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(54) **A method of consolidating soil for foundation**

(57) A method for consolidating foundation soils, comprising the operative steps of drilling a plurality of holes (1) in the soil, injecting into the soil through each hole (1) at least an at least an expanding substance (6) in one or more injection points (5) to compact the soil in proximity to said injection points (5) and monitoring the level of the soil to determine its rise. Moreover, for injection in each injection point (5), a minimum quantity of expanding substance (6) to be injected is determined, both as a function of the conditions of the soil in proximity to the injection point (5), and of the characteristics of the expanding substance (6), the quantity of expanding substance (6) injected into the soil is measured and compared to the determined minimum quantity. The injection of the expanding substance (6) is stopped when the injected quantity is at least equal to the minimum quantity, and the soil has risen by a predetermined minimum value, the consolidation being deemed to be effected in that moment. Advantageously, the expanding substance can expand less than five times.

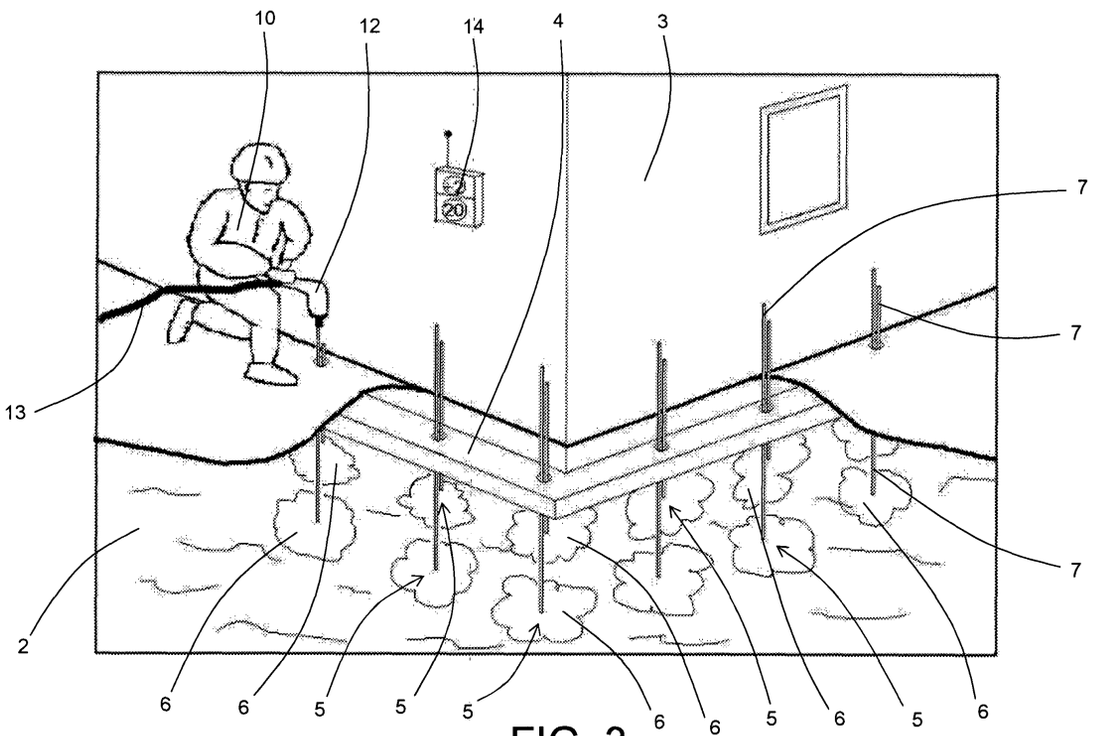

FIG. 3

EP 1 536 069 A1

Description

[0001] The present invention relates to a method for consolidating foundation soils, which is also used for lifting civil building structures and artefacts of any kind (hereinafter globally indicated as buildings) by using expanding substances, in particular resins.

[0002] Heretofore, consolidation techniques with expanding resins have been based on a technology that used some fixed parameters as operating procedures, and in which the expanding resin was studied more in view of the need to raise the structure rapidly, than of a real and definitive consolidation of the soils.

[0003] Such resins constituted by mixtures of polyols and MDI isocyanates were initially used to raise collapsed floors, for example as described in US Patent 4,567,708.

[0004] Subsequently, such resins were progressively used also for injections under the foundations of buildings, at different depths (see for instance the Italian patent application no. MI96A002520 and the corresponding European patents EP 851 064 e EP 941 388).

[0005] Said patent in particular discloses the use of expanding resins with the ability to expand in free air at least five times their initial volume, combined with a monitoring of the raising of the structure to be consolidated. According to the teaching of said patent, consolidation should be deemed to be achieved when the structure starts to rise.

[0006] The building is monitored by generally using a laser level and a millimetric sensor applied to the building structure to be consolidated.

[0007] Hence, to date the state of the art provides two teachings.

[0008] On one hand, the injection, both just below the foundation plane, and in depth, of the expanding resin by any method (i.e. both injecting into multiple, vertically distanced points and into an entire vertical hole obtained in the soil, as taught for example by the patent EP 851 064), but with the provision that the level of the overlying building must be constantly monitored, taking for granted that in the moment when the building starts to rise a consolidation level exceeding the minimum one required for this intervention has been obtained. It was deemed that when the dynamic thrust of the resin inside the soil discharged its power only upwards, and thus won over the force induced by the static load of the building, that was the moment when the underlying soil could be considered, with reasonable certainty, consolidated.

