



(11) **EP 3 452 663 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
07.10.2020 Bulletin 2020/41

(21) Application number: **17732217.9**

(22) Date of filing: **03.05.2017**

(51) Int Cl.:
E02D 1/02 (2006.01)

(86) International application number:
PCT/IB2017/052551

(87) International publication number:
WO 2017/191564 (09.11.2017 Gazette 2017/45)

(54) **MONITORING APPARATUS**

VORRICHTUNG ZUR 2D/3D-ÜBERWACHUNG VON GEOTECHNISCHEN, GEOLOGISCH-STRUKTURELLEN, HYDROGEOLOGISCH UND GEOPHYSISCHE PARAMETERN VON BÖDEN, GESTEIN UND STRUKTUREN IM ALLGEMEINEN

APPAREIL DE SURVEILLANCE 2D/3D DE PARAMÈTRES GÉOTECHNIQUES, GÉOLOGIQUES-STRUCTURAUX, HYDROGÉOLOGIQUES ET GÉOPHYSIQUES DE SOLS, DE ROCHES ET DE STRUCTURES EN GÉNÉRAL

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **05.05.2016 IT UA20163182**

(43) Date of publication of application:
13.03.2019 Bulletin 2019/11

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Description

[0001] The present invention relates to an apparatus for monitoring geotechnical, geological-structural, hydrogeological and geophysical parameters of soils, rocks and structures in general and more generally of works of geotechnical, mining and structural engineering in general, which apparatus comprises:

two or more rigid housing elements, at least one sensor for at least one parameter to be monitored being mounted into at least one of them;
 which at least two or more rigid housing elements are arranged in sequence one behind the other along a predetermined line or a predetermined axis, a deformable connection element being interposed between each rigid housing element and the immediately following one;
 which sensors communicate with means collecting output signals from said sensors that can be mounted in the apparatus or in a separate remote station;
 and at least a part of said rigid elements is provided with members removably locking in position the apparatus cooperating with the walls of a borehole drilled in the soil to be monitored.

[0002] Systems of such type are known in prior art.

[0003] A first apparatus of such type is described in document IT0001323688 with 19.10.2000 as filing date.

[0004] The document discloses a monitoring apparatus or, even better, a link of measurement modules to be inserted in the soil and which apparatus is intended to monitor many different geological, geotechnical, hydraulic and geophysical conditions.

[0005] As regards the base structure, many improvements and changes have been made during the years to the original apparatus described in the patent n. 0001323688 and intended to improve system performance and to reduce production costs.

[0006] In order to face at best many and different conditions where monitoring can be performed and in order to allow the apparatuses to be quickly removed from the soil for recovering, reusing or maintenance of instruments, improvements have been made described in documents IT001346408 of 09.09.2003, in document EP1664486B1 of 02.09.2004, in document IT0001405009 and in document IT0001405010 both of 18.04.2011, from which European Patent Application EP 2 514 916 A2 discloses the preamble to claim 1.

[0007] Such documents disclose the introduction of specific connection joints for two basic arrangements that can be used alternately depending on the type of monitoring and on the degree of freedom required and that mainly are an arrangement intended to detect displacements among the individual rigid elements interconnected with each other by flexible joints, two-dimensional or three-dimensional ones.

[0008] From such improvements derive specific 2D

(two-dimensional monitoring) monitoring columns and 3D in the market as DMS® (Differential Monitoring of Stability). Precisely DMS® 2D monitoring columns are used to monitor landslides and to monitor displacements on X, Y plane while DMS® 3D columns, particularly those with multipacker coupling devices, are used for monitoring geotechnical engineering parameters together with geotechnical engineering works and allow displacements in three-dimensional space to be monitored (x, y and z monitoring). With reference to the specific field of use, z axis defines a vertical direction or anyway oriented in the direction of a borehole where the apparatus is inserted, while x,y define two axes that subtend a plane perpendicular to said z axis and that, when z axis coincides with the vertical direction, is a horizontal plane.

[0009] Figures 1.1, 1.2, 1.3 schematically show the arrangement of a DMS® 2D apparatus according to above mentioned prior art.

[0010] The apparatus comprises a plurality of rigid modules 1 that are connected with one another by flexible joints 2 and forming together a monitoring column denoted by A. Measurement signals collected by the sensors of the individual modules are transmitted through a communication line to a data control and remote transmission unit denoted by B that collects the measurement signals and transmit them to a server processing said data.

[0011] The monitoring column is inserted in a testing or inspection borehole drilled in the soil or in the structure to be monitored.

[0012] In case of deformations in x,y directions, by its construction, it is able to follow displacements and to adapt itself to deformations while relative displacements of the individual modules are detected by sensors and transmitted to the control unit B that in turn transmits data to the processing server.

[0013] The arrangement according to figure 1.1, 1.2 1.3 of the monitoring column is quite simple and allows only displacements resulting from deformations in x,y plane to be monitored.

[0014] When it is necessary to monitor also displacements due to deformations in direction of z axis, that is the axis of the borehole that is the axis of the monitoring column, the above mentioned prior art provides an arrangement according to figures 2.1, 2.2, 2.3

They show the structural diagram of the DMS® 3D apparatus.

[0015] In this case the monitoring column has at least for some, preferably for all the rigid modules 1 a radially expandable packer 4 by means of which each element of the monitoring column is locked against the borehole wall. Sensors present in the individual elements comprise also extensometers or the like that detect relative displacements of the individual modules 1 in the direction of the borehole axis, that is in the direction of z axis, therefore in presence of deformations of the soil and therefore of the borehole the relative displacements of the modules from each x, y and z.

[0016] Such monitoring columns are made according

to the combination of characteristics described in document IT000140510.

[0017] The document IT000140510 describes an apparatus for monitoring geotechnical, geological-structural, hydrogeological and geophysical parameters of soils, rocks and structures in general, which comprises two or more rigid housing elements, at least one sensor for at least one parameter to be monitored being mounted into at least one of them. Said at least two or more rigid housing elements are arranged in sequence one behind the other along a predetermined line or a predetermined axis, a deformable connection element, particularly extensible and flexible one, being interposed between each rigid housing element and the immediately following one. Sensors communicate with means collecting output signals from said sensors that can be mounted in the apparatus or in a separate remote station. The apparatus comprises means removably locking the apparatus with respect to soil to be monitored, composed of anchor elements by radial expansion in the borehole, and a line supplying pressurized fluid for the radial expansion of said anchor elements. Inside said deformable connection element said fluid supply line is firmly integrated, which supply line has sealing connections towards said rigid housing elements and to the outside and it is in communication with said anchor elements.

parameters to be detected directly in contact with the soil/rock to which they are secured by the expansion of the packers without interposing a monitoring tube covering the borehole walls. Such instrument is quite expensive and it is specifically applied for the analysis of particular deformation problems that can affect works of geotechnical engineering particularly as regards soil failures with reference to soil-structure interaction that generally need a continuous monitoring only for the portion affected by failures.

[0018] On the contrary, for monitoring slope stability, DMS® 2D columns are widely used, which are usually used into boreholes with tubing.

[0019] This type of DMS® 2D column even if allows several geotechnical parameters (inclination and direction of horizontal deformations, water table pressure, accelerometer, temperature, etc.) to be continuously monitored, currently it does not allow extensometric information to be acquired namely in direction of the axis (z) that currently can be acquired only by means of multipacker DMS® 3D columns.

[0020] The invention aims at overcoming the limitations currently provided for monitoring columns of the DMS® 2D type, by making it possible to take a measurement according to three axes of relative displacement of the rigid elements composing the column in a substantially cheap and reliable manner, without for this reason using known arrangements of the monitoring columns comprising multipacker anchor systems that are more expensive since expansion of packers has to be carried out by supplying a pressurized fluid that has to be able to flow along the whole column in a uniform manner and

such to guarantee each individual module to be anchored to the wall of the borehole.

