



(11) **EP 2 072 686 A2**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:  
**24.06.2009 Bulletin 2009/26**

(51) Int Cl.:  
**E02D 3/10 (2006.01)**

(21) Application number: **08171995.7**

(22) Date of filing: **17.12.2008**

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

(30) Priority: **21.12.2007 IT MO20070402**

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(54) **System and method for consolidating a building foundation soil**

(57) A system for consolidating a foundation soil (2) of a building (3) comprises a plurality of dispensing devices (10; 110) supplied with water and provided with respective diffusing means (30; 130) positioned in the soil (2) around and/or below said building (3) for dispensing water to respective portions (20; 120) of said soil (2),

each device (10; 110) comprising adjusting means (40; 140) for controlling a flow of water in the respective diffusing means (30; 130) so as to maintain a set degree of humidity in the respective portion of soil (20; 120).

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## Description

**[0001]** The present invention relates to systems and methods for stabilising building foundation soil, in particular it relates to a system and a method for limiting and containing variations in volume of a foundation soil.

**[0002]** It is known that the static instabilities of buildings are due in many cases to differential yielding and/or swelling of the foundation soil that is essentially due to non-homogenous volumetric variations of the soil caused by the variation in the time of the water content of the soil.

**[0003]** In the most common case, this phenomenon is due to seasonal variations in the humidity of the soil, also depending on climatic trend (precipitation, temperature, etc.). In the particular case of clayey/muddy soil, depending on the type and corresponding physical and mechanical features thereof, these volumetric variations may be considerable in percentage terms (up to 10%), and thus cause rises and/or drops in the foundation soil of a building so as to cause cracks and/or damages of varying degrees of seriousness.

**[0004]** Currently, consolidation interventions are known for such type of instability that transfer the loads of the building to deeper layers of the soil that are not affected by variations in humidity, through the construction of piles of various types.

**[0005]** Consolidation systems using piles are nevertheless very expensive and invasive as they involve the entire load bearing structure of the building and require the site of the building to be accessible even to large equipment from both sides of the masonry. Further, as in most cases the buildings are not provided with reinforced foundations, to connect the pile to the masonry, it is necessary to proceed first of all with laying perimeter kerbs of reinforced concrete in which to butt the piles, this requiring excavations, demolition and rebuilding of external paving (pavements) and/or internal paving (floors of cellars).

**[0006]** Other known consolidation systems provide for the injection into the soil of expanding materials, typically resins, that enable cavities, fissures and the like to be filled in order to compact the soil again.

**[0007]** Said systems, in the case of clayey/muddy soil that are subject to significant variations in volume with variations in the degree of humidity may nevertheless be ineffective and not ensure a definitive solution to the problem.

**[0008]** An object of the present invention is to improve known systems and methods for stabilising and/or consolidating building foundation soil.

**[0009]** Another object is to obtain a system and a method that enable variations in the volume of foundation soil to be avoided that are caused by natural variations in the water content of the foundation soil, so as to prevent corresponding differential yielding and/or raising of said soil so as to avoid and/or remedy static instabilities originating therefrom.

**[0010]** A further object is to make a system and a method

that are simple and cheap to make and are at the same time reliable and efficient.

**[0011]** In a first aspect of the invention there is provided a system for consolidating a foundation soil of a building, comprising a plurality of dispensing devices supplied with water and provided with respective diffusing means positioned in the soil around and/or below said building for dispensing water to respective portions of said soil, characterised in that each device comprises adjusting means for controlling a flow of water in the respective diffusing means so as to maintain a set degree of humidity in the respective portion of soil.

**[0012]** The dispensing devices can be arranged both at the external foundation perimeter of the building and inside and below the building. A control unit is further provided that is able to control separately and independently the adjusting means of the dispensing devices.

**[0013]** In a second aspect of the invention there is provided a method for consolidating a foundation soil of a building, comprising dispensing water in said soil by means of a plurality of dispensing devices provided with respective diffusing means inserted into respective portions of said soil around and/or below said building, characterised in that said dispensing comprises adjusting a flow of water in said diffusing means of each dispensing device so as to maintain a set degree of humidity in said portion of soil.

