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(54) Ground improvement

(57) Pillar structures 56 are formed by repeatedly vibrating an elongate lance member down into the ground and withdrawing, filling the resultant cavity with additional material (preferably ameliorated soil) and reintroducing the lance, to cause compaction of the material. A

large weight is dropped at the top of each pillar, to flare out the surface region. A pavement 52 is then formed at the surface, by rotavation of the surface layer while mixing in further ground amelioration material. The result is a form of vaulted construction which can be used as a base for building etc.

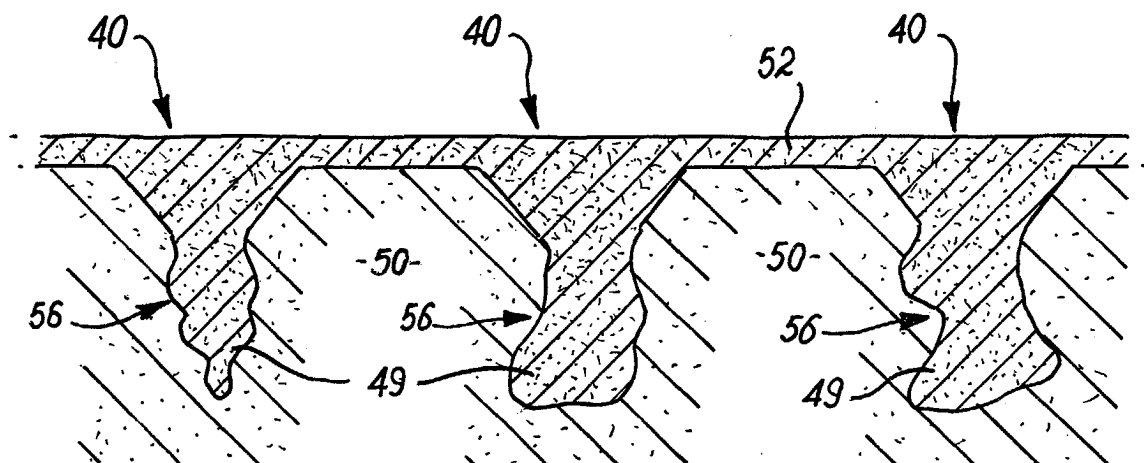


Fig 8

EP 1 382 750 A1

Description

[0001] The present invention relates to ground improvement, particularly, but not exclusively, prior to building.

[0002] The present invention provides a method of ground improvement, in which an array of locations is locally improved by vibrating a lance member into the ground repeatedly at each location, withdrawing the lance member to leave an elongate cavity, and introducing additional material into the cavities so formed, prior to the reintroduction of the lance member to compact the additional material and the surrounding ground,

and in which a cap formation is provided at each improved location by forming a depression at the surface and filling the depression with material which includes ground amelioration material,

and in which a surface layer of the ground is disturbed to mix the ground with a ground amelioration material to form a pavement which interconnects cap formations at the improved locations.

[0003] In this specification, the term "ground amelioration material" refers to a material which consists of, or includes, a binder capable of increasing cohesion in material such as soil. The binder may be a settable material such as a cementitious material. Preferably, the binder is cement. Alternatively, bitumen may be used as a binder. Ground amelioration material may also incorporate additional granular material such as pulverised fuel ash, and hydrophilic material such as quick lime, to assist in controlling pore pressure of the material and of the surrounding ground. The term "ameliorated soil" is used to refer to soil, preferably derived locally, into which ground amelioration material has been mixed.

[0004] The additional material introduced into the cavities may be particulate and may comprise stone, gravel or another aggregate material. The additional material preferably includes ground amelioration material. The additional material may comprise soil mixed with ground amelioration material.

[0005] The lance member may be repeatedly introduced at the same position, until heave is detected in the ground around that position.

[0006] The surface depressions are preferably formed by impact from a dropped weight. The dropped weight may be a tapered member having a relatively narrow nose, forming a point of first contact with the ground, and widening from the nose. The dropped weight may widen to a width greater than the lance member, whereby to flare out the top of the material compacted by the lance member.