[0021] The invention solves the above problem by an apparatus for monitoring geotechnical, geological-structural, hydrogeological and geophysical parameters of soils, rocks and structures in general and more generally of works of geotechnical, mining and structural engineering in general, which apparatus comprises:

- 10 two or more rigid housing elements, at least one sensor for at least one parameter to be monitored being mounted into at least one of them;
- 15 which at least two or more rigid housing elements are arranged in sequence one behind the other along a predetermined line or a predetermined axis, a deformable connection element being interposed between each rigid housing element and the immediately following one;
- 20 which sensors communicate with means collecting output signals from said sensors that can be mounted in the apparatus or in a separate remote station; and at least a part of said rigid elements is provided with members removably locking in position the apparatus cooperating with the walls of a borehole drilled in the soil to be monitored and wherein
- 25 the apparatus is provided in combination with a metering tube covering the borehole;
- 30 which tube is intended to be secured to the soil, that is with the walls of the borehole, while as locking members, at least a part of the rigid elements is provided with radial friction locking extensions cooperating with the inner wall of said tube and elastically compressible and
- 35 said rigid elements are made telescopically deployable and retractable and comprise a sensor measuring the axial deployment or retraction.

[0022] According to one embodiment radial locking extensions are composed of so called thin layer packers.

- 40 **[0023]** These are composed of a plurality of radial annular fins made of high density polyurethane or similar elastomers fastened to one of the telescopic parts of the rigid element. Such annular fins have such a diameter to generate a necessary friction against inner walls of the extensometric/settlement metering tube in order to make the telescope cooperating with the tube and therefore to transfer the longitudinal deformations of the tube on the extensometric measurement system.

- 45 **[0024]** According to a further characteristic, between the at least two parts telescopically coupled with each other forming at least a part of the rigid elements, preferably each rigid element there are provided anti-rotational constraint members allowing the direction of the axes to be maintained in the plane x, y of the

- 50 **[0025]** According to another characteristic between the two telescopically coupled parts there is provided a stop element preventing the two parts from being removed from each other.

[0026] Still an improvement provides between said two telescopically coupled parts to provide at least a gasket or a system of two or more gaskets, for example a combination of o-rings and a protection bellows-shaped element.

[0027] For the extensometric/settlement metering tube it is possible to substantially provide two types of tubes selected alternately among:

single wall corrugated flexible tubes made of plastic material (for example HDPE);
rigid tubes in bars (for example made of PVC, HDPE) with male-female or quick joint connection equipped with telescopic components specific for inclinometric-settlement metering measurements to be suitably placed when installing the tube in the borehole.

[0028] Said single-wall flexible corrugated tubes made of plastic material (for example HDPE) have an optimal behavior in soil that can be compared to that of a spring, able to perfectly follow both the vertical movement and the horizontal movement of the soil getting deformed with it without opposing it.

[0029] Corrugated tubes have the advantage of being flexible for the whole length and therefore are able to copy accurately the soil movement. They can be produced 150 m without junctions (DN 80 mm) and require, for being installed, a greater attention and possibly the use of a reel to prevent them to be twisted and pressed leading to tube failures.

[0030] Due to their reduced thickness such tubes have a limited resistance to external pressure and their use has to be accurately evaluated on the basis of the geotechnical characteristics of soils, depth of the borehole and water table conditions.

[0031] Rigid tubes in bars connected with one another by telescopic elements are able to adapt their length both in compression and in extension depending on the soil movement.

[0032] Rigid tubes, for example made of PVC HDPE, in bars, are of the type and thickness usually used for lining boreholes, they withstand pressures and deformations higher than the tube; their behavior is the one of a rigid tube able to adapt its length to the soil movement only at the telescopic joint. Due to such behavior therefore it is necessary to assemble the monitoring column such that telescopic sectors of the tube coincide with that of the monitoring column, paying attention in packers being placed externally to the settlement metering portion of the lining tube.

[0033] One embodiment of the apparatus according to the invention comprises:

Two or more rigid elements each one forming a tubular enclosure for holding the sensors and optionally the control electronics, and particularly sensor; said tubular enclosure having a telescopic construction composed of:

a holding and protecting male tubular element with a hollow piston acting for guiding the telescopic movement, for containing the extension and for sealing action by O-rings;

a female conical frustum tubular element having such a diameter to allow on one side the male tubular element and the relevant hollow piston to telescopically move;

said male tubular element having means for the connection to the flexible joint connecting the female tubular element of an adjacent rigid element;

said female tubular element having means for the connection to the flexible joint connecting the male tubular element of the adjacent rigid element;

a transducer detecting the displacement both as to the compression and extension of the male tubular element in relation to the female tubular element to which it is telescopically coupled;

thin layer packers composed of two or more discs made of plastic material, particularly high-density polyurethane, able to generate a removable end constraint between the male elements of the telescopic enclosures and the extensometric-settlement metering tube lining the borehole, generating a frictional constraint against the walls of said tube such to allow the male element of each rigid element to be locked transducer of the two male and female telescopic elements and allows the telescopic enclosures to be moved near/away likewise the movement of the tube, in turn integral with the soil for example by suitable cement-bentonite mixtures.

[0034] From the above the advantages of the present invention are clear that mainly are:

- it allows geotechnical monitoring to be performed, continuously, in real-time and inside the same borehole even up to high investigation depths, with a single simple and quite cheap apparatus able to detect many inclinometric, extensometric-settlement metering, piezometric, accelerometric, temperature parameters and other ones.
- It allows analogous or similar apparatuses, even having less functions, to be interconnected thereto, for example apparatuses related preferred 2D arrangements of the document IT0001405009, with a clear reduction of costs if it is necessary to perform integral monitoring of axis "Z" only for some layers and with a clear saving with respect to multiplacker DMS® 3D solution.
- it allows installation/removal time to be reduced since it is possible to work with thin-layer packers without using injection packers therefore time for inflating/deflating hydraulic or pneumatic packers are cancelled;

- it does not require to install a system for checking the pressure of packers and a pump, a necessary in injection multipacker systems, with a clear saving as regards costs and supply and for maintenances;
- it allows weights and diameter of the elements of the column to be considerably reduced while improving handling, the holding capacity of installation and transport reels;
- it allows the accurate monitoring of "Z" axis even at high depths for example for deep landslides with moderate cost increases with respect to "2D" monitoring.

[0035] These and other characteristics and advantages of the present invention will be more clear from the following description of some embodiments shown in annexed drawings wherein:

Figures 1.1, 1.2, 1.3 are an embodiment according to prior art of an apparatus of the type for two-dimensional monitoring of geotechnical, geological-structural, hydrogeological, geophysical parameters of soils and rocks and more generally of works of geotechnical, mining and structural engineering in general.

Fig.2 is an embodiment according to prior art of an apparatus of the type for three-dimensional monitoring of geotechnical, geological-structural, hydrogeological, geophysical parameters of soils and rocks and more generally of works of geotechnical, mining and structural engineering in general.

Fig.3 is a diagram of the apparatus according to with an extensometric-settlement metering corrugated tube.

Fig.4 is two typical sections of a monitoring column according to the present invention installed in a borehole conditioned with a rigid tube in bars connected by telescopic elements (fig.4.1) and with a flexible corrugated tube (fig.4.2) respectively.

Fig. 5 is an element of the monitoring apparatus according to the present invention composed of a telescopic rigid part and a flexible joint.

Fig.6 is a section according to a diametral, axial plane of the element of the monitoring apparatus of the present invention according to figure 5.

[0036] Figures 1.1, 1.2, 1.3 show a monitoring column known in prior art according to a configuration of a device called as DMS® 2D.

[0037] The monitoring column is composed of a plurality of rigid modules or enclosures 1 connected with one another by flexible joints 2. The column as a whole is denoted by A. It is inserted into a tube internally lining a borehole to which said tube is secured. Measurement signals collected by the sensors contained in the enclosure 1 composed of the individual modules are transmitted through a communication line to a data control and remote transmission unit denoted by B that collects

measurement signals and transmit them to a server processing said data.

[0038] In case of deformations in x, y directions, that is in a plane perpendicular to the drawing plane, and due to its arrangement, such monitoring column is able to follow the displacements and to adapt itself to deformations. Relative displacements of the individual modules one with respect to each other are detected by the sensors housed in each module and are transmitted to the control unit B that in turn transmits data to the processing server. Sensor equipment is known and is mentioned in prior art documents listed in the introduction and they being, insofar as applicable, a part of the present description and characteristics that can be provided in combination with the present apparatus.

[0039] The arrangement according to figure 1.1, 1.2, 1.3 of the monitoring column is quite simple and it allows only displacements due to deformations in x, y plane to be monitored.