**[0014]** Owing to these aspects of the invention it is thus possible to make a system and a method for consolidating foundation soil that enable, in a simple, efficient and economic manner, non-homogenous variations in volume of foundation soil to be avoided, so as to prevent corresponding differential yielding and/or raising of said soil so as to prevent and/or remedy static instabilities originating therefrom.

**[0015]** As each dispensing device is controlled independently by the control unit, the system is able to dispense the water only to those portions of soil in which consumption actually occurred and in the quantity necessary for maintaining the preset level of humidity. Consequently, the system of the invention maintains substantially constant, in the mass of treated soil, a set humidity value correlated to the level of water in the diffusers and defined in function of specific needs. If the features of the soil portions vary noticeably in the foundation soil to be treated, the system is completely adaptable, being able to modify for each dispensing device both the depth interval to be hydrated and the level of water to be maintained constant. The adjustment of the level can be changed even after the system has been installed and started up.

**[0016]** The invention can be better understood and implemented with reference to the attached drawings, which show an embodiment thereof by way of non-limiting example, in which:

Figure 1 is a schematic section of the consolidation system of the invention associated with the founda-

tion soil of a building;

Figure 2 is a schematic top plan view of the system in Figure 1;

Figure 3 is a schematic section of a version of the system in Figure, showing a water-dispensing device and reservoir means;

Figure 4 is a section like that in Figure 3, that illustrates another embodiment of the water-dispensing device of the system in figure 1.

**[0017]** With reference to Figures 1 and 2, there is illustrated schematically a system 1 for consolidating a foundation soil 2 of a building 3 comprising a plurality of dispensing devices 10 supplied with water by supplying means 6.

**[0018]** Each dispensing device 10 is provided with respective diffusing means 30 suitably positioned in the soil 2 around and/or below said building 3 for dispensing water in portions 20 of the soil 2.

**[0019]** Each dispensing device 10 comprises adjusting means 40 that adjusts a flow of water coming from the supplying means 6 and directed to the diffusing means 30 so as to maintain a preset degree of humidity in the portion of soil 20. The aforesaid preset degree of humidity is, for example, a value near the saturation limit of the soil, said saturation limit being a function of the chemical-physical features of the soil.

**[0020]** The dispensing device 10 dispenses the water in the respective portion of soil 20 at a substantially atmospheric pressure, through percolation and/or suction.

**[0021]** For this purpose, the diffusing means 30 of the dispensing device 10 has a cavity 31 that is suitable for containing a defined quantity of water and which is bounded by permeable walls to enable the water A to flow to an adjacent portion 20 of soil through the aforesaid process of percolation and/or of suction. This cavity 31 is substantially "an atmospheric pressure" reservoir that is subjected to atmospheric pressure and the water contained therein is dispensed to the adjacent portion 20 with hydrostatic pressure values that are variable between a zero value, at the aforesaid atmospheric pressure, and a maximum value, at a bottom of said cavity 31.

**[0022]** The diffusing means 30 of the dispensing device 10 comprises a pipe, for example a rectilinear pipe, of a length that is variable according to specific needs and is provided with an internal cavity 31 bounded by side walls 32, having a plurality of through holes 33 for the water to pass to the portion of soil 20.

**[0023]** A head end 35 of the drilled pipe 30 is fixed to a containing sump 14, inside which the adjusting means 40 is housed. A feeding conduit 13 conveys the water from the adjusting means 40 to inside the pipe 30 (Figure 3).

**[0024]** The defined quantity of water contained in the dispensing device 10 can be such as to fill completely the internal cavity 31 of the pipe 30 and partially said containing sump 14.

**[0025]** Permeable coating means 34 covers the side

walls 32 of the drilled pipe 30 to prevent or reduce the blockage of said holes 33 with earth and/or with sludge. The coating means 34 is made, for example, of non-woven fabric.

**[0026]** The drilled pipe 30 can be fixed in the soil 2 through drilling and/or ramming and be arranged vertically adjacent to the foundations 3a of the building 3, as illustrated in the figure.

