(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 239 258 B1**

(12) # EUROPEAN PATENT SPECIFICATION

(45) Date of publication of patent specification: **20.03.91 Bulletin 91/12**

(51) Int. Cl.[5]: **E02D 3/08**

(21) Application number: **87301756.0**

(22) Date of filing: **27.02.87**

(54) **Improvements in or relating to ground strengthening.**

(30) Priority: **27.02.86 GB 8604823**

(43) Date of publication of application: **30.09.87 Bulletin 87/40**

(45) Publication of the grant of the patent: **20.03.91 Bulletin 91/12**

(84) Designated Contracting States: **DE ES FR IT NL**

(56) References cited:
EP-A- 0 039 654
DE-A- 1 528 159
DE-A- 2 631 745
FR-A- 2 313 506
GB-A- 2 058 182
US-A- 3 802 204

(73) Proprietor: **UNIVERSITY COLLEGE CARDIFF CONSULTANTS LTD.**
P.O. Box 78
Cardiff, CF1 1XL (GB)

(72) Inventor: **Bridle, Ronald**
Parsonage Farm Kemys Commander
Usk Gwent NP5 1JU (GB)

(74) Representative: **Mayes, Stuart David et al**
BOULT, WADE & TENNANT 27 Furnival Street
London, EC4A 1PQ (GB)

EP 0 239 258 B1

Description

This invention relates to a method of ground strengthening to resist shear failure in which an array of elongate members is driven into the ground so as to cross a critical failure surface thereof.

GB-1580142 (DE-A-2631745 Bauer) discloses a method of ground strengthening in which an array of elongate members is driven into the ground by vibration, pressure or impact in order to improve its bulk properties and in particular to provide improved shear strength.

It is also known from US-3802204 (Mason) to provide a method of ground strengthening to resist shear failure in which an array of elongate members are inserted in the ground so as to cross a critical failure surface thereof.

A method in accordance with the present invention is characterised in that the members comprise pickets which are driven into the ground by being fired from a launcher, sufficient momentum being imparted to a picket on being fired to enable the picket to thereafter penetrate and become embedded within the ground.

According to a further aspect of the invention there is provided a method of sinking a cutting in the ground in which the ground is at the same time strengthened in accordance with the invention as defined above, comprising the steps of driving a line of pickets into the ground so that the pickets extend at an angle to the vertical to one side of the line, excavating the ground to the other side of the line, driving a further line of pickets into the ground below the level of the first line so that the pickets extend at an angle to the vertical to the same side of the vertical as the first line, and repeating the steps of excavating and driving further lines of pickets into the ground until the cutting so formed is of a required depth, each picket being driven into the ground in accordance with the above disclosed method.

According to a still further aspect of the invention there is provided a method of raising an embankment above the ground in which the ground forming the embankment is at the same time strengthened in accordance with the invention as defined above, comprising the steps of driving a line of pickets into the ground so that the pickets extend at an angle to the vertical to one side of the line, raising the ground to that side of the line, driving a further line of pickets into the ground above the level of the first line so that the pickets extend at an angle to the vertical to the same side of the vertical as the first line, and repeating the steps of raising and driving further lines of pickets into the ground until the cutting so formed is of the required height, each picket being driven into the ground in accordance with the above disclosed method.

Preferably in such methods the pickets in each line are offset vertically from pickets in next higher and next lower lines of pickets.

Preferably each picket is fired into the ground by a gas gun which conveniently may be mounted on a vehicle and advantageously such a method of driving a line of pickets into the ground includes the steps of moving the vehicle along the bottom of the cutting or top of the embankment, as the case may be, and firing pickets into the ground one after another to form the line of pickets.

The array of pickets may comprise two or more sets, the pickets within each set being substantially parallel with one another and each set defining a different picket orientation such that in a projected view the pickets intersect in reticular fashion.

Surface cladding may conveniently be added to ground strengthened by the use of pickets and conveniently the cladding may be held in place by the pickets. Such cladding may include apertures through each of which a respective picket is driven and wherein each picket includes a radially enlarged head of greater diameter than the respective aperture such that the picket is arrested by engagement of the head with the cladding.

This is particularly useful where the reinforced ground surface is vertical.

The picket may have a conically tapered head which is co-engageable in use with a conformally tapered seat of the surface cladding. The seat may be lined by a metallic shoe. Conveniently the cladding may be in the form of concrete slabs with a suitable array of apertures.