[0040] When it is necessary to monitor also displacements due to deformations in the direction of z axis, that is of the axis of the borehole namely of the axis of the monitoring column, above mentioned prior art provides an arrangement according to figures 2.1, 2.2. 2.3.

[0041] They show the schematic structural diagram of the device DMS® 3D.

[0042] In this case the monitoring column A has for at least some, preferably for all the rigid modules 1 a radially expandable packer 4 by means of which each module 1 of the monitoring column is locked against the borehole wall. Sensors present in the individual elements comprise also extensometers denoted by 5 or individual modules 1 in the direction of the axis of the borehole, that is in direction of z axis, therefore in presence of deformations of the soil and therefore of the borehole the relative displacements of modules with respect to one another according to three space directions x, y and z are detected.

[0043] Known embodiments do not need a lining of the borehole interposed between the monitoring column and the wall of the borehole. Radially expandable packers are supplied with a pressurized fluid by means of which they radially expand causing the corresponding module to be anchored to the wall of the borehole. Therefore each module is anchored to the borehole independently from adjacent modules and relative displacements along the axis of the borehole that is along z axis are detected by means of the extensometric sensors.

[0044] Figure 3 shows a monitoring column according to the present invention composed of inclination-settlement metering modules 1 connected to one another by flexible joints 2 and cooperating by thin layer packers 6 with a tube lining the borehole having extensometric-settlement metering characteristics 10. The column follows soil deformations both on x,y plane and along z axis by the action exerted by thin layer packers 6.

[0045] In a borehole an extensometric/settlement metering tube, denoted schematically by 10, is inserted and secured to said borehole. The tube is flexible and exten-

sible and compressible and it is secured to the or more of the x, y and z axes is followed by the extensometric/settlement metering tube that fits the shape of the borehole.

[0046] As it will be clear below different shapes of the extensometric/settlement metering tube 10 are possible.

[0047] A monitoring column is inserted into the tube, which is composed of a sequence of rigid modules 1 each one forming an enclosure housing one or more different sensors.

[0048] Between the individual rigid modules 1 a flexible joint 2 is provided connecting two consecutive sensors allowing them to accomplish relative displacement according to two directions x and y.

[0049] In order to allow deformations along z axis to be detected, each module 1 is made as telescopically deployable and retractable, while a sensor detecting the deployment/retraction condition and therefore the relative displacement between two consecutive modules along z axis is provided.

[0050] Each module 1 is fastened to the extensometric/settlement metering tube 10 by means of friction anchor elements that are elastically deformable and that in the shown example are composed of so called thin layer packers generally denoted with 6.

[0051] Figure 4 shows a detail of the monitoring column according to the present invention cooperating with two different types of borehole lining tubes respectively a rigid tube in bars equipped with telescopic connection (fig.4.2).

[0052] Particularly with reference to further figures 5 and 6, each rigid module is composed of two tubular elements 101 and 201 telescopically constrained with each other.

[0053] A male tubular element 101 acts for containing and protecting a support 301 housing the sensors and the control electronics and it has a hollow piston end head 401 acting for guiding such male tubular element 101 in the axial, telescopic sliding movement inside the female upper element 201.

[0054] Such female upper element 201 has such a diameter to allow the telescopic movement to be accomplished for the travel substantially corresponding to the axial extension of the cylindrical part of the female tubular element 201 both under compression and extension and it tapers at the end opposite to that coupling to the male tubular element 101 with a frustum of cone portion having an end 501 coupling to the flexible joint 2.

[0055] The telescopic sliding between the two elements 101 and 201 is limited in the extension by a stop element 601.

[0056] The chamber formed by the two elements 101 and 201 is tightly sealed by gaskets for example a pair of o-rings, while the male element 101 is externally protected by a bellows 11.

[0057] Between the two male and female cylindrical elements 101 and 201, there is provided an anti-rotational constraint as regards the rotation about the alignment

references of the inclinometric sensors 20.

[0058] According to a preferred embodiment such constraint is generated by a longitudinal groove, that is axial groove, along the external surface of the male tubular element wherein a radial projection integral with the female tubular element 201 slidably engages along said groove.

[0059] The support 301 in the male tubular element 101 bears a position transducer 21.

10 **[0060]** In addition to such transducer into the rigid module 1 it is possible to house one or more further sensors and one or more control electronic cards depending on functionality needs provided for the monitoring column.

15 **[0061]** In the non-limitative embodiment shown there is provided one control electronic card 22, to which accelerometric sensors, temperature sensors and possibly other sensors can be associated.

[0062] Preferably the electronic card 22 and said further sensors are mounted on the support 301.

20 **[0063]** Still according to a further characteristic, inside each module there are further provided one or more sensors, such as a piezometric sensor 24 and possibly other types of sensors.

25 **[0064]** The piezometer communicates with the outside through an opening provided with a micropore filter for piezometers denoted by 25.

[0065] The position transducer 21 is provided with a coiled electric connection cable 121 having a terminal

30 **[0066]** Moreover the position transducer is provided with a measurement rod 122 whose end is removably connected to the female tubular element 201.

35 **[0067]** Particularly the connection of the electrical connector of the cable 121 and of the measurement rod of the position transducer 122 is of the magnetic type, that is provided with a magnet cooperating with a further attraction magnetized magnet provided on the electrical connection outlet of the female tubular element 201 and on the seat fastening the measurement rod of the extensometer, that is of the position transducer.

40 **[0068]** In the shown embodiment the measurement rod 122 is connected with the electrical connection terminal 124 of the multicore cable 121 by a magnet secured on the electric connector. Thus said electrical connection terminal 124 acts also for connecting the measurement rod 122 of the position transducer to the female tubular element 201.

45 **[0069]** The magnetic coupling can occur between two magnets each one on the corresponding terminal to be coupled to each other or only one magnet on one of the two terminals to be coupled together and one ferromagnetic element on the other terminal to be coupled.

50 **[0070]** As regards the so called thin-layer packers generally denoted by 6, they are composed of discs for example of high-density polyurethane or other materials able to generate a removable end constraint between the metering tube 9 or 10 lining the borehole. Packers generate a friction constraint against the walls of the tube 9 or 10 such to allow the male tubular element of each

module 1 to be locked and therefore allow individual modules 1 to be moved near/away by their telescopic deployment or retraction and likewise the deployment and retraction movement of the pipe 9 or 10.

[0071] A disc 106 acting as a centralizer is provided in the end region of the male tubular element opposite to the female tubular element 201 and coupling with the flexible joint 2.

[0072] The tube 9 or 10 that in turn is made integral with the soil for example by means of suitable cement-bentonite mixtures has to exhibit a flexible and extensible and compressible behavior such to follow soil deformations according to the different directions x, y and z.

[0073] According to a first embodiment, the tube can be composed of a flexible corrugated tube of plastic material 10, for example HDPE, and with a single wall (fig.4.2).

[0074] The behavior in the soil of such tube is optimal since it can be compared to a spring and it is able to perfectly follow both the horizontal and the vertical movement of the soil by getting deformed with it without opposing it.

[0075] Such corrugated tubes 10 have the advantage of being flexible for the whole length and therefore are able to accurately copy the soil movement.

with considerable lengths longer than 150 m without junctions (DN 80 mm) and require, for being installed, a greater attention and possibly the use of a reel to prevent them to be twisted and pressed leading to tube failures.

[0076] Due to their reduced thickness such tubes have a limited resistance to external pressure and their use has to be accurately evaluated on the basis of the geotechnical characteristics of soils, depth of the borehole and water table conditions.

[0077] According to a variant embodiment (fig.4.1) the tube can be composed of rigid tubes in bars 9, for example PVC or HDPE, connected with one another by telescopic sleeves able to allow the individual rigid sections of the tube to move, within predetermined ranges moving away and near one to the other following the deformations of the borehole in the axial direction thereof, that is along the z axis.

[0078] Junctions between the several rigid elements can be of the male/female type or quick joint type and can contain the telescopic sleeves.

[0079] Such elements are able to adapt their length both in compression and extension depending on the soil movement.

[0080] It is important to consider that in this embodiment the telescopic elements of the lining tube and of the apparatus have to be set or to substantially coincide with one another.