**[0027]** It is also possible to position the drilled pipe 30 below the foundations 3a of the building 3. For this purpose, the drilled pipe 30 can be fixed in the soil 2, tilted or horizontal, in the latter case through horizontal perforation technique.

**[0028]** In each case, the drilled pipe 30 is inserted into the soil 2 spaced away from the foundations 3a of the building 3 by a distance so as to avoid possible phenomena of capillary ascent for the water.

**[0029]** The system 1 comprises an electronic control unit 5 connected to the plurality of devices 10, arranged in the soil 2 around the foundation of the building 3, to drive the respective adjusting means 40 of the device 10.

**[0030]** The dispensing device 10 is further provided with one or more sensors 15 arranged to detect a level of water in the respective cavity 31 and send to the control unit 5 a corresponding signal. Typically, the sensor 15 detects a minimum level of the water in the cavity 31 that determines the opening of the adjusting means 40, comprising, for example, a solenoid valve.

**[0031]** The solenoid valve 40 is connected and controlled by the control unit 5 and is supplied via a supply conduit 16 by the supplying means 6.

**[0032]** Alternatively, the dispensing device 10 comprises one or more sensors that are able to measure a degree of humidity in the soil portion 20 adjacent to the device and send to the control unit 5 a corresponding signal for opening or closing the adjusting means 40. In this case, the set degree of humidity in each soil portion can be lower than the saturation limit, which is both a function of the physical-chemical features of the soil 2 and of the differential yielding and/or raising of the soil 2.

**[0033]** The supplying means 6 comprises, for example, a public water system, a watercourse, a lake, a well, a basin.

**[0034]** With particular reference to figure 3, in an embodiment of the consolidation system 1 there is provided reservoir means 4 comprising, for example, a collecting tank connected in turn to supplying means 6 by further adjusting means 7. The further adjusting means 7, which includes, for example, a floating tap, is arranged to maintain a substantially constant level of water in the reservoir 4.

**[0035]** In a further embodiment of the system 1, which is not illustrated, the reservoir means 4 is not supplied by the supplying means 6, but collects, for example, rain-water.

**[0036]** The operation of the consolidation system 1 of the invention supplies the plurality of dispensing devices 10 with water taken, for example, from the supplying

means 6.

**[0037]** The dispensing devices 10 can be arranged both at the external perimeter of the foundations 3a of the building 3 and inside and below the building 3, as also the internal soil can be subjected to drying phenomena.

**[0038]** As each dispensing device 10 is controlled independently by the control unit 5 so as to maintain a preset level of water inside the respective diffusing means 30, the system 1 is able to dispense the water only to those soil portions in which the consumption actually took place and in the quantity necessary for maintaining the aforesaid preset level. Consequently, the system 1 of the invention tends to maintain constant, in the mass of treated soil, a set humidity value linked to the level of water in the diffusers and defined in function of specific needs. If the features of the soil portions vary noticeably in the foundation soil to be treated, the system 1 is completely adaptable, for each dispensing device 10 both the interval of depth to be hydrated and the level of water to be maintained constant being able to be modified. The level adjustment can also be changed after laying and starting the plant, simply by modifying the calibration of the sensors 15.

**[0039]** The number, the arrangement of the dispensing devices 10 and the type of the corresponding diffusing means 30 depend on both the chemical-physical features of the foundation soil and on the type of structure of the foundation.

**[0040]** The dispensing devices 10, can in fact be positioned at a distance from one another that is such that the respective soil portions 20, which are adjacent and hydrated, are partially superimposed, for example in the case of a concrete-bed foundation. On the other hand, the dispensing devices 10 can be positioned at a distance from one another such that the soil portions 20, which are adjacent and hydrated, are separated and distinct, for example in the case of a punctiform and/or ribbon-shaped foundation, with load bearing walls.

**[0041]** Installing the system provides for conducting suitable preliminary investigations in order to define the size parameters of the system and to maintain the humidity level.