In a preferred embodiment the gas gun is operated by compressed air.

Embodiments of the invention will now be described by way of example only and with reference to the accompanying drawings of which :

Figures 1A to 1E are cross-sections through the ground illustrating various stages in the sinking of a cutting ;

Figure 2 is a perspective view of the side wall of the cutting ;

Figure 3 illustrates various stages in the raising of an embankment,

Figure 4 is a sectional view of a gas gun,

Figure 5 is a schematic sectional view of a site in which ground is reinforced with a reticular array of pickets,

Figure 6 is a similar view showing the way in which the ground supporting a foundation tends to fail,

Figure 7 is a similar view taken in the direction 1 of Figure 5,

Figure 8 is a part section view of a picket having a tapered head which is received in an aperture having a tapered seat in a surface cladding, and

Figure 9 is a similar view of an alternative picket having a head of T shaped cross section received in an alternative surface cladding having a cylin-

drical aperture.

Referring to Figure 1, and in particular Figure 1A, in sinking a cutting firstly two lines of pickets 101, 102 are fired into the ground each at an angle to the vertical so that the pickets extend downwardly and to the right of the line, as viewed in Figure 1A.

The ground to the left (as seen in Figure 1A) of the line of pickets 102 is then excavated to a depth equal to the desired vertical spacing of the lines of pickets which will strengthen the cutting wall. A further line of pickets 103 is then fired into the ground at the corner 10 between the bottom 12 of the excavation and the portion of the cutting wall 14 so far formed. The pickets 103 extend generally parallel to the pickets 101, 102 as shown in figure 1B.

The excavation and picket firing steps are then repeated so that the cutting is step-by-step made deeper as shown in Figures 1C and 1D, until the cutting is of the required depth, as illustrated in figure 1E. In the example shown in Figure 1E, the cutting wall is strengthened by the initial line of pickets 101 and a series of seven lines of pickets 102 to 108 at equally spaced levels along the cutting wall 14. Finally, a further line of pickets 109 is forced into the bottom 12 of the cutting adjacent the corner 10 with the cutting wall 14.

The pickets in adjacent lines are preferably offset as shown in Figure 2 and as designated by dashed lines in Figure 1.

A similar method is used to strengthen the opposite wall of the cutting as excavation proceeds.

Figure 3 illustrates a method of raising an embankment, which is somewhat similar to the cutting sinking method described above. Referring to Figure 3A, firstly two lines of pickets 201, 202 are fired into the ground so that they extend downwardly and to the right of the line as viewed in Figure 2A.

The ground above the pickets 202 and to the right thereof, as seen in Figure 3A, is then raised to a height equal to the desired vertical spacing of the lines of the pickets and a further line of pickets 203 is then fired into edge 16 formed by the top 18 and wall 20 of the embankment raised so far.

The raising and picket firing steps are then repeated until the embankment is of the desired height, and then a further line of pickets 209 are fired into the top 22 of the embankment adjacent the edge 16 between the top and side wall 20 of the embankment.

Figure 4 illustrates a gas gun 30 in which a picket 31 is loaded. The gas gun shown is operated by compressed air received through air lines (not shown) connected to ports 32, 33 and 34. An inlet port 32 admits compressed air to an annular reservoir 35 separated from a chamber 36 of the gun by a cylindrical valve member 37.

The chamber is closed by breech 38 through which the picket 31 is loaded. Air admitted through a firing port 34 actuates the valve member 37 which moves downwards as shown in the drawing to release air from the reservoir 35 to the chamber 36 whereupon the picket 31 is fired from the barrel 39. A reset port 33 admits air to return the valve member 37 after firing.

Figure 5 illustrates an application of ground stengthening at a site in which ground 300 lies between a wall 301 having a foundation 302 and a cutting 303 for pipe work 304. A reticular array of pickets 305 is formed by firing two sets of pickets 306 and 307 from a launcher such that each set forms a parallel array defining a different picket orientation such that in a projected view the pickets intersect in reticular fashion. In this example the sets of pickets also intersect in reticular fashion when viewed in projection in a second direction at right angles to the first as shown in Figure 7.