[0007] An example of the present invention will now be described in more detail, by way of example only, and with reference to the accompanying drawings, in which:

Fig. 1 is an elevation of a lance member for use in accordance with the method of the invention;

Figs. 2 and 3 illustrate the sequence of steps of a first part of the method;

Fig. 4 is an elevation of a weight for use in a second part of the method;

Figs. 5, 6 and 7 show the sequence of steps of the second part of the method; and

Fig. 8 illustrates the third part of the method and the final condition of the ground.

[0008] The drawings illustrate a method of preparing ground in accordance with the present invention. The method is primarily intended for bad ground which has low natural load bearing capacity. Bad ground may, for example, include peat. It will be understood by the skilled reader that in many practical situations, no clear delineation can be made between good ground and bad ground, there being a continuous spectrum of ground quality. Indeed, the term "marginal ground" is sometimes used to refer to ground which is between good and bad ground. Consequently, the choice of technique to be used will be made in accordance with the quality of the ground in its natural state, the nature of the load imposed by the building to be constructed and other factors.

[0009] Fig. 1 shows a lance member 14, for use in the method of the invention. The lance is used to provide local improvement of the ground at each location of an array of locations across the area being improved. At each location, the lance 14 is driven into the ground by vibration, to form an elongate cavity 16 (Fig. 2) in the ground 17. The lance 14 is then withdrawn and the cavity 16 is filled with additional material 19. The additional material may be particulate in nature, such as stone, gravel or another aggregate. Alternatively, the additional material may be ground amelioration material, or ameliorated soil.

[0010] Preferably quick lime is included in the additional material. The presence of quick lime, which is highly hydrophilic, causes ground water to be drawn strongly from the surrounding ground 17, causing a significant reduction in local pore pressure. Consequently, the addition of quick lime is particularly preferred in locations at which excessive pore pressure is expected to be a problem. The reduction in pore pressure helps overcome any tendency of fine-grained soils to liquefy during the procedure.

[0011] The lance 14 has an inverted frusto-conical shape. In one example, the lance 14 may have a diameter of about 300mm at its upper end and about 150mm at its lower end 14A, with a length of approximately 3m. The lance 14 is attached to extend down, substantially vertically, from a vibrator arrangement 18 which applies vertical oscillation to the lance 14 during use. For example, the vertical oscillation may have an amplitude of about 25mm and a frequency of 1500 cycles per minute,

with a rated impact per blow in excess of 40 tonnes. The cone angle of the lance 14 may be low, such as between 2° and 5°.

[0012] In consequence of the shape of the lance 14 and the use of vertical vibration, the lance 14 will be driven into the ground substantially without impact in a horizontal direction between the surface of the lance 14 and the sides of the cavity 16. That is, the main impact with the ground will be at the bottom of the cavity 16 as the lance 14 forces itself deeper into the ground.

[0013] Contact with the sides of the cavity 16 will consist primarily of a pressing action, causing ground material to be pressed gently sideways to form the cavity 16, without harsh impacts. Avoiding impacts in this manner results in the technique minimising shocks which can result in increased pore pressure in water-laden ground and, in extreme cases, can cause liquefaction of ground. Depressions formed by impact can cause significant and sudden increases in pore pressure, with consequential disturbance to the ground at some considerable distance from the point of working.

[0014] The lance 14 can be driven, by vibration, to any chosen depth without causing pore pressure problems, whereas the depth of compaction created by impact must be limited because of the force of impact and the resultant shock waves of pore pressure.

[0015] Once the cavity 16 has been formed, the lance 14 is withdrawn. Additional material 19 is then introduced into the cavity. As has been described, the additional material may be particulate, but preferably includes ground amelioration material or is ameliorated soil. This introduction of additional material results in the intermediate situation illustrated in Fig. 2.

[0016] The lance 14 is then reintroduced into the ground, at the same location, and vibrated down to cause compaction of the additional material. This may result in bulging of the cavity 16, as shown at 38 (Fig. 3), arising from the inability of the surrounding ground 17 to contain the compaction forces created by the lance 14. The degree of bulging which occurs will depend on the size of downward compacting forces created by the vibration of the lance 14, and the natural capacity of the surrounding ground 34 to provide lateral containment of the additional material. The lance 14 is repeatedly vibrated in, removed and reintroduced after additional material has been introduced, until the cavity 16 is full of material which has been adequately compacted, with resultant bulging of the cavity.