[0009] On the other hand, the state of the art teaches the use of an expanding resin that is capable of increasing its own volume by at least five times when expanding in free air (free air expansion means the expansion of the material freely without said material being confined in a predetermined volume).

[0010] Little innovation was provided, relative to what is described above, by the patent EP 1 314 824, which simply discloses the use, to consolidate soils requiring consolidation pressures exceeding 500 kPa, of expanding resins capable of developing pressures greater than 500 kPa.

[0011] However, these known technologies have some drawbacks.

[0012] A first drawback is caused by the fact that the moment of consolidation is identified as the moment when the soil and/or the overlying building start to rise.

[0013] In the course of its direct and multi-year experience, the Applicant has noted that this system of determining the consolidation of the soil has a high likelihood of error because it does not take into account the geo-technical characteristics of the soil itself. Attempts have been made to overcome this drawback by conducting geo-technical surveys, in particular performing penetration measuring tests.

[0014] Such tests are normally conducted by sampling in two or three points, adjacent to the building to be consolidated. Considering that the composition of the soils can vary very rapidly even at short distances, it would be necessary to perform the tests in every injection point, which is a complicated operation, or even impossible in some cases, in addition to being highly onerous.

[0015] The consequence of such difficulties is the lack of a parameter that allows to determine with reasonable certainty the moment when the soil is consolidated and therefore, though injecting the expanding resin underneath a building structure sooner or later always leads to its rise, only in some cases does that rise correspond to the definitive consolidation of the foundation soil, meaning by definitive consolidation of the soil such a state of compaction as to assure stable support to the overlying structure over time.

[0016] With the experience of thousands of interventions already made, the Applicant has observed that in some cases the structure rises immediately with a few kilograms of expanding material injected into the significant pressure bulb (for the definition of significant pressure bulb, see farther on), whilst in other cases, in spite of the repeated injection of many kilograms of expanding material, the soil fails to rise or rises only slightly and it subsequently drops again after a short time.

[0017] For example, if a soil collapse was not caused by a collapse of the surface layers of the soil, which are well consolidated, but by a collapse of the deeper layers, the injection of an expanding substance into the surface layers causes an immediate rise of the overlying structure. If the only check that consolidation has been accomplished is based, as taught by the patents EP 851 064, EP 941 388 and EP 1 314 824, on the rise of the soil, it is immediately

apparent that in fact a mistake is made, since in actuality there is only a false consolidation. The deep layers have not been consolidated, in within a short time span they will cause the soil to collapse again.

[0018] The diversity of the results obtained in similar interventions, conducted in different sites, depends on many concurrent factors, i.e. on the type of soil, on the presence or absence of cavities, on the amplitude of the foundation plane, on the depth of the injections, and on the quantity of water contained in the soil.

[0019] Considering that, even in the presence of geological tests, the type of soil and its dynamic resistance can determined with precision only in part, and that such data are in any case impossible to obtain or it is not economically feasible to verify them in every point where the injections are to be made, merely monitoring the rise of the structure is insufficient to determine with reasonable certainty whether consolidation has been achieved. It is therefore indispensable to determine the state of consolidation of the soil in a different, more reliable manner than is provided by currently known methods.

[0020] A second drawback of currently known techniques is linked to the type of resin used.

[0021] According to the operating procedures used today, although the aforementioned patents provide for the use of resins with free air expansion coefficient of at least five times the initial volume, in practice the expansion coefficients of actually utilised resins usually are 15-25 times the initial volume (operators in the industry are convinced that the greater the expanding capacity, and the smaller the speed of expansion, the better are the results achievable in terms of consolidation), whereto corresponds a free air density (i.e. a density after the resin has expanded in free air) of 40-66 kg/m^3, and a compression resistance ranging from 4 to 5 kg per square centimetre.

[0022] However, it has been verified in the field that such resistance is merely theoretical, since these resins, expanded nearly in free air, have an elastic behaviour if subjected to compression.

[0023] In the frequent case in which a resin with the characteristics described above is injected below the foundations and into the foundation soil, and encounters voids due to wash-off, vertical fissures due to drying, or cavities of any kind and nature, it momentarily expands until it fills the existing void as if it were in free air, thus assuming the compression resistance characteristics described above.

[0024] In cases of this kind, it has been verified that the consolidation provided by the resin is absolutely insufficient both to assure the necessary lift to support the structure and the durability of the consolidation intervention.

[0025] It is no accident that the result of many consolidation interventions conducted with expanding resins of the kind described above has been to provide a momentary improvement of the static conditions of the structure but not comforted by its duration over time, since the expanded resin, stressed by the load, tended slowly to compress, even slightly, causing the re-opening of the cracks in the overlying structure.

[0026] In this situation, a technical task constituting the basis of the present invention is to provide a method for consolidating foundation soils that overcomes the aforementioned drawbacks.

[0027] In particular a technical task of the present invention is to provide a method for consolidating foundation soils in which the achieved consolidation can be determined with greater certainty than in currently known consolidation methods.