This sytem of ground strengthening may also be termed root piling since the driven pickets may be likened to roots

The way in which the ground supporting a foundation fails under load is illustrated in Figure 6 in which a wall 308 is supported on a foundation 309. The wedge of earth 310 immediately beneath the foundation is driven downwards putting the adjacent wedges 311 into plastic deformation so that the surrounding zone of earth 312 shears out of the ground in the direction arrowed. The foundation therefore fails at critical failure surfaces shown in the drawing as dashed lines and in strengthening the ground surrounding such a foundation a reticular array of pickets crossing the critical failure surfaces increases the bearing capacity of the foundation. Such strengthening is readily achieved in accordance with the present invention by firing the pickets from a launcher.

Figure 8 shows an alternative picket 400 having a radially enlarged head 401 which is conically tapered in the direction in which the picket is driven in use. A surface cladding layer 402 of concrete is shown applied to an embankment 403 and the cladding layer includes an aperture 404 comprising a tapered seat lined with a metallic shoe 405. In use the picket is driven through the aperture 404 and penetrates the embankment 403 until the head 401 encounters the shoe 405. The picket 400 is then arrested. In this position the head 401 is positioned in a predetermined manner relative to the surface cladding layer 402.

figure 9 shows an alternative picket 406 which has a head 407 which is not tapered but has a cylindrical form such that the end of the picket is of T shaped cross section. The picket is shown received in an aperture 408 in a surface cladding layer 409. The head 407 functions to arrest the picket 406 such that the head is in contact with the surface cladding layer 409 and the penetration of the picket 406 is controlled to a pre-determined depth.

Surface cladding layers 402, 409 may be applied to embankments or other surface areas where pickets are to be used for ground strengthening and such layers are typically provided with a regular array of apertures corresponding to the required pattern of driven pickets.

The use of pickets 400, 406 having radially enlarged heads 401, 407 serves a dual purpose of controlling the depth of penetration of the picket and of retaining surface cladding 402, 409 in position.

The pickets used in any of the above examples could be of metallic material or of other material such as plastics.

Claims

1. A method of ground strengthening to resist shear failure in which an array (101-109) of elongate members is driven into the ground so as to cross a critical failure surface thereof characterised in that the members comprise pickets (31) which are driven into the ground by being fired from a launcher (30), sufficient momentum being imparted to a picket on being fired to enable the picket to thereafter penetrate and become embedded within the ground.

2. A method as claimed in claim 1 characterised in that pickets are fired into the ground by a gas gun (30).

3. A method as claimed in claim 1 or 2, characterised in that the gas gun is mounted on a vehicle.

4. A method as claimed in claim 3 characterised in that a line of pickets is driven into the ground by moving the vehicle along or parallel to the line and firing pickets into the ground one after another to form the line of pickets.

5. A method of sinking a cutting in the ground in which the ground is at the same time strengthened in accordance with a method as claimed in any preceding claim and comprising the further steps of driving a line of pickets (102) into the ground so that the pickets extend at an angle to the vertical to one side of the line, excavating the ground to the other side of the line, driving a further line of pickets (103) into the ground below the level of the first line so that the pickets extend at an angle to the vertical to the same side of the vertical as the first line, and repeating the steps of excavating and driving further lines of pickets (104 to 109) into the ground until the cutting so formed is of a required depth.

6. A method of raising an embankment above the ground in which the ground forming the embankment is at the same time strengthened in accordance with a method as claimed in any of claims 1 to 4 and further comprising the steps of driving a line of pickets (202) into the ground so that the pickets extend at an angle to the vertical to one side of the line raising the ground to that side of the line, driving a further line of pickets (203) into the ground above the level of the first line so that the pickets extend at an angle to the vertical to the same side of the vertical as the first line, and repeating the steps of raising and driving further lines of pickets (204 to 209) into the ground until the embankment so formed is of the required height.

7. A method as claimed in claim 5 or 6, characterised in that the pickets in each line are offset vertically from pickets in next higher and next lower lines of pickets.

8. A method as claimed in any of claims 1 to 4 characterised in that the array of pickets comprises two or more sets (306, 307), the pickets within each set being substantially parallel with one another and each set defining a different picket orientation such that in a projected view the pickets intersect in reticular fashion.

9. A method as claimed in any preceding claim characterised by including the further step of adding characterised by including the further step of adding surface cladding (402, 409).

10. A method as claimed in claim 9 characterised in that the pickets are driven into the ground through the cladding.

11. A method as claimed in claim 10 characterised in that pickets driven through the cladding are embedded in the ground to a predetermined extent and are prevented by the cladding from further penetration.