[0017] Compaction of the additional material in the cavity 16 is preferably continued until the ground 17 is seen to heave upwardly (indicated at 39) around the position of the cavity 16. This heave indicates that no further additional material can be accommodated, and no further compaction is possible.

[0018] The next stage of the method is to provide a cap formation (to be described) at each of the locations which has been improved as described above. The cap formation is provided by forming a depression at the sur-

face, and filling the depression with material which includes ground amelioration material or ameliorated soil. The depression is preferably formed by impact from a dropped weight. A preferred device for use as a drop weight is shown in Fig. 4. The device 30 has a relatively narrow nose 32 which provides, in use, the point of first contact with the ground, when the device 10 is dropped. The device tapers down to the nose 32, over a portion 34. A clevis arrangement 36 allows the device 30 to hang from a cable 37 to allow the device 30 to be raised by a crane, and then dropped to the ground. The weight of the device 30 is preferably at least 2,500 kg and preferably considerably more, such as 7,500 kg or 8,000 kg. The portion 34 preferably widens at an angle of 14° or greater, i.e. greater than the so called Morse angle of 14°. (The angle is measured between the central (vertical) axis of the device 30, and the tapering outer surface of the portion 34). The Morse angle of 14° is generally considered as the minimum angle required, to prevent the device 30 sticking in the ground, after being dropped. An angle between 14° and 20°, preferably about 17° may be chosen.

[0019] Fig. 5 schematically shows the device 30, prior to it being dropped onto a location 40 which has already been improved by the first part of the method, in the manner described above. It is to be noted, and is preferred, that the device 30 is considerably wider than the lance 14, and is thus wider than the mouth 42 of the cavity 16.

[0020] The device 30 is then dropped to embed itself in the material of the cavity 16 and is then removed. The result is shown in Fig. 6. The compacted material previously introduced into the cavity 16 has been flared out at 44. The depression 46 is then filled with ground amelioration material to ground level, indicated at 48.

[0021] After the additional material has been introduced into the depression 46, the device 30 is dropped again and then removed, to form a further depression 30A. This results in additional outward and downward compaction of the surrounding ground 26. In addition, the additional material introduced prior to the drop is forced out into the surrounding ground forming a body of ameliorated soil around the depression 30A.

[0022] The process is then repeated again, by filling the depression with additional material, dropping the device 30 to form a depression (not shown) and then filling the resulting depression again. It is preferred that additional material is introduced after each drop, but in some circumstances it may be appropriate to drop the device 30 more than once, before further additional material is introduced.

[0023] Fig. 7 schematically shows three locations which have been treated in this manner, by means of the lance and subsequently by means of the device 30. The improved locations now form an array of pillars 49 of improved ground, separated by regions 50 which may still be in their original condition, but are likely to have been improved to some degree, as a result of the com-

paction, bursting etc. This completes the second part of the method.

[0024] Further steps are now taken to interconnect the structures which have been formed in the manner described above, across the whole area to be improved. A surface layer 52 of the ground 17 (the depth of which is indicated by a broken line 54 in Fig. 7) is disturbed and mixed with ground amelioration material. This may be achieved by using a rotavator device, introducing the ground amelioration material either before or after rotation. Alternatively, the material of the surface layer 52 may be removed for mixing and reintroduction. In a further alternative, the surface layer 52 may be disturbed to mix in ground amelioration material prior to the use of the lance 14. It is preferred that the surface layer 52 is formed without removing soil from the site, in order to speed up the process and minimise external environmental impact.

[0025] The surface layer 52 is preferably formed before cementitious binder introduced into the depressions 46 (and in the cavities 16, if they were filled with ground amelioration material including a settable binder) has set, so that a unitary structure is formed as shown in Fig. 8. Fig. 8 shows a series of neighbouring locations 40, interconnected by the surface layer 52. The surface layer 52 has been formed prior to the cementitious binder setting at the locations 40 and consequently, once the material sets, a single unitary structure is formed, consisting of supporting pillars 56 and a surface pavement 52. Naturally, the pillars 56 will be arrayed in two dimensions across the ground and thus, the pavement 52 will cover the entire area being treated, with support at each pillar 56. The result is a structure similar to a vaulted roof construction and with similar strength and load bearing characteristics arising from the unitary nature of the complete structure. The similarity with a vaulted roof is enhanced by the flaring achieved at the top of the pillars 56, by the use of the weight 30. However, it is expected that the load bearing capacity will be further increased by the presence of the ground between the pillars 56, which will provide lateral stability for the pillars 56, and support for the pavement 52. The load bearing capacity of the pavement 52 is thus expected to be greater than that of an unsupported pavement, by virtue of the support provided by the ground beneath, and by the pillars 56.