[0028] Another technical task of the present invention is to provide a method for consolidating foundation soils that assures the duration of the consolidation intervention over time.

[0029] The specified technical task and the indicated aims are substantially achieved by a method for consolidating foundation soils as described in the appended claims.

[0030] Further features and advantages of the invention shall become more readily apparent from the detailed description of some preferred, but not exclusive, embodiments of a method for consolidating foundation soils, described with reference to the accompanying drawings, in which:

- Figures 1, 2 and 3 respectively illustrate three successive operating steps of a method according to the present invention.

[0031] The method for consolidating foundation soils of the present invention comprises a first operating step in which a plurality of holes 1 is drilled in the soil 2 to be consolidated, appropriately distanced from each other, with a distance between centres, for example, of one metre. In case of consolidation of an existing building 3, the holes 1 are drilled in proximity to the foundations 4 thereof (Figure 1).

[0032] Said holes 1 can be drilled both vertical and inclined relative to the vertical, in particular in such a way as to extend underneath the foundation plane.

[0033] Advantageously, the holes 1 involve the significant pressure bulb of the foundations 4, where the significant pressure bulb is the area of the soil underlying the foundation plane, involved by a pressure, exerted by the foundations 4 themselves, of significant value. Conventionally, the significant pressure bulb is identified in a band of soil underlying the foundation plane, as wide as the base of the foundations 4 and twice as deep (starting from the foundations) as its width.

[0034] In the second step of the method are identified, along each hole 1, one or more injection points 5, in corre-

spondence with which an expanding substance 6 will be injected into the soil to compact the soil itself.

[0035] Alternatively, the injection may also involve the entire hole 1, which thus coincides with the injection point 5.

[0036] As shown in the accompanying drawings, in the case of injection points 5 not coinciding with the entire hole 1, for each injection point 5 is advantageously inserted into the hole 1 a tube 7 whose lower end is in correspondence with the injection point 5, and whose upper end 9 is accessible from the exterior by an operator 10. Obviously, the hole 1 must be drilled with sufficient diameter to allow the insertion of a number of tubes 7 equal to the number of injection points 5.

[0037] Before starting to inject the expanding substance 6, it is necessary to determine a minimum quantity of expanding substance 6 to be injected into each injection point 5, according both to the conditions of the soil in proximity to the injection point 5 and of the characteristics of the expanding substance 6.

[0038] It is necessary, during the injection phase, to reach or exceed said minimum quantity, in order to assure that the soil whereon the weight of a building 3 is definitively consolidated and stable.

[0039] In particular, according to the preferred manner of executing the present invention, the minimum quantity of expanding substance 6 to be injected into each injection point 5 is determined according to the degree of humidity of the soil in correspondence with the related injection point 5, in consideration of the fact that as water content increases, soils become more prone to deformation and their resistance consequently decreases.

[0040] Therefore, before being able to determine the minimum quantity of expanding substance 6 to be injected, a preliminary operating step is necessary during which the degree of humidity of the soil is measured in correspondence with each injection point 5.

[0041] According to the preferred embodiment, the measurement of the degree of humidity of the soil is obtained by measuring the electrical resistance of the soil itself, since there is a close correlation between the water content in the soil and its electrical resistance.

[0042] As stated, into the holes 1 are inserted the tubes 7 for the injections which are usually made of copper or aluminium, both materials with good electrical conductivity.

[0043] In consideration then of the correlation existing between the electrical resistance of the soil and its degree of humidity, it is sufficient to connect with an appropriate instrument 11, to two adjacent tubes 7 driven into the soil, to be able to measure the electrical resistance of the soil between them and thus determine the degree of humidity of the soil in that area (Figure 2).

[0044] Advantageously in any case, in an enhanced version of the present invention, only the end of each tube 7 are made of conducting material, in such a way as precisely to locate the measurement in the exact injection point 5.

[0045] By conducting the measurement between each pair of (both horizontally and vertically) adjacent injection points 5 it is possible to determine with good approximation the electrical resistance of the soil in that area.

[0046] For example, if for a hole 1 two injection points at different depths are planned, for each of them it will be possible to measure the electrical resistance both in relation to the overlying or underlying injection point 5, and to the two injection points 5 positioned at its sides in the horizontal plane (or anyway to the two injection points 5 closest to it). By calculating the weighted average of the values thus obtained, it will be possible to determined with good precision the electrical resistance of that area of the soil, and consequently the degree of humidity.

[0047] Depending on requirements, the number of measurements taken may be adapted to the individual operative case. For instance, resistance may be measured in relation to a single injection point 5 for each hole 1.

[0048] As stated, the minimum quantity of expanding substance 6 to be injected depends on the characteristics of the expanding substance 6, in particular on its expansion capacity.

[0049] The following Table 1 shows the free air expansion coefficients of seven types of expanding substance 6, constituted by a resin of the type described below, generically designated with the letters A, B, C, D, E, F, and G.