12. A method as claimed in any of claims 9 to 11 characterised in that the cladding is secured in position by said pickets.

13. A method as claimed in claim 12 characterised in that the cladding is held in place by said pickets (400, 406) the surface cladding including apertures (408) through each of which a respective picket is driven and wherein each such picket includes a radially enlarged head (401, 407) of greater diameter than the respective aperture such that the picket is arrested by engagement of the head with the cladding.

14. A method as claimed in claim 13 characterised by each such picket comprising a tapered head (401) which is co-engageable in use with a conformally tapered seat (405) of the surface cladding.

Ansprüche

1. Verfahren zur Bodenbefestigung zum Standhalten eines Scherbruchs, bei dem eine Reihe (101-109) von länglichen Teilen in den Boden derart getrieben wird, daß eine kritische Bruchfläche hiervon kreuzend durchquert wird, dadurch **gekennzeichnet**, daß die Teile Pflöcke (31) aufweisen, die in den Boden dadurch getrieben werden, daß sie von einer Abschußeinrichtung (30) abgeschossen werden, wobei ein so ausreichendes Moment beim Abschießen auf einen Pflock ausgeübt wird, daß der Pflock

anschließend eindringen kann und in dem Boden eingebettet wird.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß die Pflöcke in den Boden mittels einer Gaspistole (30) abgeschlossen werden.

3. Verfahren nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß die Gaspistole an einem Fahrzeug angebracht ist.

4. Verfahren nach Anspruch 3, dadurch gekennzeichnet, daß eine Linie von Pflöcken in den Boden dadurch getrieben wird, daß das Fahrzeug längs oder parallel zu der Linie bewegt wird und die Pflöcke in den Boden hintereinander zur Bildung der Linie von Pflöcken abgeschossen werden.

5. Verfahren zum Verfestigen eines Einschnitts im Boden, bei dem der Boden zugleich gemäß einem Verfahren nach einem der vorangehenden Ansprüche verfestigt wird, und das ferner die Schritte aufweist, gemäß denen eine Linie von Pflöcken (102) in den Boden derart getrieben wird, daß die Pflöcke unter einem Winkel zur Vertikalen auf einer Seite der Linie verlaufen, der Boden auf der anderen Seite der Linie ausgehoben wird, eine weitere Linie von Pflöcken (103) in den Boden unterhalb des Niveaus der ersten Linie derart getrieben wird, daß die Pflöcke unter einem Winkel zu der Vertikalen auf derselben Seite der Vertikalen wie die erste Linie verlaufen, und die Schritte zum Ausheben und Eintreiben von weiteren Linien von Pflöcken (104-109) in den Boden wiederholt ausgeführt werden, bis der so gebildete Einschnitt eine gewünschte Tiefe hat.

6. Verfahren zum Anheben eines Erddammes über den Boden, bei dem der den Erddamm bildende Boden gleichzeitig nach einem Verfahren gemäß einem der Ansprüche 1 bis 4 verfestigt wird, und das ferner die Schritte aufweist, gemäß denen eine Linie von Pflöcken (202) in den Boden derart getrieben wird, daß die Pflöcke unter einem Winkel zur Vertikalen auf einer Seite der Linie verlaufen, der Boden auf dieser Seite der Linie gehoben wird, eine weitere Linie von Pflöcken (203) in den Boden oberhalb des Niveaus der ersten Linie derart eingetrieben wird, daß die Pflöcke unter einem Winkel zur Vertikalen auf der gleichen Seite der Vertikalen wie die erste Linie verlaufen, und die Schritte zum Heben und Eintreiben von weiteren Linien von Pflöcken (204 bis 209) in den Boden wiederholt ausgeführt werden, bis der so gebildete Erddamm die erforderliche Höhe hat.

7. Verfahren nach Anspruch 5 oder 6, dadurch gekennzeichnet, daß die Pflöcke in jeder Linie vertikal versetzt zu den Pflöcken in den nächst höheren oder nächst tieferen Linien von Pflöcken angeordnet sind.

8. Verfahren nach einem der Ansprüche 1 bis 4, dadurch gekennzeichnet, daß die Reihe von Pflöcken zwei oder mehr Sätze (306, 307) aufweist, die Pflöcke jedes Satzes im wesentlichen parallel zueinander sind, und jeder Satz eine unterschiedliche Pflockausrichtung derart bestimmt, daß in einer Projektionsansicht die Pflöcke sich netzartig schneiden.