[0081] According again to such embodiment the rigid tubes usually used for lining boreholes, they withstand higher pressures and deformations; their behavior is the one of a rigid tube able to adapt its length to the soil movement only at the telescopic joint. Due to such behavior therefore it is necessary to assemble the monitor-

ing column such that telescopic sectors of the tube coincide with that of the monitoring column, paying attention in packers being placed externally to the settlement metering portion of the lining tube.

[0082] Figure 6 shows a section of a column showing a rigid module 1 and a part of at least one adjacent rigid module connected by a flexible joint 2. As mentioned above the number of modules connected with one another can also be a high number considering the depths to which monitoring has to be carried out.

[0083] According to an improvement of the present invention it is possible to connect to one another several different monitoring columns one or more of them being made according to the present invention and one or more of them according to prior art mentioned in the introduction of the description.

Claims

1. Apparatus for monitoring geotechnical, geological-structural, hydrogeological and geophysical parameters of soils, rocks and structures in general and more generally of works of geotechnical, mining and structural engineering in general, which apparatus comprises:

two or more rigid housing elements, at least one sensor for at least one parameter to be monitored being mounted into at least one of them; which at least two or more rigid housing elements are arranged in sequence one behind the other along a predetermined line or a predetermined axis, a deformable connection element being interposed between each rigid housing element and the immediately following one; which sensors communicate with means collecting output signals from said sensors that can be mounted in the apparatus or in a separate remote station; and at least a part of said rigid elements is provided with members removably locking in position the apparatus cooperating with the walls of a borehole drilled in the soil and more generally in the medium to be monitored and **characterized in that**

the apparatus is provided in combination with a compressible and extensible extensometric/settlement metering tube lining the borehole; which tube is intended to be secured to the soil, that is with the walls of the borehole, while as locking members, at least a part of the rigid elements is provided with radial friction locking extensions cooperating with the inner wall of said tube and elastically compressible and said rigid elements are made telescopically deployable and retractable and comprise a sensor measuring the axial deployment or retraction.

2. Apparatus according to claim 1, wherein the radial locking extensions are composed of the so called thin layer packers.
3. Apparatus according to claim 2, wherein said thin layer packers are composed of a plurality of radial annular fins surrounding one of the rigid element parts telescopically coupled with one another, fastening it to the extensometric/settlement metering tube and allowing at least the further telescope part to freely translate.
4. Apparatus according to one or more of the preceding claims, **characterized in that** between the at least two telescopically coupled parts forming at least a part of the rigid elements, preferably each rigid element, there are provided anti-rotational constraint members allowing the direction of the axes to be maintained in the plane x, y of the inclinometric sensors.
5. Apparatus according to one or more of the preceding claims, **characterized in that** between the two telescopically coupled parts there is provided a stop means preventing the two parts from being removed from each other.
6. Apparatus according to one or more of the preceding claims, **characterized in that** between said two telescopically coupled parts there is provided at least one gasket or a system of two or more sealing gaskets, for example an arrangement of O-rings and protective bellows.
7. Apparatus according to one or more of the preceding claims, **characterized in that** as the extensometric/settlement metering tube one tube is provided selected alternatively among one of the following two types:
- Flexible corrugated tubes made of plastic material (for example HDPE) with single wall;
Sections of rigid tube with a predetermined length connected to each other by telescopically deployable and retractable joints
and wherein the length of the rigid tube sections and the position of the telescopically deployable and retractable joints are set with the corresponding telescopically deployable modules of the monitoring column associated with said extensometric/settlement metering tube.
8. Apparatus according to one or more of the preceding claims, **characterized in that** it comprises:
- Two or more rigid elements each one forming a tubular enclosure for holding the sensors and optionally the control electronics, and particular-

ly inclinometric and/or acceleration and/or temperature and/or piezometric sensors and at least one extensometric sensor;
said tubular enclosure having a telescopic arrangement composed of;
a holding and protecting male tubular element with a hollow piston functioning for guiding the telescopic movement and containing the extension and sealing by O-ring;
a female conical frustum tubular element having such a diameter to allow on one side the male tubular element and the relevant hollow piston to telescopically move;
said male tubular element having means for the connection to the flexible joint connecting the female tubular element of an adjacent rigid element;
said female tubular element having means for the connection to the flexible joint connecting the male tubular element of the adjacent rigid element;
a displacement transducer detecting the displacement both as to the compression and extension of the male tubular element with reference to the female tubular element telescopically coupled with each other;
thin layer packers composed of two or more discs made of plastic material, able to generate a removable end constraint between the female elements of the telescopic enclosures and the extensometric-settlement metering tube lining the borehole, generating a frictional constraint against the walls of said tube such to allow the female element of each rigid element to be locked while the male element houses the transducer of the relative displacement of the two male and female telescopic elements and allows the telescopic enclosures to be moved near/away likewise the movement of the tube, in turn integral with the soil for example by suitable cement-bentonite mixtures.

Patentansprüche

1. Vorrichtung zur Überwachung von geotechnischen, geologischen-strukturellen, hydrogeologischen und geophysikalischen Parametern von Böden, Gestein und Strukturen im allgemeinen und allgemeiner von Arbeiten im Bereich der Geotechnik, der Bergbautechnik und des konstruktiven Ingenieurbaus im allgemeinen, welche Vorrichtung zwei oder mehr starke Gehäuseelemente umfasst, wobei in mindestens einem von ihnen mindestens ein Sensor für mindestens einen zu überwachenden Parameter angebracht ist, wobei die mindestens zwei oder mehr starke Gehäuseelemente in Sequenz entlang einer vorbestimmten Linie oder einer vorbestimmten Achse

- hintereinander angeordnet sind und zwischen jedem starren Gehäuseelement und dem unmittelbar darauf folgenden ein verformbares Verbindungselement angeordnet ist, wobei die Sensoren mit Mitteln kommunizieren, die Ausgangssignale von diesen Sensoren sammeln und in der Vorrichtung oder in einer separaten Fernstation montierbar sind, und zumindest ein Teil der starren Elemente mit Elementen versehen ist, die zur lösbaren In-Position-Blockierung der Vorrichtung mit den Wänden einer im Boden und allgemeiner in dem zu überwachenden Medium eingebrachten Bohrung zusammenwirken und **dadurch gekennzeichnet, dass** die Vorrichtung in Kombination mit einem die Bohrung auskleidenden, komprimierbaren und dehnbaren Dehnungs-/Setzungsmessrohr vorgesehen ist, welches Rohr an dem Boden, d.h. mit den Wänden der Bohrung befestigt werden soll, während ein Teil der starren Elemente als Blockierungselemente zumindest mit radialen, mit der Innenwand des Rohres zusammenwirkenden und elastisch komprimierbaren Reibschlussfortsätzen versehen ist und die starren Elemente teleskopartig ausfahrbar und einziehbar ausgebildet sind und einen das axiale Ausfahren oder Einziehen messenden Sensor umfassen.
2. Vorrichtung nach Anspruch 1, **dadurch gekennzeichnet, dass** die radialen Blockierungsfortsätze aus sogenannten Lamellenpackern gebildet sind.
 3. Vorrichtung nach Anspruch 2, wobei die Lamellenpacker aus einer Vielzahl von radialen ringförmigen Rippen zusammengesetzt sind, die eines der starren teleskopartig miteinander gekoppelten Elementteile umgeben und am Dehnungs-/Setzungsmessrohr befestigen und dabei das freie Verfahren des mindestens weiteren Teleskopteils ermöglichen.
 4. Vorrichtung nach einem oder mehreren der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** zwischen den mindestens zwei teleskopisch gekoppelten Teilen, die zumindest einen Teil der starren Elemente und vorzugsweise jedes starre Element bilden, Verdrehsicherungsglieder vorgesehen sind, durch welche die Richtung der Achsen in der Ebene x, y der Neigungssensoren gehalten werden kann.
 5. Vorrichtung nach einem oder mehreren der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** zwischen den beiden teleskopisch gekoppelten Teilen ein Stoppmittel vorgesehen ist, das ein Entfernen der beiden Teile voneinander verhindert.
 6. Vorrichtung nach einem oder mehreren der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** zwischen diesen beiden teleskopisch gekoppelten Teilen mindestens eine Dichtung oder ein System aus zwei oder mehreren Versiegelungsdichtungen vorgesehen ist, beispielsweise eine Anordnung aus O-Ringen und Schutzbälgen.
7. Vorrichtung nach einem oder mehreren der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** als Dehnungs-/Setzungsmessrohr ein Rohr wahlweise aus einem der folgenden beiden Typen ausgewählt wird:
 - flexible Wellrohre aus Kunststoffmaterial (z. B. HDPE) mit einer Wand,
 - Abschnitte des starren Rohrs mit einer vorbestimmten Länge, die durch teleskopisch ausfahrbare und einziehbare Gelenke miteinander verbunden sind, und wobei die Länge der starren Rohrabschnitte und die Position der teleskopartig ausfahrbaren und einziehbaren Gelenke an den entsprechenden teleskopartig ausfahrbaren Modulen der dem Dehnungs-/Setzungsmessrohr zugeordneten Überwachungssäule angepasst sind.
 8. Vorrichtung nach einem oder mehreren der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** sie zwei oder mehrere starre Elemente umfasst, von denen jedes ein rohrförmiges Gehäuse zur Aufnahme der Sensoren und gegebenenfalls der Steuerelektronik und insbesondere Neigungs- und/oder Beschleunigungs- und/oder Temperatur- und/oder Piezosensoren und mindestens einen Dehnungsmesssensor ist, wobei das rohrförmige Gehäuse eine teleskopierbare Anordnung aufweist, umfassend ein männliches Halte- und Schutzrohrelement mit einem zur Führung der Teleskopbewegung dienenden Hohlkolben, der die Verlängerung und Abdichtung durch O-Ring enthält, ein weibliches rohrförmiges kegelstumpfförmiges Element mit einem solchen Durchmesser, dass sich einerseits das männliche rohrförmige Element und der betreffende Hohlkolben teleskopartig bewegen können, wobei das männliche rohrförmige Element Mittel zur Verbindung mit dem flexiblen Gelenk aufweist, die das weibliche rohrförmige Element eines benachbarten starren Elements verbinden, wobei das weibliche rohrförmige Element Mittel zum Verbinden mit dem flexiblen Gelenk aufweist, das das männliche rohrförmige Element des benachbarten starren Elements verbindet, einen Verschiebungswandler, der sowohl die Kompression-Verschiebung als auch die Ausdehnungs-Verschiebung des männlichen rohrförmigen Elements relativ zum weiblichen rohrförmigen Element erfasst, wobei die Elemente teleskopartig miteinander gekoppelt sind, aus zwei oder mehr Kunststoffscheiben bestehenden Lamellenpacker, der in der Lage ist, eine lösbare Endverbindung zwischen den weiblichen Elementen der Teleskopgehäuse und dem das Bohrloch auskleidenden Deh-