TABLE 1

	RESIN TYPE						
	A	B	C	D	E	F	G
EXPANSION COEFFICIENT OF THE RESIN USED	4.8	4.6	4.4	4.2	4.0	3.5	3.0
DENSITY AFTER EXPANSION IN FREE AIR OF THE RESIN USED, kg/m^3	208	218	228	238	250	286	333

[0050] The following Table 2 instead shows the minimum quantity to be injected for each of the resins of Table 1, as a function of the electrical resistance of the soil (and hence of its degree of humidity).

[0051] The average data shown in this table refer to standard soils, such as clay or clay-silt soils with the presence of sand and/or gravel, with few cavities of limited size. Moreover, the table was determined for injection points 5 positioned at a distance of one metre from each other.

MINIMUM QUANTITY OF RESIN TO BE INJECTED IN kg		RESIN TYPE						
		A	B	C	D	E	F	G
ELEC	Up to 50 kohm	65	68	71	74	77	83	89
	From 50 to 150 kohm	53	54	55	56	57	59	61
	From 150 to 300 kohm	46	47	48	49	50	52	54
	From 300 to 500 kohm	42	43	44	45	46	48	50
	From 500 to 800 kohm	36	37	38	39	40	42	44
	From 800 to 1200 kohm	28	29	30	31	32	34	36
	From 1200 to 1800 kohm	24	25	26	27	28	30	32
	From 1800 to 2500 kohm	20	21	22	23	24	26	28
	Over 2500 kohm	16	17	18	19	20	22	24

Table 2

[0052] In general, the table must be obtained empirically for each type of soil and each type of expanding substance 6, by means of field tests. In particular, it will be necessary to verify with appropriate tests whether for a given quantity of resin injected for each injection point 5 a good compaction is actually achieved or not (see also what is stated below about monitoring the soil level).

[0053] Thus, if a table similar to Table 2 is available for each type of soil, once the resistance of the soil to be consolidated is measured in correspondence with each injection point 5, for each of them the minimum value of expanding substance 6 to be injected can easily be determined.

[0054] In general, the minimum quantity of expanding substance 6 to be injected into each injection point 5 increases as the free air expansion capacity of the expanding substance 6 decreases, and as the electrical resistance of the soil

[0055] in that injection point 5 decreases.

[0056] At this point the operator 10 can start injecting the expanding substance 6 into the soil in correspondence with each injection point 5.

[0057] During the injection, the method of the present invention also provides for the continuous monitoring of the level of the soil and/or of a building 3 bearing thereon to determine the rise of the soil itself, and for measuring the quantity of expanding substance 6 injected into the soil, and comparing said value with the value of the minimum quantity to be injected, determined for that injection point 5.

[0058] As shown in Figure 3, the injection is performed by the operator 10 by means of a gun 12 fed, through an injection pump (not shown), from a tank (not shown) of the expanding substance 6 (or from multiple tanks, through several pumps, when the expanding substance 6 is obtained by mixing two or more components in the injection point 5.

[0059] Both the injection pump and the conduits 13 which extend between the tank and the gun are appropriately heated to maintain the expanding substance 6 at the optimal temperature, in known ways.

[0060] Advantageously, the operator 10 can be provided with a display 14 enabling to view the values of the quantity of substance 6 injected and of the rise of the soil or of the building 3.

[0061] The injection of the expanding substance 6 is stopped when the injected quantity is at least equal to the

minimum quantity, provided the soil and/or the building 3 bearing thereon have risen by a predetermined minimum value, which is usually no less than 1 mm.

[0062] In general, the predetermined minimum value is not a constant, but must be determined for each intervention according to the extent of the required consolidation (this value in particular varies with the extent of the collapses of the soil which made the consolidation intervention necessary). Said minimum value can therefore vary also from one point to another in the same intervention.

[0063] To assure an even better consolidation result, however, if, before reaching the minimum quantity of expanding substance 6, the soil and/or the building 3 bearing thereon have risen by an amount exceeding a predetermined maximum value (also variable from one intervention to the other, similarly to the predetermined minimum value) beyond which there is a risk of damaging the building 3, the injection step is cancelled and a new injection point 5 for which the steps described heretofore are repeated. Said new injection point can be selected in the same hole 1 at a different depth, in an extension thereof, or in a new hole 1 drilled in proximity thereto.

[0064] Said procedure may be repeated several times until an injection point 5 is identified for which a quantity of expanding substance 6 at least equal to the predetermined minimum quantity can be injected.

[0065] The safety check described above is opportune in particular when although a soil collapse has taken place, the surface layers of that soil are well consolidated, and the deeper layers were the ones that collapsed (as described above in relation to the drawbacks of currently used techniques).

[0066] In this case, all injections will have to be conducted at great depth.

[0067] According to the preferred embodiment of the method of the present invention, an expanding substance 6 is to be used which is able to expand its own volume in free air less than five times, and which consequently has, after free air expansion, a density of at least 200 kg per cubic metre. Preferably, said expanding substance 6 has an expansion coefficient of between three and five times.

[0068] Advantageously, said type of expanding substance 6 used has, after expansion in free air, a compression resistance of at least 5 kg per square centimetre, and preferably at least 9 kg per square centimetre, with deformation of less than 0.5%.

[0069] Preferably, the expanding substance 6 is a resin which expands by means of a chemical reaction, and which is constituted by a mixture of two components, a polyol/polyether such as the polyol Eterol 317/X1 produced by the Company Polychem System, and an MDI based isocyanate, such as the MDI isocyanate Desmodur VKS 20 F produced by Bayer.

