some relative longitudinal displacement of the axial ends of adjacent segments.

[0047] A possible configuration of such a joint member **40** is shown in FIG. **9**. In this case, the joint member **40** has an annular shape with a diameter adapted to that of the second sheath **22**, and an H-shaped cross-section. The H-shaped joint member **40** has two opposite annular openings, one receiving the upper end of a first segment of the second sheath **22**, and the other one receiving the lower end of a second segment of the second sheath adjacent to the first segment.

[0048] When installing the second sheath **22**, a spacing d is left between the axial ends of the adjacent segments. The spacing d and the axial length D of the joint member **40** are selected depending on the length of the sheath segments and the thermal expansion coefficients of the plastic material of the sheath **22** and of the metal of the wire rope **30**, so that the axial ends of the adjacent segments remain held in the openings of the H-shaped joint member **40** when the stay cable undergoes temperature variation in the relevant range for the construction work. The temperature range is typically 50° C. or more.

[0049] In another configuration, the upper end of a sheath segment overlaps the lower end of the sheath segment located just above it, for example as described in U.S. Pat. No. 5,479,671. Thus, a tulip-shaped overlap joint is formed between the two adjacent segments. In case the second sheath **22** is not flexible or ductile enough, a space is provided between the female and male parts of this tulip-shaped overlap joint to allow some telescoping movement of the two sheath segments so as to accept some thermal expansion and rotation of the sheath segments.

[0050] A segment of the second sheath **22** may consist of an integral piece of tube, as illustrated in FIG. **2**.

[0051] Alternatively, the segment may consist of a plurality of sector-shaped elements assembled together around the first sheath **20**. In the illustration of FIG. **3**, there are four elements **22***a*, **22***b*, **22***c*, **22***d* each having a cross-section in the form of a 90° sector. In the illustration of FIG. **4**, there are two elements **22**A, **22**B each having a cross-section in the form of a 180° sector. Those elements are assembled together by fitting the male edge **42** of an element in the female edge **43** of an adjacent element.

[0052] Another way of assembling sheath elements is illustrated in FIG. **5**. Here, the elements **22**A, **22**B of a segment of the second sheath **22** are assembled using clips **45** holding opposing edges of adjacent elements.

[0053] In the example of FIG. **5**, each sheath element **22**A, **22**B has longitudinal grooves **46** next to its longitudinal edges, one on each face. The clip **45** has a generally H-shaped cross-section, with each half fitted on the longitudinal edge of a sheath element **22**A, **22**B. The profile of the clip **45** also has inner dogs or ribs **47** engaging the longitudinal grooves **46** of the sheath element **22**A, **22**B to secure the elements in position.

[0054] As shown in FIGS. **3** and **4**, spacing members **50** may be disposed in the gap between the first and second sheaths **20**, **22**, in order to limit transversal movement of the second sheath **22** with respect to the first sheath **20**. The spacing members **50** may have elastic or viscoelastic properties. They can be fixed to the first sheath **20**, the second sheath **22**, or both.

[0055] When the designer of the construction work takes advantage of the gap between the first and second sheaths **20**, **22** to add some functional element to the stay cable, that functional element may, if appropriate, play the role of a spacing member **50**.

[0056] In the embodiment illustrated by FIG. **6**, the second sheath **22** is made of a transparent plastic material, and light sources are disposed in the gap between the first and second sheaths **20**, **22**. The light sources are, for example, light-emitting diodes (LEDs) arranged along strips **50**. Each strip **50**, mounted on a profile **51** fixed on the outside of the first sheath **20**, plays the role of a spacing member.

[0057] Making the second sheath **22** of a transparent plastic material offers a variety of options to add architectural features to the cabled suspension of the construction work. Ornamental or colored patterns can be inserted to give a distinctive appearance to the construction work. In particular, light patterns can be created using LEDs or other kinds of sources.

[0058] More generally, the second sheath **22** may be made of a light-transmissive material, e.g. transparent, translucent, with or without color filters, etc. The light-transmissive property can be provided on the whole surface of the second sheath **22**, or only on part of it, for example where rows of light sources are disposed.

[0059] If it is desired for maintenance purposes, the annular gap between the first and second sheaths **20**, **22** can be made accessible from the outside by the arrangement of the segments making up the second sheath **22**. The elements forming the sheath segments are removable to provide the access to the gap. This can be done by removing the connectors **36** of the fasteners **32** (FIGS. **7**-**8**) and using flexibility of the materials of the joint members **40** (FIG. **9**) and/or clips **45** (FIG. **5**) to extract the element. The joint members **40** and/or clips **45** may have a removable part on the outside to facilitate dismounting of a sheath element when needed.