**[0042]** Such investigations aim in particular to determine the lithological nature and the physical-mechanical features of the foundation soil and comprise a series of operating steps briefly disclosed below.

**[0043]** In a first step a suitable number of penetrometric tests and continuous coring geognostic drilling are performed up to a set depth, generally equal to 1-2 times the minimum dimension of the plan view of the building, in order to detect a stratigraphic sequence and a level of the possible groundwater.

**[0044]** Soil samples are taken to perform a plurality of tests, including:

- determining the water content and the weight volume of the soil;

- granulometric analysis;
- determining consistency limits (Atterberg limits i.e. liquid limit, plastic limit and shrinkage limit);
- classification of the material.

**[0045]** A graph is then plotted that shows the humidity values in function of the depth in order to show the presence of the soil layers that have undergone drying phenomena. Determining the Atterberg limits, and in particular the shrinkage limit, enables the degree of drying to be checked, and through the comparison with the detected natural humidity, enables the tendency of the soil to increase or not increase yielding to be evaluated. After the cores have been extracted, the drillings are equipped with open-pipe piezometers.

**[0046]** In a second step the soil is soaked by supplying the piezometers so as to maintain the level of water constant at the laying height of the foundations of the building and for a time such as to enable the permeability of the soil in question to be determined.

**[0047]** In a third step, for each drilling conducted, another two are conducted, one immediately next to the other at a preset distance, for example 1 m (depending on the detected permeability values), in order to check the humidity variation that occurred in the soil surrounding the piezometer following the soaking step. In this manner, it is possible to determine the distance between two adjacent dispensing devices 10. Once the soil layers have been identified that have undergone drying phenomena and the area of influence of the dispensing devices has been evaluated, in other words the diameter of the actually hydrated soil cylinder, it is possible to decide the type, dimensions and position of the diffusing means 30, also in function of the features of the building, of the surrounding area, etc.

**[0048]** With reference to Figure 4, there is illustrated a version of the system 1 of the invention comprising a dispensing device 110 provided with respective diffusing means 130 comprising one of a well, ditch, trench, gallery or the like, possibly already present at the building 3. In this case, the diffusing means 130 has a respective cavity 131 open to the atmosphere and provided with permeable walls 132 for enabling the passing of the water A to the zone of the soil 120 adjacent to the building 3.

**[0049]** Respective adjusting means 140 controlled by the electronic control unit 5 and supplied by the supplying means 6 maintains the level of the water inside the cavity 131 substantially constant or anyway greater than a preset minimum level. Respective sensor means 115, for example of the floating type, detects the level of the water.

**[0050]** The operation of this embodiment of the system is substantially the same as the previously disclosed embodiment.

**[0051]** In an embodiment of the system 1 which is not illustrated, the dispensing device 110 is provided with adjusting means 140 comprising a floating tap of known type that is suitable for restoring the level of the water inside the cavity 131 when the level of the water

is lowered by a preset quantity. In particular, the floating tap substantially operates as an on/off valve, i.e. remains closed when the level of the water in the cavity 131 is comprised between a maximum height and a minimum height and is opened to enable the water to flow when the level of the water falls below the minimum height. The difference in levels between the two heights can be adjusted according to specific needs.

**[0052]** If the aforesaid floating tap is used, sensor means is not necessary for measuring the level of the water inside the cavity 131 and neither is the electronic control unit 5 necessary.

**[0053]** The floating tap can also be applied to the diffusing means 30 of the previously disclosed dispensing device 10, comprising a pipe provided with an internal cavity 31 bounded by side walls 32, having a plurality of holes 33 for the passage of the water.