[0070] According to a different embodiment of the consolidation method of the present invention, two or more expanding substances with different expanding capacity are injected into different injection points 5. Preferably, in any case, all expanding substances to be used will have an expansion coefficient lower than five.

[0071] In particular, for a hole 1 where two superposed injection points 5 are planned, in each of said two superposed injection points 5 may be injected two different expanding substances 6, chosen in such a way that the expanding substance 6 injected into the deeper injection point 5 has greater expansion capacity than the expanding substance 6 injected into the less deep injection point 5.

[0072] The operating steps described above can be managed directly by an operator 10, or with the aid of a programmable electronic control unit which, for instance, can store the data relating to the electrical resistance of the soil determining for each point the minimum quantity of substance 6 to be injected, monitor soil level and the quantity of substance 6 injected and disable the dispensing of the substance 6 once the aforesaid conditions are met, or once the predetermined maximum value of rise is exceeded.

[0073] The present invention thus achieves important advantages.

[0074] In the first place, the method for consolidating foundation soils of the present invention assures the ability to determine with greater certainty than currently known consolidation methods the moment in which the soil can be deemed to be consolidated.

[0075] The durability of the consolidation intervention over time is thereby assured.

[0076] Additionally, considering that on average foundations are computed to discharge on the soil from a minimum of 0.2-0.3 kg per square centimetre to a maximum of 3-3.5 kg per square centimetre, an absolute lift of at least 9 kg per square centimetre (as is assured by the method of the present invention which uses expanding substances able to expand less than five times), and said term means that said load bearing capacity is guaranteed with deformations of less than 0.5%, amply complies with all safety margins required by construction codes.

[0077] Said load bearing capacity was confirmed by conducting tests on samples of material expanded at atmospheric pressure (in free air).

[0078] Comparative tests conducted on currently used expanding resins, with an expansion coefficient of 15-25 times which entails theoretical compression resistance varying from 4 to 5 kg per centimetre square, have shown that the application of a load of 4-5 kg per square centimetre to samples of such resins expanded in free air causes deformation in proportion to the applied load, which highlight their indisputable elastic behaviour.

[0079] Additionally, the correlation between consolidation quality to the quantity of water present in the soil has prov-

en, in numerous tests conducted, to be an optimal choice which combines ease of implementation with the reliability of the information thereby obtained.

[0080] It should further be noted that the present invention is relatively easy to implement and that the cost connected with the implementation of the invention is not very high, compared to industry standards.

[0081] The invention thus conceived can be subject to numerous modifications and variations, without thereby departing from the scope of the inventive concept that characterises it.

[0082] All components can be replaced with other, technically equivalent elements and in practice all materials employed, as well as the shapes and sizes of the various components, may be any depending on requirements.

Claims

1. A method for consolidating foundation soils, comprising the operative steps of:

drilling a plurality of holes (1) in the soil;
injecting into the soil through each of said holes (1) at least an expanding substance (6) in one or more injection points (5) to compact the soil in proximity to said injection points (5); and
monitoring the level of the soil and/or of a building (3) bearing thereon to determine its rise;

characterised in that it further comprises, for injection in each injection point (5), the operative steps of:

determining a minimum quantity of expanding substance (6) to be injected, both as a function of the degree of humidity of the soil in correspondence with the related injection point (5), and of the expansion capacity in free air of the expanding substance (6);
measuring the quantity of expanding substance (6) injected into the soil; and
comparing the quantity of substance (6) injected to said minimum quantity;

the injection of the expanding substance (6) being stopped when the injected quantity is at least equal to said minimum quantity, and said soil and/or the building (3) bearing thereon have risen by a predetermined minimum value, the consolidation being deemed to be effected **in that** moment.

2. A method for consolidating foundation soils as claimed in claim 1
characterised in that it further comprises, before said step of determining the minimum quantity of expanding substance (6) to be injected, the operative step of measuring the degree of humidity of the soil in correspondence with the injection point (5).

3. A method for consolidating foundation soils as claimed in claim 2
characterised in that said step of measuring the degree of humidity of the soil is carried out measuring the electrical resistance of the soil itself.

4. A method for consolidating foundation soils as claimed in claim 3
characterised in that the electrical resistance of the soil is measured between pairs of adjacent injection points (5).

5. A method for consolidating foundation soils as claimed in claim 3
characterised in that the electrical resistance of the soil is measured between pairs of adjacent holes (1).

6. A method for consolidating foundation soils as claimed in any of the claims from 3 to 5 **characterised in that** the minimum quantity of expanding substance (6) to be injected into each injection point (5) increases as the electrical resistance of the soil **in that** injection point (5) decreases.

7. A method for consolidating foundation soils as claimed in any of the previous claims **characterised in that** the minimum quantity of expanding substance (6) to be injected into each injection point (5) increases as the expansion capacity in free air of the expanding substance (6) decreases.

8. A method for consolidating foundation soils as claimed in any of the previous claims **characterised in that** said expanding substance (6) is able to expand its volume in free air by less than five times.