nungs-/Setzungsmessrohr zu erzeugen und dabei eine Reibschlussblockierung gegen die Wände des Rohrs derart erzeugen, dass das weibliche Element jedes starren Elements verriegelt werden kann, während das männliche Element den Wandler für die relative Verschiebung der zwei männlichen und weiblichen Teleskopelemente aufnimmt und dabei die Annäherungs- und Entfernungsbewegungen der Teleskopgehäuse analog der Bewegung des Rohrs ermöglicht, das seinerseits integral mit dem Boden, beispielsweise durch geeignete Zement-Bentonitmischungen, ausgebildet ist.

Revendications

1. Appareil pour la surveillance de paramètres géotechniques, géologiques-structuraux, hydrogéologiques et géophysiques des sols, des roches et des structures en général et plus généralement des travaux de génie géotechnique, minier et structurel en général, lequel appareil comprend:

deux ou plusieurs éléments de logement rigides, au moins un capteur pour capter au moins un paramètre à surveiller et étant monté à l'intérieur d'au moins l'un d'entre eux;

lesquels au moins un ou plusieurs éléments de logement rigide sont disposés en séquence l'un après l'autre le long d'une ligne prédéterminée ou d'un axe prédéterminé, un élément de connexion déformable étant interposé entre chaque élément de logement rigide et le suivant;

lesquels capteurs communiquent avec des moyens collectant des signaux de sortie desdits capteurs qui peuvent être montés à l'intérieur de l'appareil ou dans une station distante séparée;

et au moins une partie desdits éléments rigides est pourvue d'éléments bloquant en position de manière amovible l'appareil coopérant avec les parois d'un trou de sonde foré dans le sol et plus généralement dans le milieu à surveiller et

caractérisé en ce que

l'appareil est pourvu en combinaison avec un tube de mesure extensométrique/de tassement compressible et extensible recouvrant le trou de sonde;

lequel tube est destiné à être fixé au sol, c.à.d. aux parois du trou de sonde, tandis que comme membres de verrouillage, au moins une partie des éléments rigides est pourvue d'extensions de verrouillage à friction radiales coopérant avec la paroi interne dudit tube et élastiquement compressibles et

lesdits éléments rigides sont réalisés de manière télescopiquement déployable et rétractable et comprennent un capteur mesurant le déploie-

ment ou la rétraction axiale.

2. Appareil selon la revendication 1, dans lequel les extensions de verrouillage radiales sont composées de ce que l'on appelle packers de fine couches.

3. Appareil selon la revendication 2, dans lequel lesdits packers de fine couches sont composés d'une pluralité d'ailettes annulaires radiales entourant l'une des parties de l'élément rigide couplées télescopiquement les unes aux autres, la fixant au tube de mesure extensométrique/de tassement et permettant à au moins la partie supplémentaire du télescope de se déplacer librement.

4. Appareil selon l'une ou plusieurs des revendications précédentes, **caractérisé en ce que**, entre au moins deux parties couplées télescopiquement et formant au moins une partie des éléments rigides, de préférence chaque élément rigide, des membres de contrainte anti-rotation permettant de maintenir la direction des axes x, y des capteurs inclinométriques sont pourvus.

5. Appareil selon l'une ou plusieurs des revendications précédentes, **caractérisé en ce que**, entre les deux parties couplées télescopiquement, un moyen d'arrêt empêchant les deux parties de s'éloigner l'une de l'autre est prévu.

6. Appareil selon l'une ou plusieurs des revendications précédentes, **caractérisé en ce que**, entre lesdites deux parties couplées télescopiquement, au moins un joint ou un système de deux ou plusieurs joints d'étanchéité, par exemple une disposition de joints toriques et de soufflets de protection, est prévu.

7. Appareil selon l'une ou plusieurs des revendications précédentes, **caractérisé en ce que** un tube est prévu comme tube de mesure extensométrique/de tassement, sélectionné alternativement parmi l'un des deux types suivants:

1. Tubes ondulés flexibles réalisés en matière plastique (par exemple HDPE) avec une seule paroi;

2. Sections de tube rigide d'une longueur prédéterminée reliées les unes aux autres par des joints télescopiquement déployables et rétractables

et dans lequel la longueur des sections de tube rigide et la position des joints télescopiquement déployables et rétractables sont établis avec les modules télescopiquement déployables correspondants de la colonne de surveillance associées avec ledit tube de mesure extensométrique/de tassement.

8. Appareil selon l'une ou plusieurs des revendications précédentes, **caractérisée en ce qu'il** comprend:

Deux ou plusieurs éléments rigides chacun formant une enceinte tubulaire pour maintenir les capteurs et éventuellement l'électronique de commande, et notamment les capteurs inclinométriques et/ou d'accélération et/ou de température et/ou piézométriques et au moins un capteur extensométrique; 5

ladite enceinte tubulaire ayant une disposition télescopique composée de; 10

un élément tubulaire mâle de maintien et de protection avec

un piston creux fonctionnant pour guider le mouvement télescopique et contenant l'extension et l'étanchéité par joint torique; 15

un élément tubulaire femelle à tronc de cône ayant un diamètre tel que pour permettre à l'élément tubulaire mâle et au piston creux correspondant de se déplacer télescopiquement sur un côté; 20

ledit élément tubulaire mâle ayant des moyens pour la connexion au joint flexible reliant l'élément tubulaire femelle d'un élément rigide adjacent; 25

ledit élément tubulaire femelle ayant des moyens pour la connexion au joint flexible reliant l'élément tubulaire mâle d'un élément rigide adjacent; 30

un transducteur de déplacement détectant le déplacement à la fois en ce qui concerne la compression et l'extension de l'élément tubulaire mâle par rapport à l'élément tubulaire femelle télescopiquement couplés l'un à l'autre; 35

packers de fine couches composés de deux ou plusieurs disques réalisés en matière plastique, capables de générer une contrainte d'extrémité amovible entre les éléments femelles des enceintes télescopiques et le tube de mesure extensométrique/de tassement recouvrant le trou de sonde, générant une contrainte de frottement contre les parois dudit tube de manière à permettre le verrouillage de l'élément femelle de chaque élément rigide, tandis que l'élément mâle loge le transducteur du déplacement relatif des deux éléments télescopiques mâle et femelle et permet de rapprocher/éloigner les enceintes télescopiques ainsi que le mouvement du tube, à son tour intégral avec le sol, par exemple par des mélanges ciment-bentonite appropriés. 40