## Claims

1. System for consolidating a foundation soil (2) of a building (3), comprising a plurality of dispensing devices (10; 110) supplied with water and provided with respective diffusing means (30; 130) positioned in the soil (2) around and/or below said building (3) for dispensing water to respective portions (20; 120) of said soil (2), **characterised in that** each device (10; 110) comprises adjusting means (40; 140) for controlling a flow of water in the respective diffusing means (30; 130) so as to maintain a set degree of humidity in the respective portion of soil (20; 120), in particular a degree of humidity near a saturation limit of said soil (2).
2. System according to the preceding claim, wherein said diffusing means (30; 130) of each dispensing device (10; 110) comprises cavity means (31; 131) suitable for containing a defined quantity of water supplied by the respective adjusting means (40; 140), said dispensing devices (10; 110) dispensing said water to said portions of soil (20; 120) at a substantially atmospheric pressure.
3. System according to claim 2, wherein said diffusing means (30; 130) comprises permeable wall means (32; 132) to enable said water to flow from said cavity means (31; 131) to a portion (20; 120) of adjacent soil, through percolation and/or suction.
4. System according to claim 2 or 3, wherein said diffusing means (30) comprises pipe means provided with an internal cavity (31) bounded by side walls (32) provided with through holes (33) for the water.
5. System according to any one of claims 2 to 4, wherein said adjusting means (40; 140) comprises floating tap means arranged for dispensing water to the respective diffusing means (30; 130) when a level of water inside the corresponding cavity means (31; 131) reaches a preset minimum height.
6. System according to any preceding claim, comprising a control unit (5) connected to said plurality of devices (10; 110) to drive and control the adjusting means (40; 140) of said plurality of devices (10; 110).
7. System according to claim 6, as appended to any one of claims 2 to 5, wherein each dispensing device (10; 110) comprises sensor means (15; 115) arranged at least for detecting a level of water in said respective cavity means (31; 131) and sending to said control unit (5) data relating to said measured level of water.
8. System according to claim 6 or 7, wherein each dispensing device (10; 110) comprises further sensor means suitable for measuring a degree of humidity of a portion (20; 120) of soil adjacent to said device (10; 110) and sending to said control unit (5) data relating to said measured degree of humidity.
9. System according to claim 7 or 8, as claim 8 is appended to claim 7, wherein said adjusting means (40; 140) comprises solenoid valve means and wherein said electronic control unit (5) is arranged for driving said solenoid valve means (40; 140) of each dispensing device (10; 110) on the basis of said data sent by the respective sensor means (15; 115).
10. System according to any preceding claim, comprising supplying means (6) and/or reservoir means (4) for supplying said dispensing devices (10; 110) with water.
11. Method for consolidating a foundation soil (2) of a building (3), comprising dispensing water in said soil (2) by means of a plurality of dispensing devices (10; 110) provided with respective diffusing means (30; 130) inserted into respective portions (20) of said soil (2) around and/or below said building (3), **characterised in that** said dispensing comprises adjusting a flow of water in said diffusing means (30) of each dispensing device (10; 110) so as to maintain a set degree of humidity in said portion of soil (20), in particular a degree of humidity near a saturation limit of said soil (2).
12. Method according to claim 11, wherein said dispensing is performed at substantially atmospheric pressure and comprises yielding said water to said portions (20; 120) of soil by percolation and/or suction.
13. Method according to claim 12, wherein said adjusting said flow of water comprises maintaining inside said diffusing means (30; 130) of each dispensing device

(10; 110) a defined quantity of water and further comprises detecting and/or measuring said defined quantity of water in each dispensing device (10; 110) and/or a degree of humidity of a portion of soil (20; 120) adjacent to each dispensing device (10; 110). 5

**14.** Method according to any one of claims 11 to 13, comprising positioning said plurality of dispensing devices (10; 110) so that the respective diffusing means (30; 130) is spaced away from foundations (3a) of said building (3) by a distance that is such as to avoid phenomena of capillary ascent for the water. 10

**15.** Method according to claim 14, wherein before said positioning performing a plurality of tests and/or drilling is provided to determine the lithological nature and/or physical-mechanical features of said foundation soil (2). 15