[0026] There has thus been described a method which can readily be used for good or bad ground. The method may be used to prepare ground for large commercial buildings such as retail sheds. Retail sheds may require relatively low loading on the ground over relatively large areas, with high loads around the edge of the building. Consequently, the unitary pillar and pavement structure described above can be used for providing adequate ground over the area of the building. It may be desirable to provide conventional piling systems at the edges of the building, to improve support for the building itself.

[0027] Various modifications and alterations can be made to the steps described above, without departing from the scope of the present invention. In particular, the number and layout of locations to be treated by the lance can be varied according to the original quality of the ground and the required final quality. The relative dimensions of the pavement and pillars may also be changed.

[0028] Additional steps can be incorporated in the method, to further improve the performance of the ground. For example, a large weight, in the form of a plate, may be dropped to provide additional compaction of the ground, prior to the formation of the surface pavement layer. The weight may be a device of the type described in International patent application no. WO 99/09261, particularly in relation to Figs. 9, 10 or 11 of that application. The weight is repeatedly dropped as it is moved across the ground, so that substantially the whole of the area has been subjected to impact from the weight, thus further consolidating the ground prior to the formation of the pavement layer. A final step of passing a roller over the site may be used, to further improve levelling and compacting.

[0029] Whilst endeavouring in the foregoing specification to draw attention to those features of the invention believed to be of particular importance it should be understood that the Applicant claims protection in respect of any patentable feature or combination of features hereinbefore referred to and/or shown in the drawings whether or not particular emphasis has been placed thereon.

Claims

1. A method of ground improvement, in which an array of locations is locally improved by vibrating a lance member into the ground repeatedly at each location, withdrawing the lance member to leave an elongate cavity, and introducing additional material into the cavities so formed, prior to the reintroduction of the lance member to compact the additional material and the surrounding ground,
and in which a cap formation is provided at each improved location by forming a depression at the surface and filling the depression with material which includes ground amelioration material,
and in which a surface layer of the ground is disturbed to mix the ground with a ground amelioration material to form a pavement which interconnects cap formations at the improved locations.
2. A method according to claim 1, wherein the additional material introduced into the cavities is particulate.
3. A method according to claim 2, wherein the additional material comprises stone, gravel or another aggregate material.

4. A method according to any preceding claim, wherein the additional material includes ground amelioration material.
5. A method according to any preceding claim, wherein the additional material comprises soil mixed with ground amelioration material. 5
6. A method according to any preceding claim, wherein the lance member is repeatedly introduced at the same position, until heave is detected in the ground around that position. 10
7. A method according to any preceding claim, wherein the surface depressions are formed by impact from a dropped weight. 15
8. A method according to claim 7, wherein the dropped weight is a tapered member having a relatively narrow nose, forming a point of first contact with the ground, and widening from the nose. 20
9. A method according to claim 8, wherein the dropped weight widens to a width greater than the lance member, whereby to flare out the top of the material compacted by the lance member. 25