9. A method for consolidating foundation soils as claimed in any of the previous claims **characterised in that** said

expanding substance (6) is able to expand its volume in free air by between three and five times.

10. A method for consolidating foundation soils as claimed in any of the previous claims **characterised in that** said expanding substance (6) has, after expansion in free air, a density exceeding 200 kg per cubic metre.

11. A method for consolidating foundation soils as claimed in any of the previous claims **characterised in that** for said injection step an expanding substance (6) is used which, after expansion in free air, has a compression resistance of at least 5 kg per square centimetre with deformation of less than 0.5%.

12. A method for consolidating foundation soils as claimed in claim 11 **characterised in that** the expanding substance (6), after expansion in free air, has a compression resistance of at least 9 kg per square centimetre with deformation of less than 0.5%.

13. A method for consolidating foundation soils as claimed in any of the previous claims **characterised in that** said expanding substance (6) expands by means of a chemical reaction.

14. A method for consolidating foundation soils as claimed in any of the previous claims **characterised in that** said expanding substance (6) comprise a mixture of polyols/polyethers and of MDI base isocyanate.

15. A method for consolidating foundation soils as claimed in any of the previous claims **characterised in that** said holes (1) are drilled vertical.

16. A method for consolidating foundation soils as claimed in any of the previous claims **characterised in that** said holes (1) are drilled inclined relative to the vertical.

17. A method for consolidating foundation soils as claimed in any of the previous claims **characterised in that**, for each hole (1), multiple injections of expanding substance (6) are performed in correspondence with injection points (5) located at different depths.

18. A method for consolidating foundation soils as claimed in any of the claims from 1 a 16 **characterised in that**, for each hole (1), a single injection of expanding substance (6) is performed for the entire length of the hole (1), said hole (1) coinciding with a single injection point (5).

19. A method for consolidating foundation soils as claimed in any of the previous claims **characterised in that** said minimum predetermined rise value is at least 1 mm.

20. A method for consolidating foundation soils as claimed in any of the previous claims **characterised in that** said injection points (5) are located below the foundations (4) of a building (3) to be consolidated.

21. A method for consolidating foundation soils as claimed in any of the previous claims **characterised in that** said injection points (5) are located inside the significant pressure bulb of the foundations (4) of a building (3) to be consolidated.

22. A method for consolidating foundation soils as claimed in any of the previous claims **characterised in that** it provides for the injection of two or more of said expanding substances (6) with different expanding capacity, into distinct injection points (5).

23. A method for consolidating foundation soils as claimed in claim 22 **characterised in that** for at least a hole (1) are provided two superposed injection points (5), and **in that** in each of said two superposed injection points (5) are injected two different expanding substances (6), the expanding substance (6) injected into the deeper injection point (5) having greater expansion capacity than the expanding substance (6) injected into the less deep injection point (5).

24. A method for consolidating foundation soils as claimed in any of the previous claims **characterised in that** if the soil and/or the construction (3) which bears thereon have risen by a value exceeding a predetermined maximum value before said minimum quantity of expanding substance (6) has been injected, said injection step is cancelled and a new injection point (5) is identified and for said new injection point (5) all said operative steps are carried out.

25. A method for consolidating foundation soils as claimed in claim 24
characterised in that the identification of a new hole (1) is repeated until for an injection point (5) the injection of the expanding substance (6) is stopped because the injected quantity is at least equal to said minimum quantity, and said soil and/or the building (3) which bears thereon have risen by said predetermined minimum value.