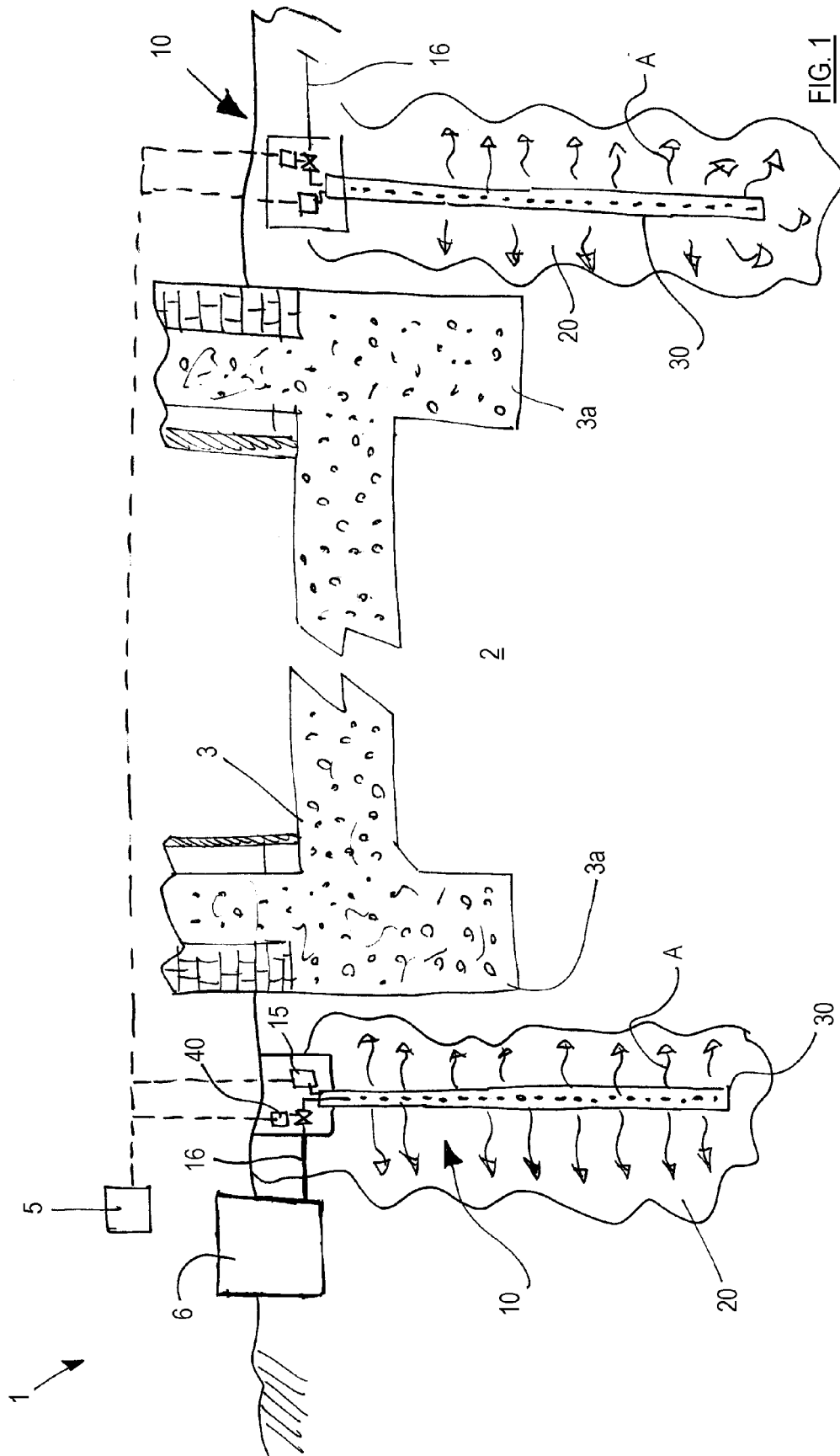
**16.** Method according to claim 15, wherein said tests and/or drilling comprise, in a first step, running penetrometric tests and geognostic drilling to detect a stratigraphic sequence and a level of a possible water-bearing stratum of said foundation soil (2) and performing on samples of said soil (2) at least one between: 20 25