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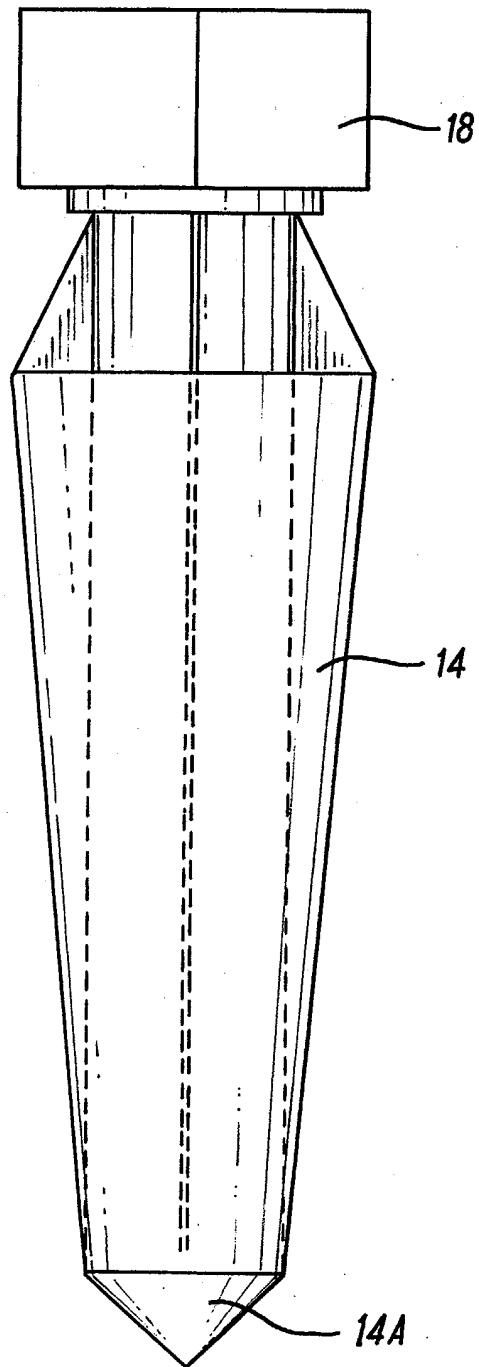