[0060] The fact that the second sheath **22** is made independent of the first sheath **20** and the bundle of tendons **15** regarding longitudinal efforts ensures that an element of the second sheath **22** can be temporarily removed to have access to the gap without causing problems.

[0061] During the lifetime of the construction work, maintenance or replacement of part or all of the structural tendons within the bundle **15** and the first sheath **20** may have to be undertaken. When the proposed double sheath arrangement is used, such maintenance or replacement can be carried out without any interference with the second sheath **22** and associated equipment.

[0062] In some cases, the second sheath **22** may cover only a portion of the running part of the structural cable **10**. However, it will generally be preferred to install it over the whole running part. It is not practical to have the second sheath **22** extended all the way to the anchoring devices **16**, **17**. Also, the second sheath **22** may have to be interrupted at places if some of the cables are connected together by vibration damping devices as described, e.g., in U.S. Pat. No. 7,631,384 or application US 2015/113744 A1. Where such damping devices are provided, adjacent sheath segments are spaced apart at the level of their fixing collars, and the ropes **30** should pass through or around the collars to properly hold the second sheath **22**. Overall, the cable portions not covered by the second sheath **22** are minimized. Typically, the second sheath **22** extends over more than 80% of the length of the bundle of tendons **15** between the anchoring devices **16**, **17**, or even more than 90% for long stay cables.

[0063] In the configuration diagrammatically illustrated by FIG. **1**, the upper end of the second sheath **22** is located within the upper tube **26** mounted on the first part **11** of the construction work, so that it is not visible and run off water is prevented from flowing inside the second sheath **22**.

[0064] To ensure good dynamic properties of the stay cable **10**, it is preferable to give the second sheath **22** a regular profile, typically with a circular cross-section. The second sheath **22** may also be provided with specific surface structure, known in the art, e.g. double helical ribs, to improve its behavior in the presence of a combined action of rain and wind.

[0065] It will be appreciated that the embodiments described above are illustrative of the invention disclosed herein and that various modifications can be made without departing from the scope as defined in the appended claims.

[0066] For example, the invention is applicable to structural cables other than stay cables.

1-7. (canceled)

8. A structural cable of a construction work, the structural cable comprising:

a bundle of load-bearing tendons extending between upper and lower anchoring devices, the outer sheath being made of at least one segment having a cross-section formed of an integral piece of tube;

an outer sheath containing the bundle of tendons; and

light sources arranged within a cross-sectional profile of the outer sheath so as to radiate light out of the structural cable.

9. The structural cable as claimed in claim **8**, wherein the sheath extends over more than 80% of a length of the bundle of tendons between the upper and lower anchoring devices.

10. The structural cable as claimed in claim **8**, further comprising an inner sheath concentrically arranged with the outer sheath, wherein the bundle of tendons is inside the inner sheath, wherein the outer sheath is at least in part light-transmissive, and wherein the light sources are arranged in a gap between the inner and outer sheaths.

11. The structural cable as claimed in claim **10**, wherein the outer sheath is configured to transmit substantially no longitudinal effort to the inner sheath.

12. The structural cable as claimed in claim **10**, further comprising at least one rope extending along the bundle of tendons in the gap between the inner and outer sheaths, wherein the outer sheath is attached to the at least one rope.

13. The structural cable as claimed in claim **12**, wherein the outer sheath comprises a plurality of segments assembled along the bundle of tendons, each segment being connected to the at least one rope.

14. The structural cable as claimed in claim **13**, wherein each segment of the outer sheath is configured to transmit substantially no longitudinal effort to an adjacent segment of the outer sheath.

15. The structural cable as claimed in claim **13**, further comprising a joint member disposed between an upper end of a first segment of the second sheath and a lower end of a second segment of the second sheath adjacent to the first segment, wherein the joint member is configured to accommodate a longitudinal displacement of the upper end of the first segment relatively to the lower of the second segment.

16. The structural cable as claimed in claim **8**, wherein the outer sheath has transparent portions where the light sources are disposed.

17. The structural cable as claimed in claim **8**, wherein the profile of the outer sheath has a circular cross-section.

18. The structural cable as claimed in claim **8**, wherein the outer sheath is provided with a surface structure to improve a behavior of the structural cable in the presence of a combined action of rain and wind.

* * * * *