- determining a water content and a weight volume of the soil;
  - granulometric analysis; 30
  - determining consistency limits (Atterberg limits i.e liquid limit, plastic limit and shrinkage limit);
  - classification of the material;
- in a second step, determining permeability of the soil under examination and, in a third step, determining a maximum distance between two dispensing devices (10; 110) such that portions (20; 120) of soil (2) hydrated by said dispensing devices (10; 110) are partially superimposed. 35 40

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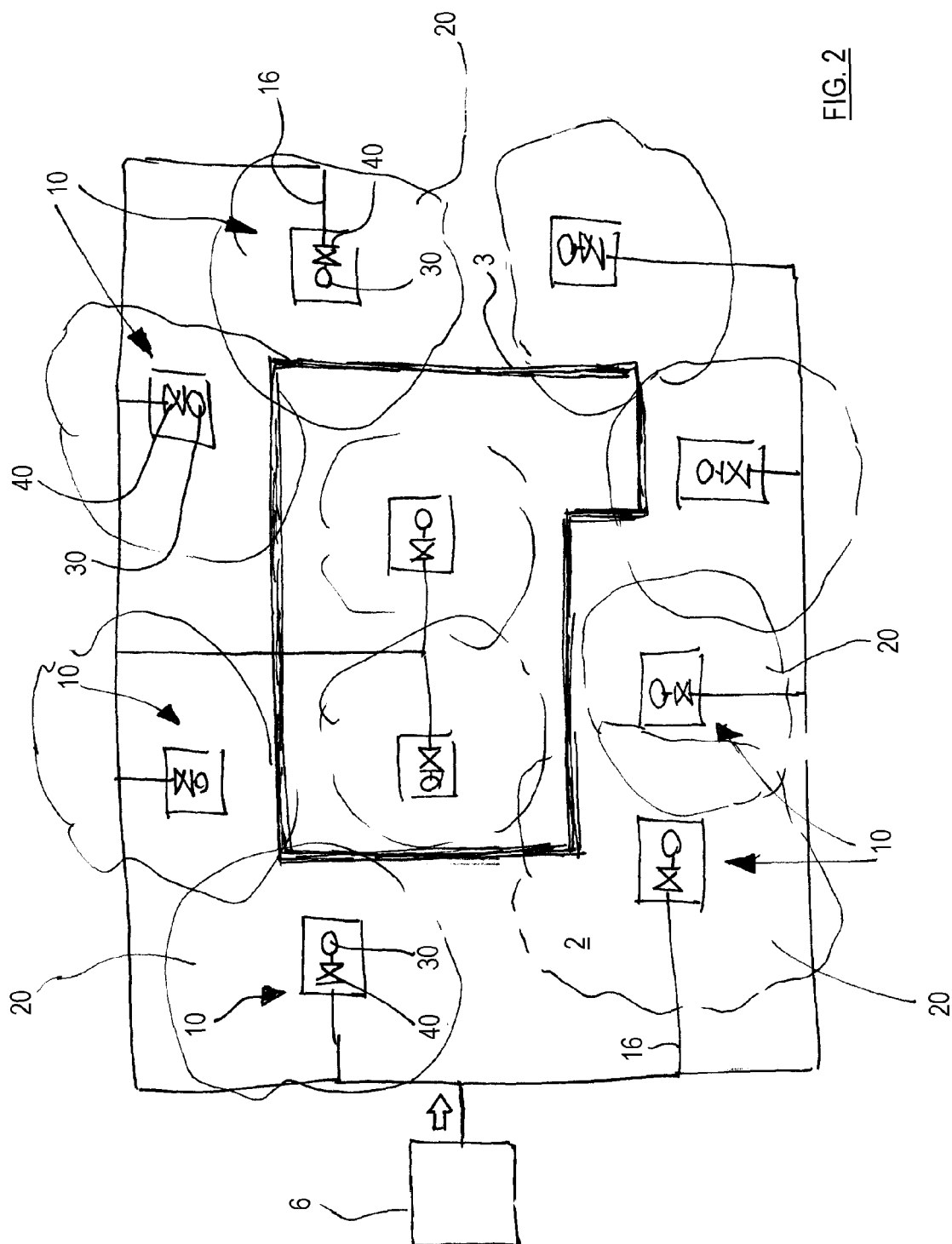