Fig. 1

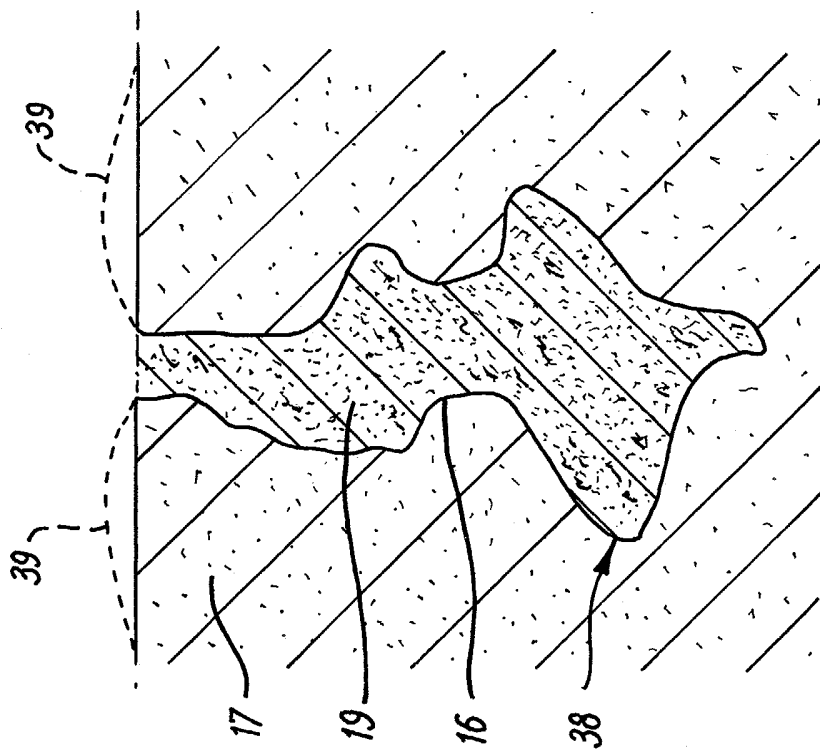


Fig. 3

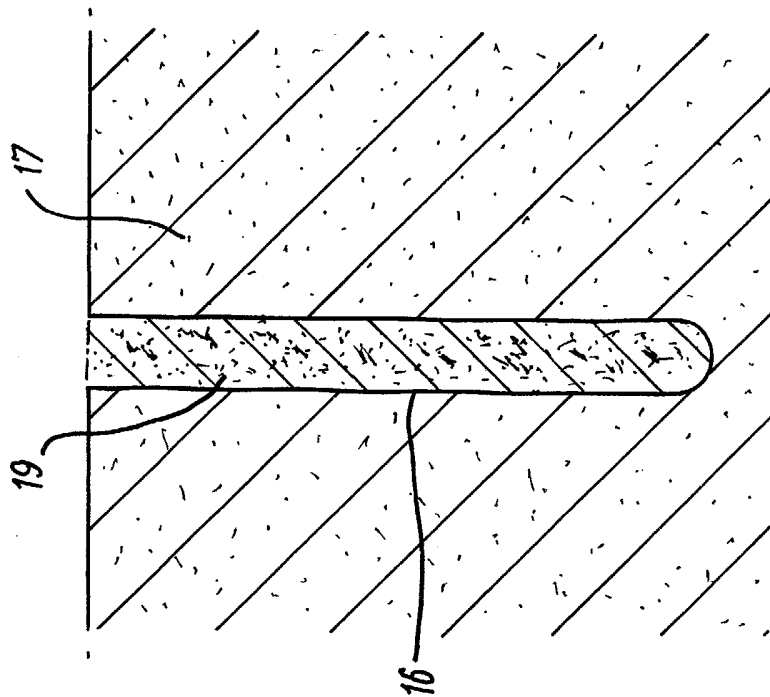


Fig. 2