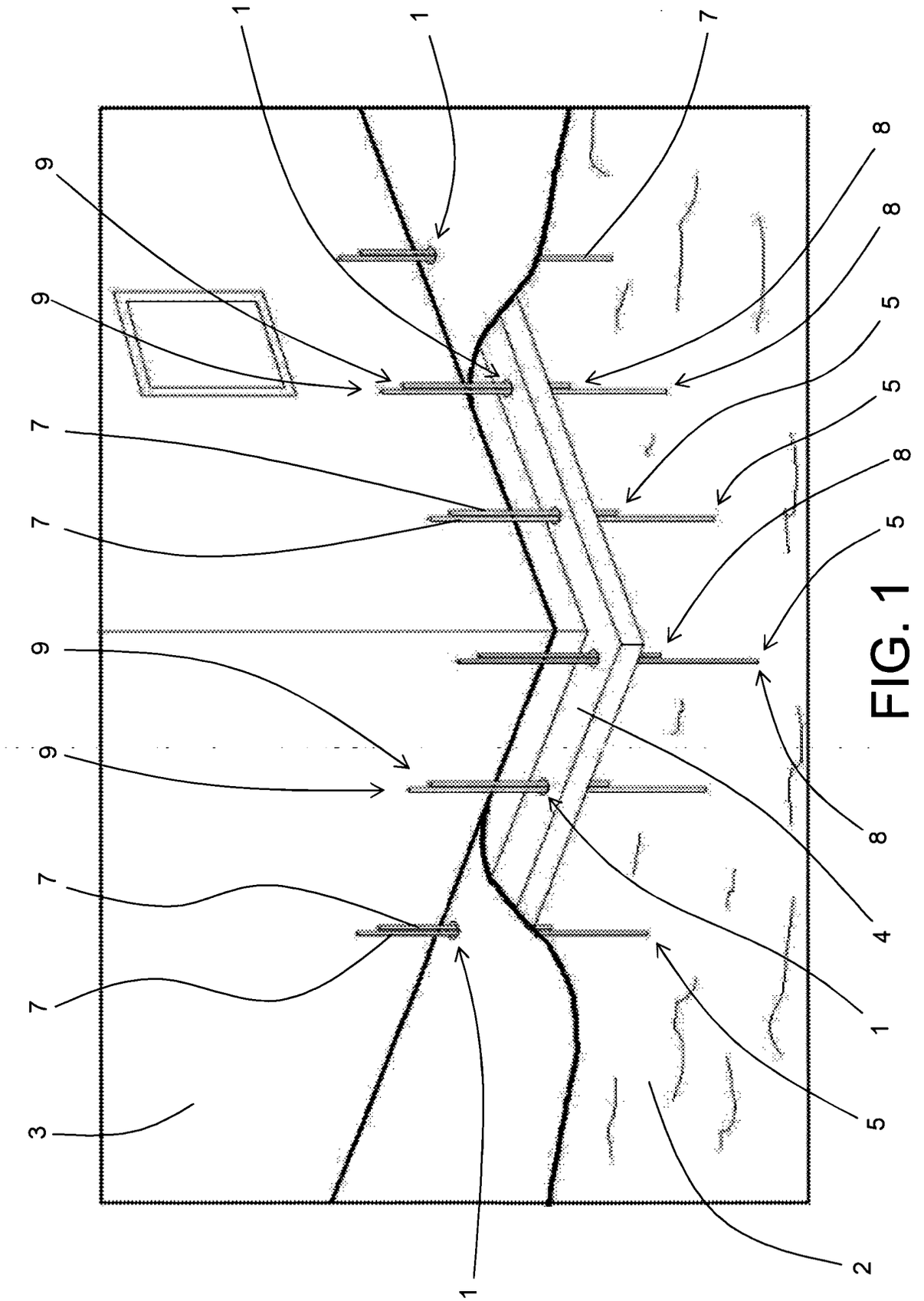

FIG. 1

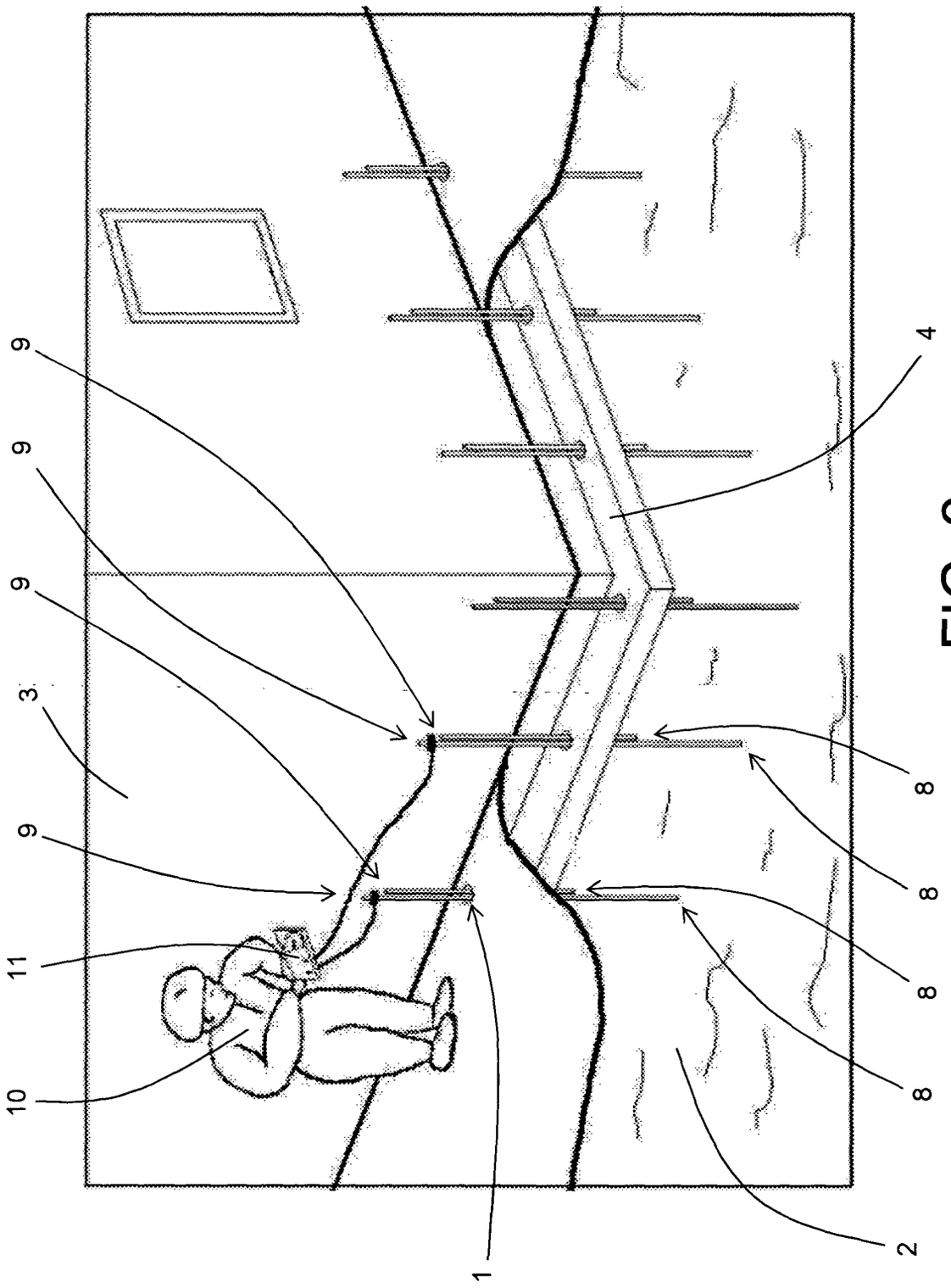

FIG. 2

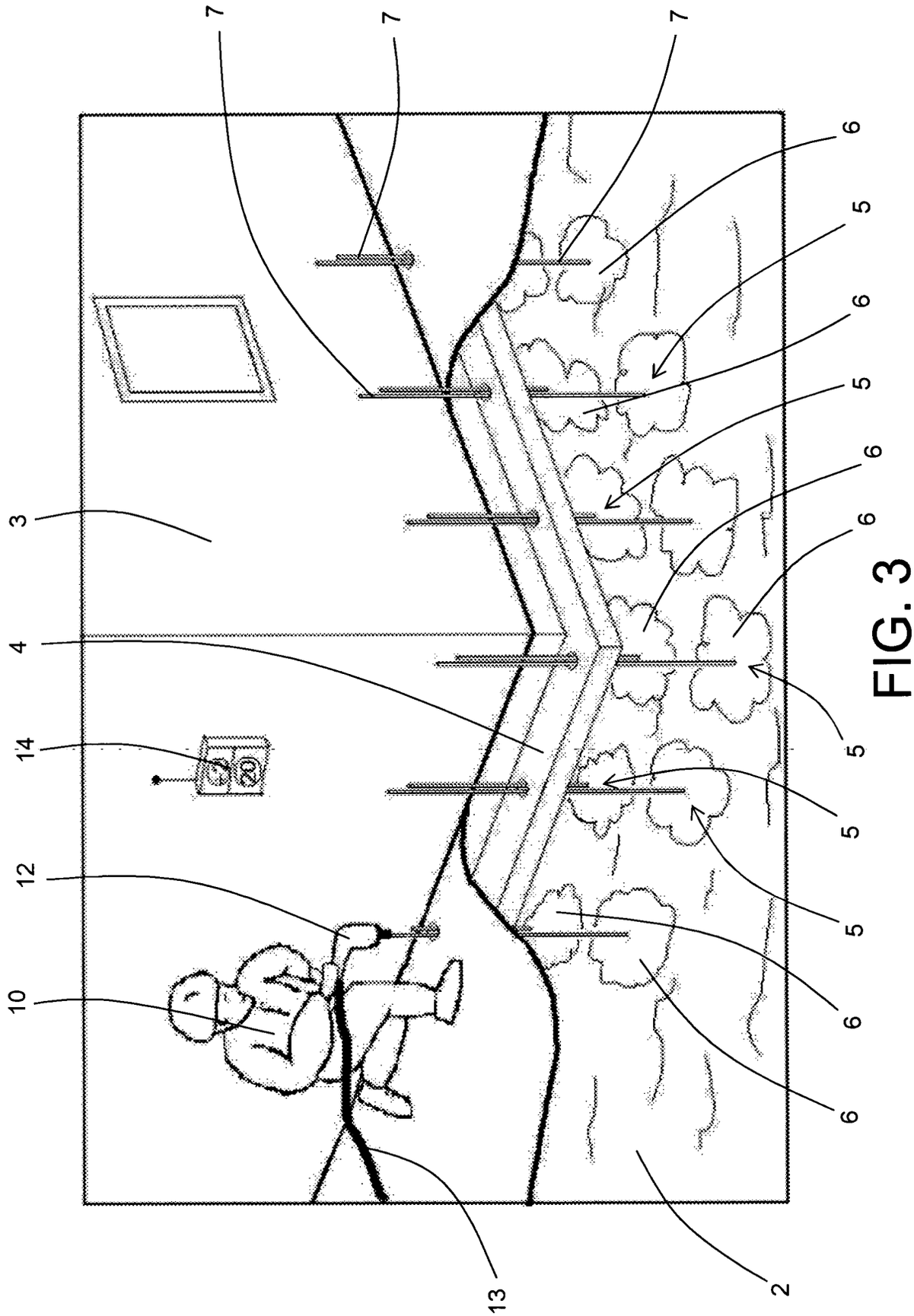

FIG. 3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 03 42 5756

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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A	DE 198 42 072 C (SCHOENBERGER MARTIN) 28 October 1999 (1999-10-28) * column 1, line 3 - column 3, line 10; figures 1-3 * -----	1-25	TECHNICAL FIELDS SEARCHED (Int.Cl.7) E02D C09K

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	4 May 2004	Geiger, H

CATEGORY OF CITED DOCUMENTS

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1

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