FIG. 2

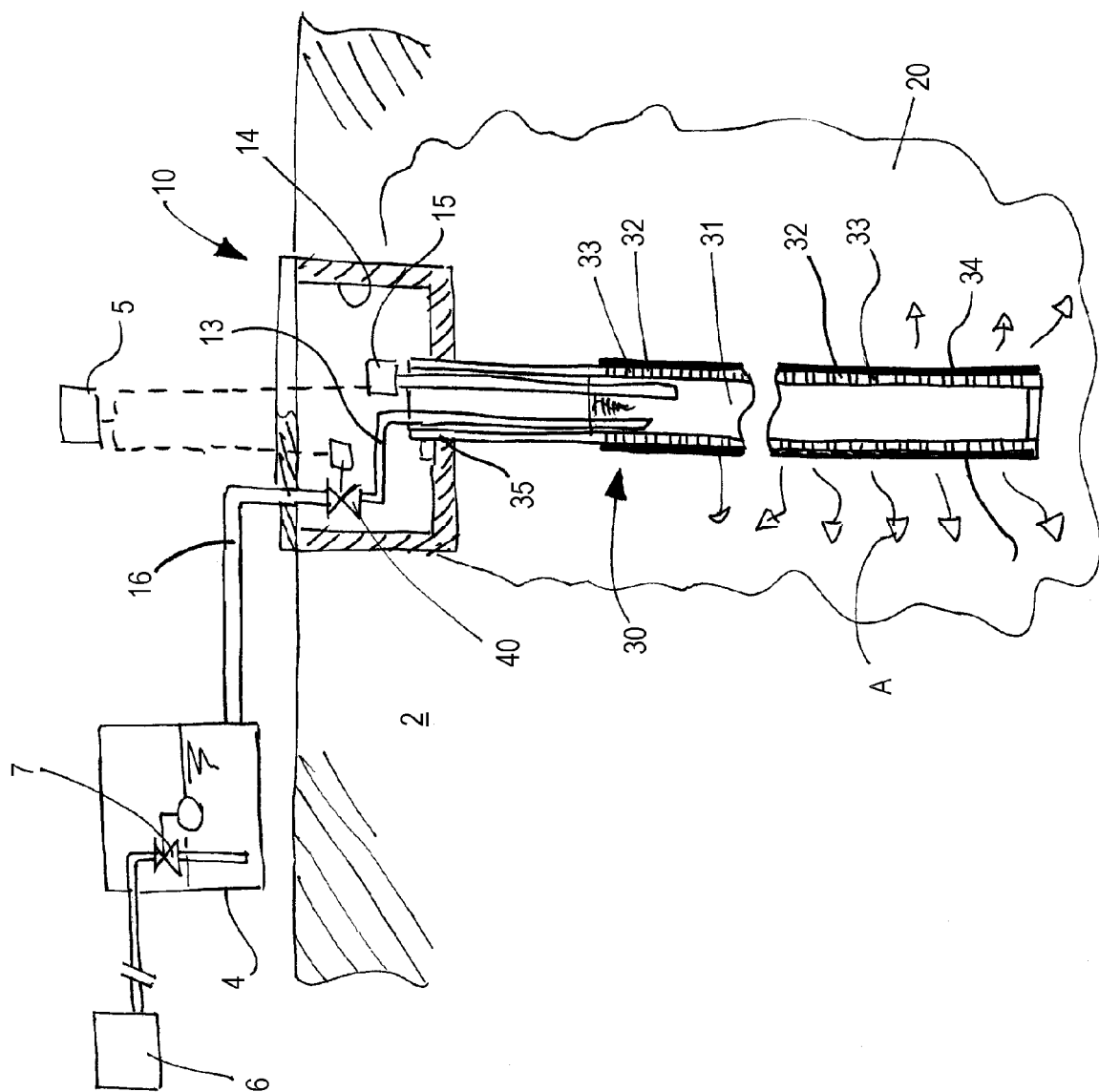


FIG.3