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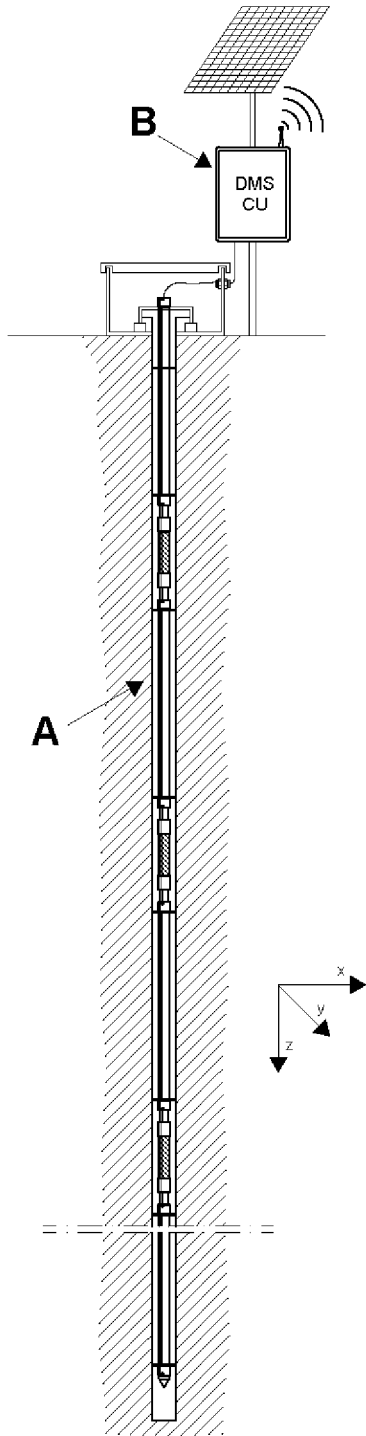