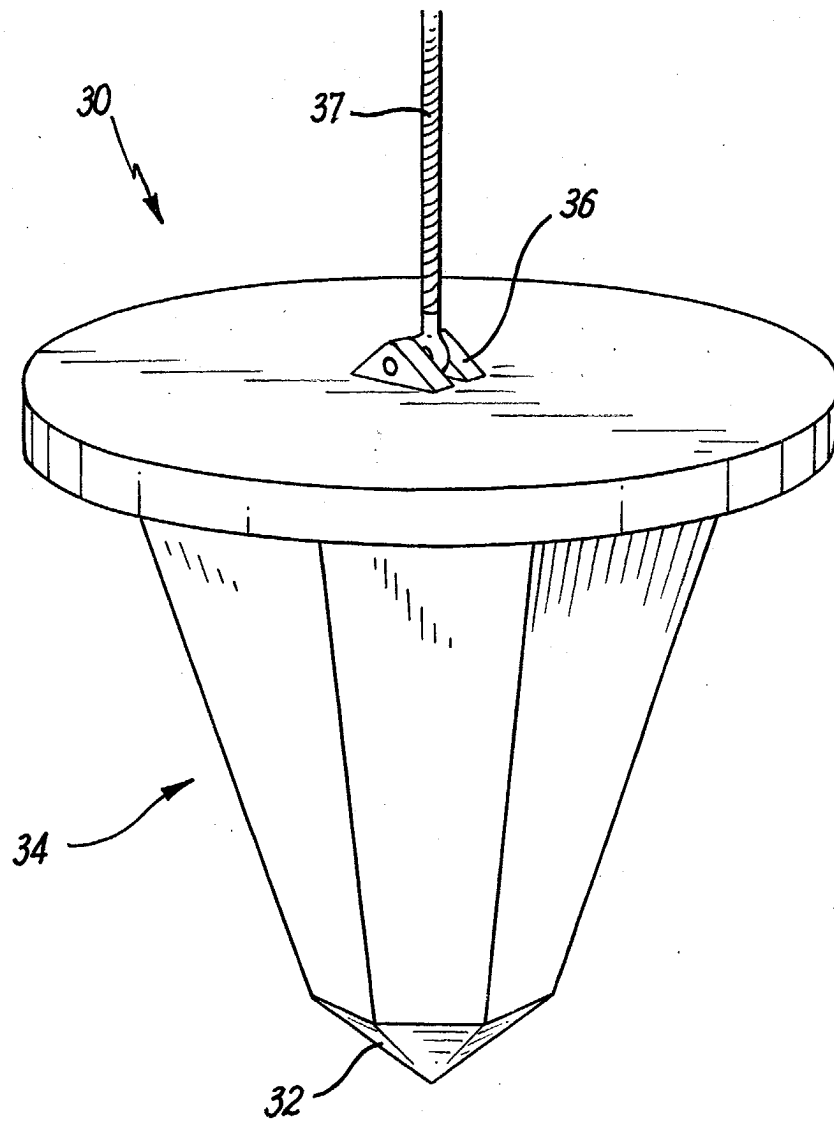
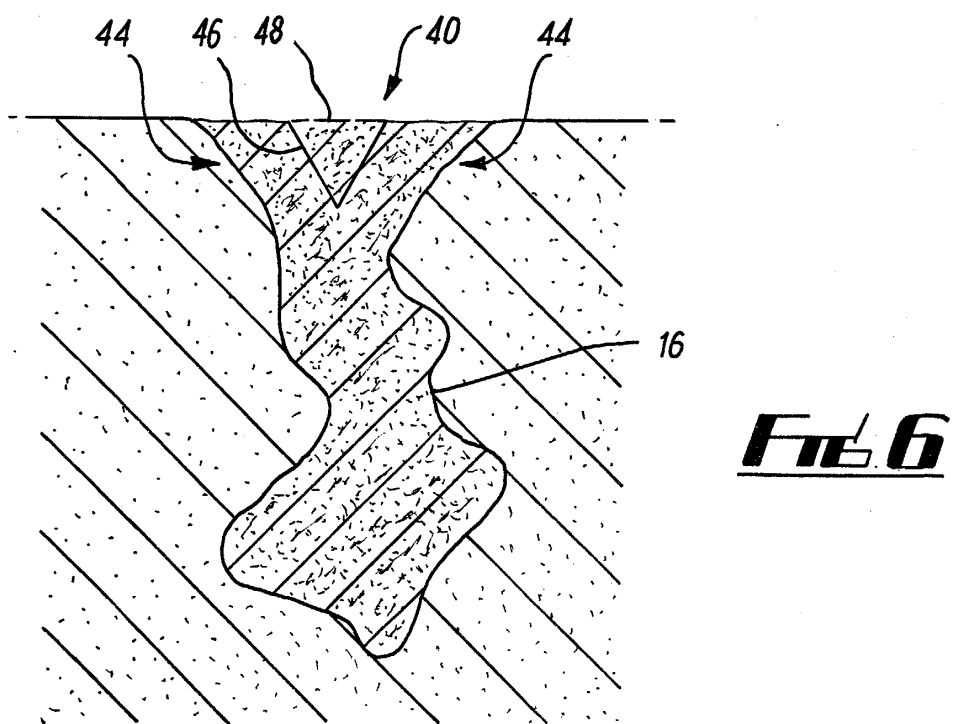
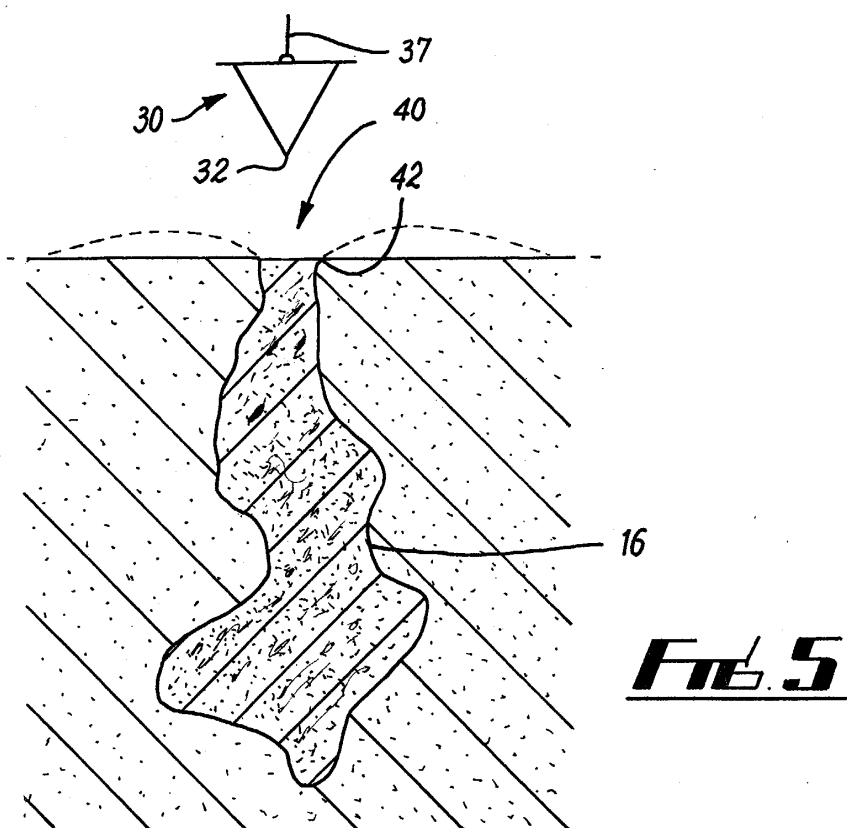