Fig. 1.1

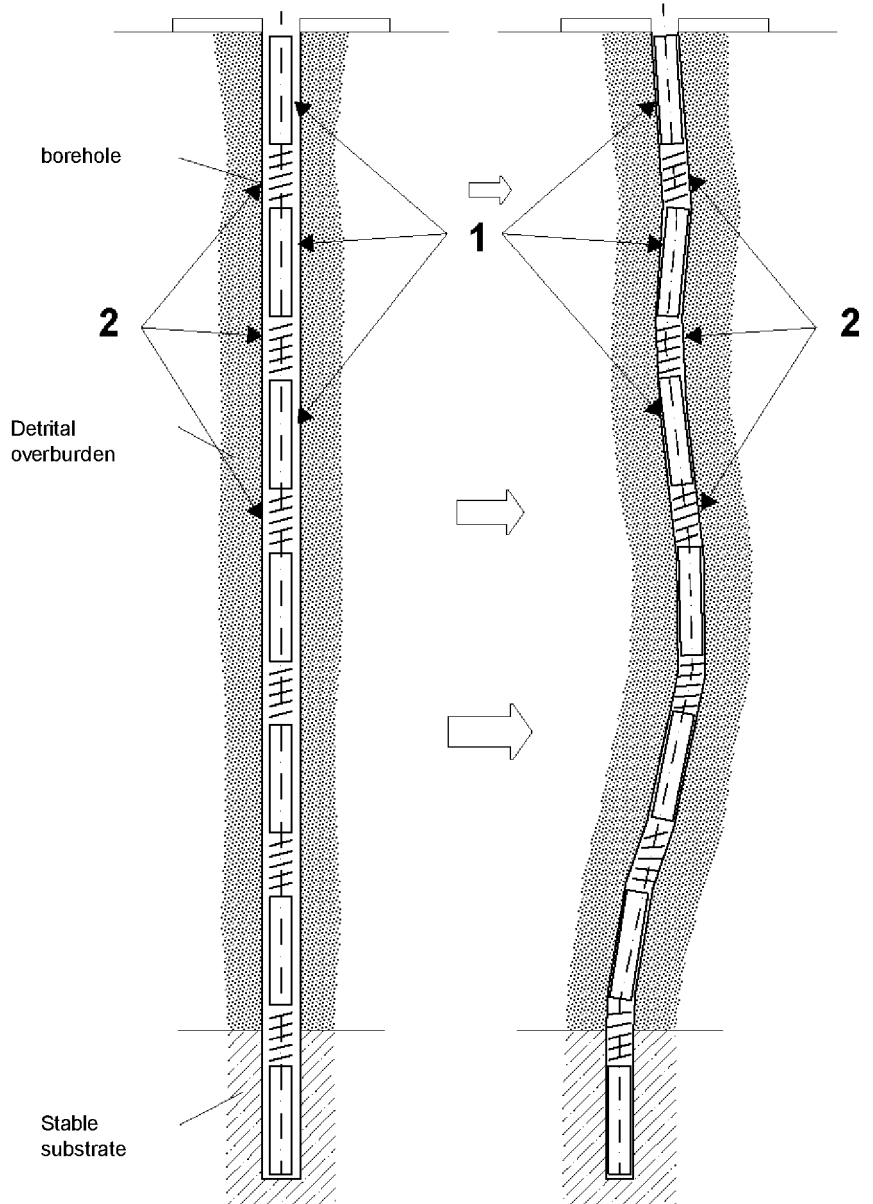


Fig. 1.2

Fig. 1.3

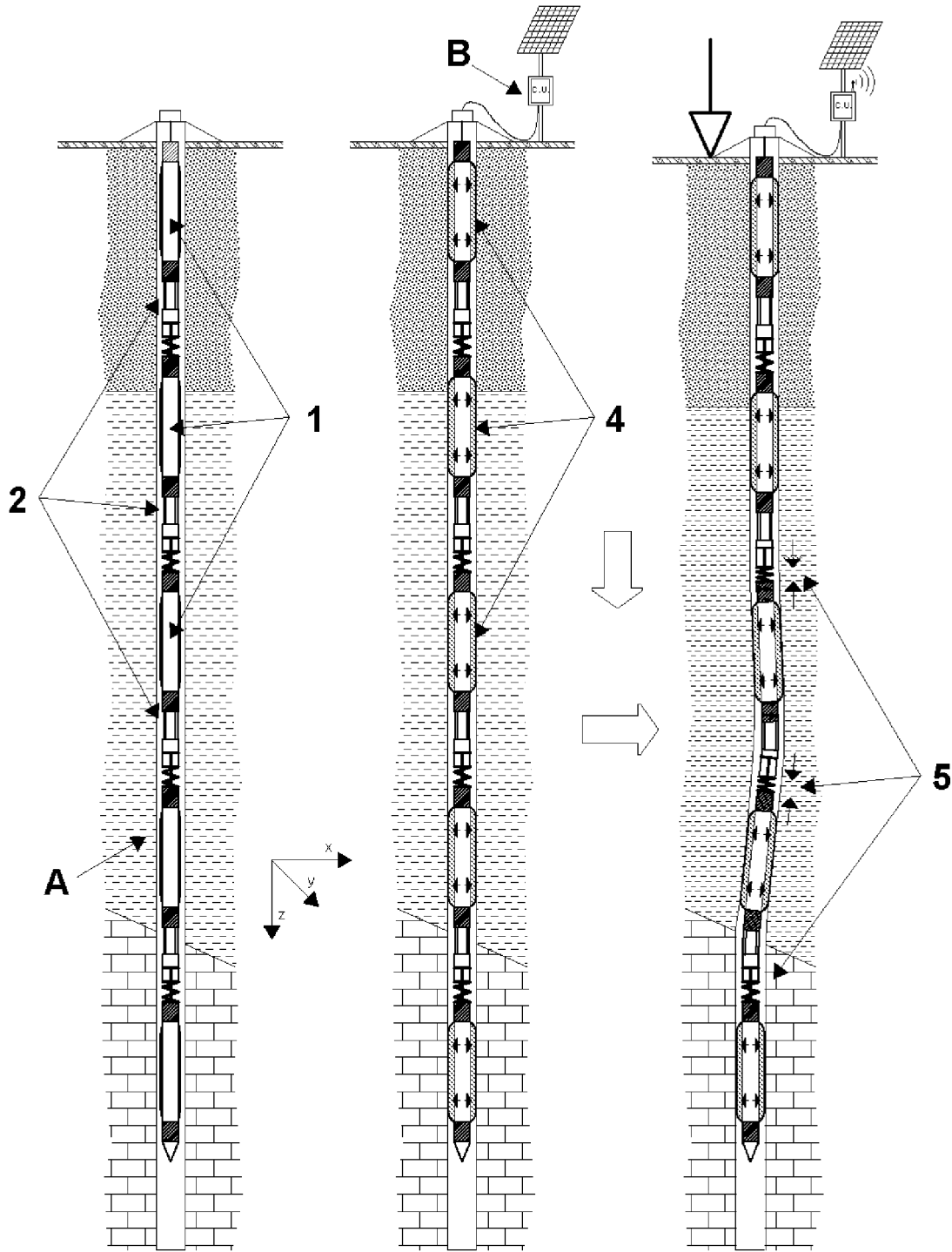


Fig. 2.1

Fig. 2.2

Fig. 2.3

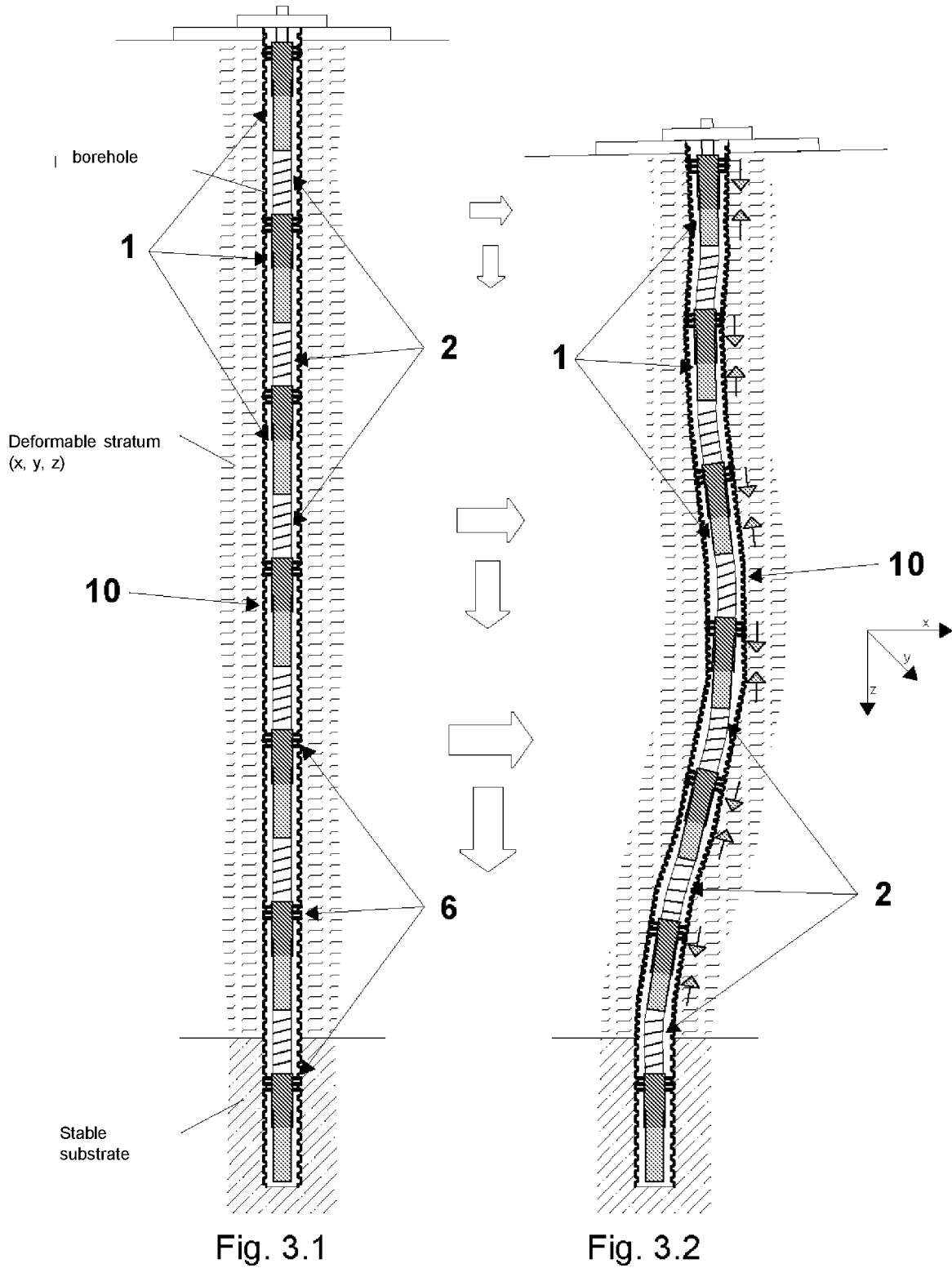


Fig. 3.1

Fig. 3.2

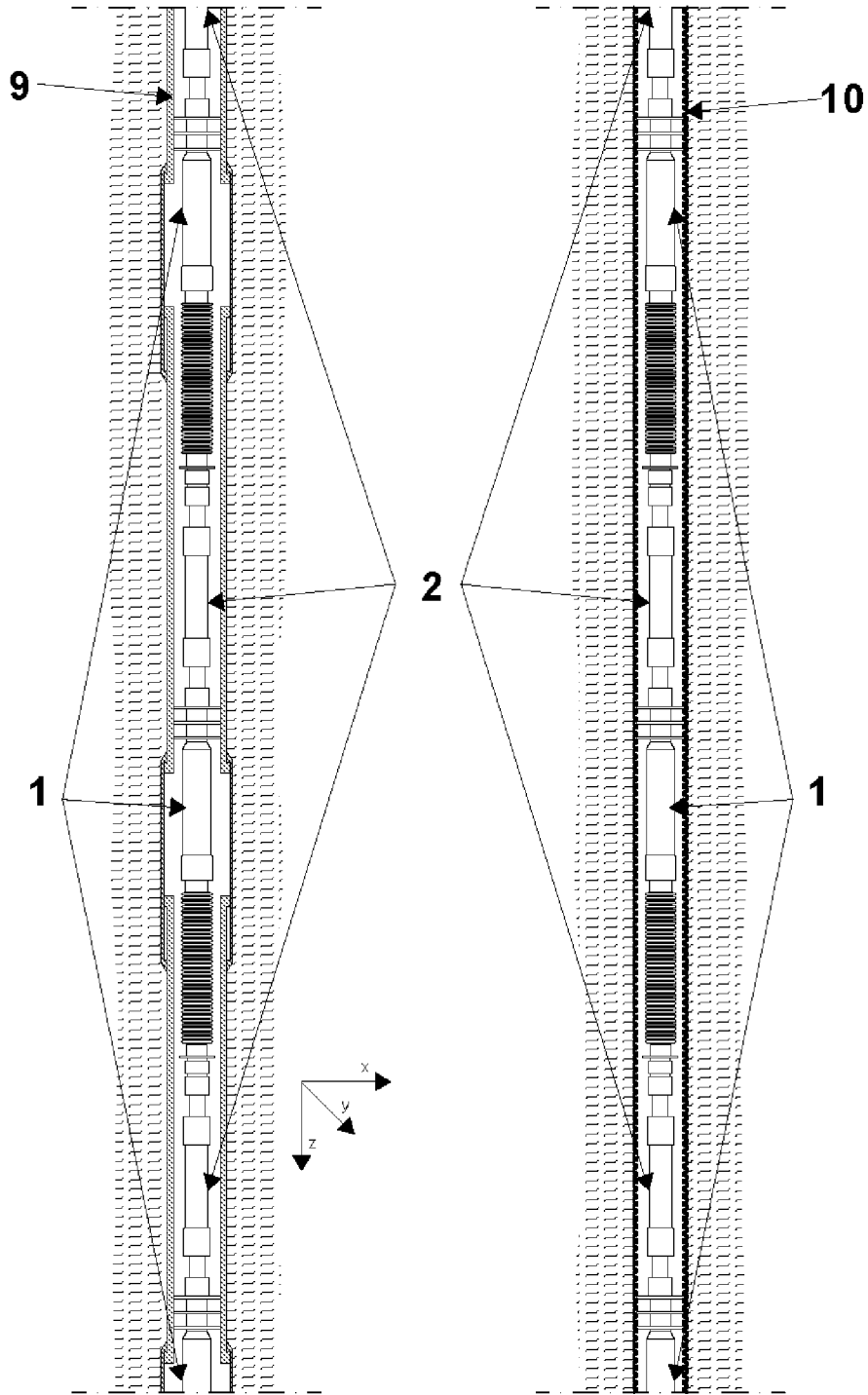


Fig. 4.1

Fig. 4.2

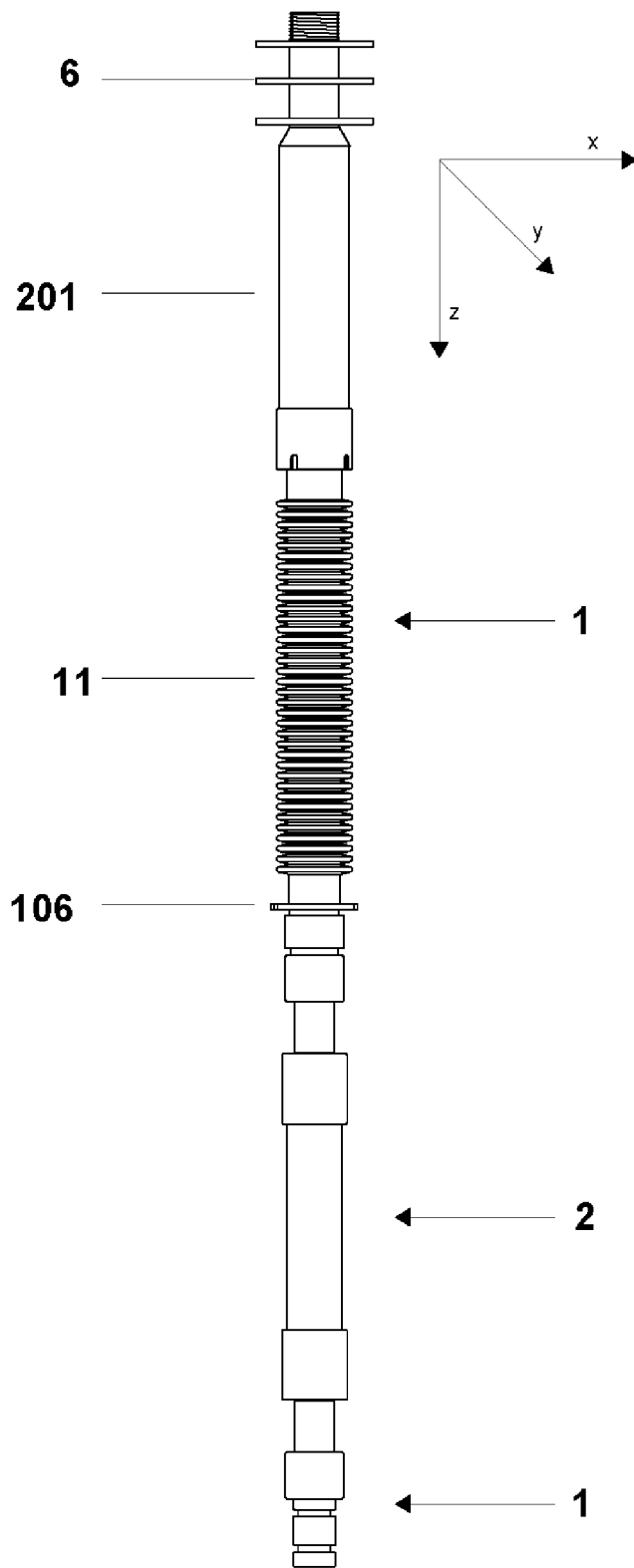


Fig. 5

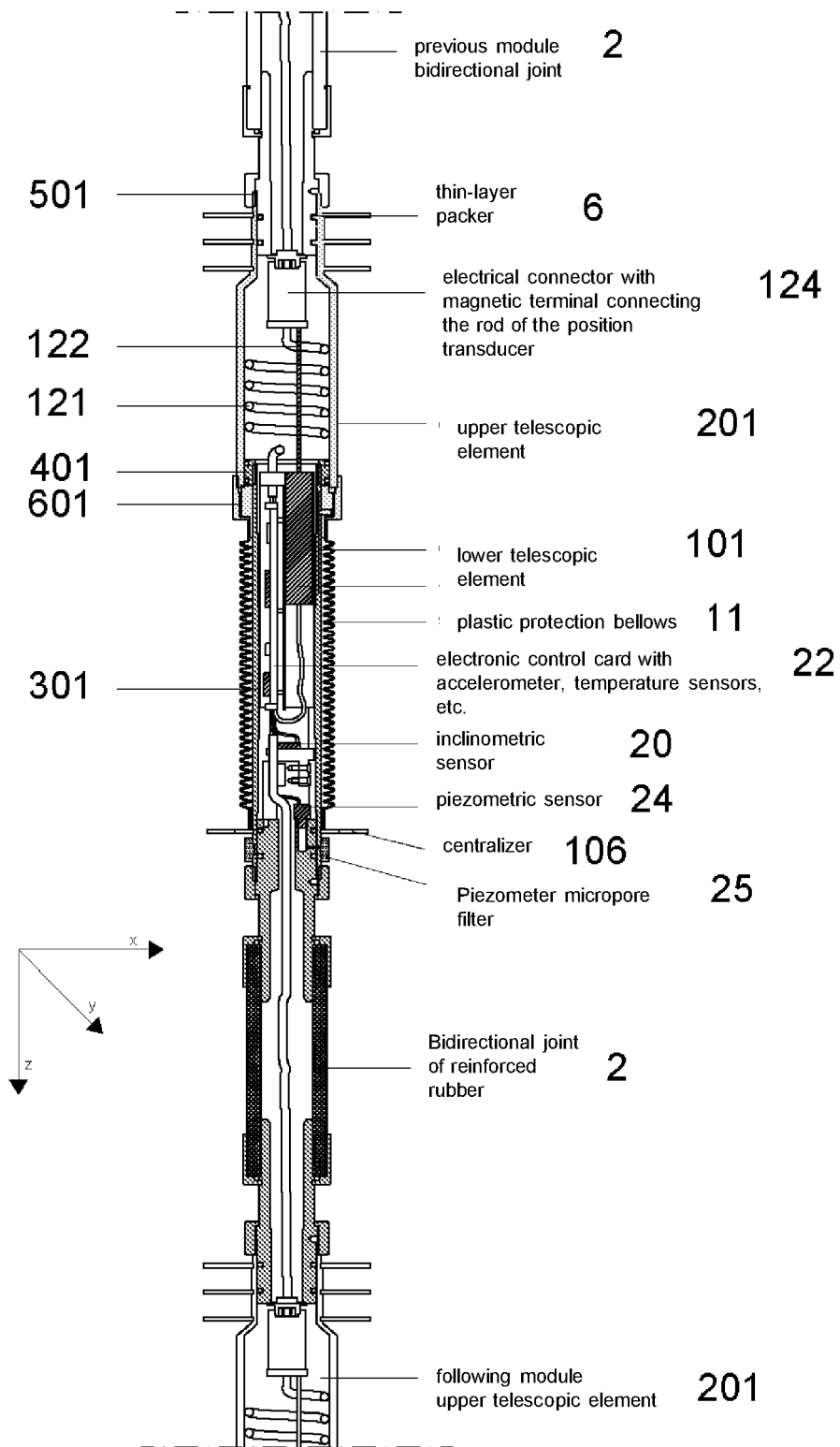


Fig. 6

REFERENCES CITED IN THE DESCRIPTION

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