FIG. 4



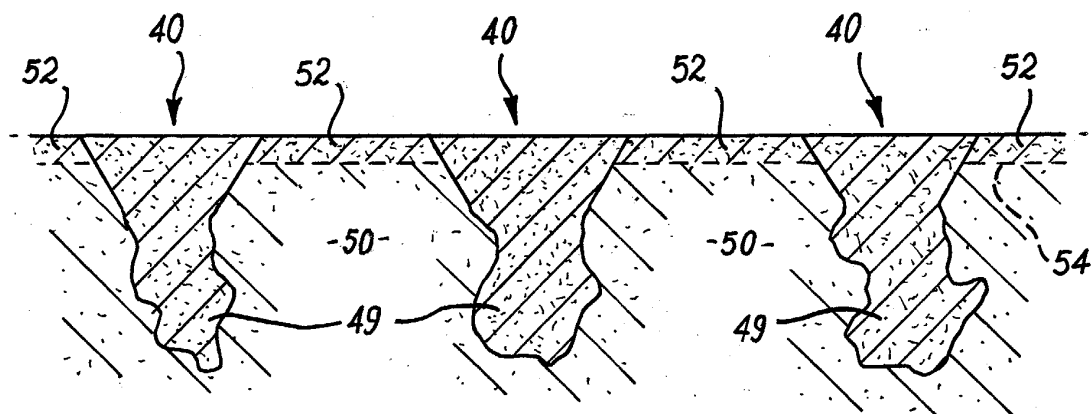


FIG. 7

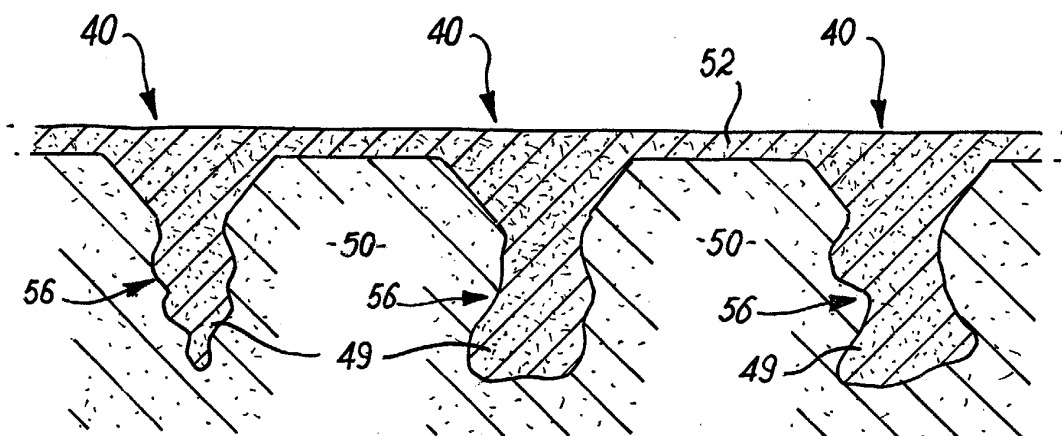


FIG. 8



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EUROPEAN SEARCH REPORT

Application Number
EP 03 25 4512

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)
A	GB 2 286 613 A (ROXBURY LTD) 23 August 1995 (1995-08-23) * page 3, paragraph 4 - page 12, paragraph 1; figures 1-3 *	1-9	E02D3/054 E02D3/08 E02D3/02
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A	GB 2 366 819 A (ROXBURY LTD) 20 March 2002 (2002-03-20) * abstract; figures 1,2,4 *	1-9	
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The present search report has been drawn up for all claims			
Place of search MUNICH		Date of completion of the search 10 November 2003	Examiner Geiger, H
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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