9. Verfahren nach einem der vorangehenden Ansprüche, dadurch gekennzeichnet, daß der weitere Schritt mitumfaßt wird, gemäß dem eine Oberflächenauflage (402, 409) zusätzlich vorgesehen wird.

10. Verfahren nach Anspruch 9, dadurch gekennzeichnet, daß die Pflöcke in den Boden durch die Auflage getrieben werden.

11. Verfahren nach Anspruch 10, dadurch gekennzeichnet, daß die Pflöcke, die durch die Auflage getrieben sind, im Boden in einem vorbestimmten Maße eingebettet sind und durch die Auflage an einem weiteren Eindringen gehindert werden.

12. Verfahren nach einem der Ansprüche 9 bis 11, dadurch gekennzeichnet, daß die Auflage in der Stellung mittels Pflöcken festgelegt ist.

13. Verfahren nach Anspruch 12, dadurch gekennzeichnet, daß die Auflage an Ort und Stelle durch die Pflöcke (400, 406) gehalten wird, die Oberflächenauflage Öffnungen (408) umfaßt, durch die jeweils ein zugeordneter Pflock getrieben wird, und daß jeder Pflock einen radial erweiterten Kopf (401, 407) mit einem größeren Durchmesser als die zugeordnete Öffnung derart hat, daß der Pflock durch das Zusammenarbeiten von dem Kopf mit der Auflage festgehalten wird.

14. Verfahren nach Anspruch 13, dadurch gekennzeichnet, daß jeder Pflock einen konischen Kopf (401) aufweist, der im Gebrauchszustand mit einem formgleich ausgebildeten konischen Sitz (405) der Oberflächenauflage zusammenarbeitet.

Revendications

1. Procédé de consolidation des sols pour résister à l'affaissement par cisaillement dans lequel un ensemble (101-109) d'éléments allongés est enfoncé dans le sol pour traverser une surface de celui-ci risquant de s'affaisser caractérisé en ce que les éléments consistent en des piquets (31) qui sont enfoncés dans le sol par projection à partir d'un dispositif de lancement (30), une force suffisante étant donnée au piquet lors du lancement pour lui permettre alors de pénétrer et de s'enterrer dans le sol.

2. Procédé selon la revendication 1 caractérisé en ce que les piquets sont enfoncés par lancement dans le sol par un canon à gaz (30).

3. Procédé selon la revendication 1 ou 2, caractérisé en ce que le canon à gaz est monté sur un véhicule.

4. Procédé selon la revendication 3 caractérisé en ce qu'une rangée de piquets est enfoncée dans le sol en déplaçant le véhicule le long de la rangée ou parallèlement à la rangée et en enfonçant les piquets dans le sol par lancement l'un après l'autre pour former la rangée de piquets.

5. Procédé de creusement d'une entaille dans le

sol dans lequel le sol est en même temps consolidé conformément à un procédé selon l'une quelconque des revendications précédentes et comprenant les opérations supplémentaires consistant à enfoncer une rangée de piquets (102) dans le sol de manière que les piquets s'étendent à un angle relativement à la verticale d'un côté de la rangée, creuser le sol de l'autre côté de la rangée, enfoncer une autre rangée de piquets (103) dans le sol en dessous du niveau de la première rangée de manière que les piquets s'étendent à un angle relativement à la verticale du même côté de la verticale que la première rangée, et à répéter les opérations de creusement et d'enfoncement d'autres rangées de piquets (104 à 109) dans le sol jusqu'à ce que l'entaille ainsi formée soit d'une profondeur adéquate.

6. Procédé de réalisation d'un remblai au-dessus du sol dans lequel le sol formant le remblai est en même temps consolidé conformément à un procédé selon l'une quelconque des revendications 1 à 4 et comprenant en outre les opérations consistant à enfoncer une rangée de piquets (202) dans le sol de manière que les piquets s'étendent à un angle relativement à la verticale d'un côté de la rangée, hausser le sol de ce côté de la rangée, enfoncer une autre rangée de piquets (203) dans le sol au-dessus du niveau de la première rangée de manière que les piquets s'étendent à un angle relativement à la verticale du même côté de la verticale que la première rangée, et à répéter les opérations de remblayage et d'enfoncement d'autres rangées de piquets (204 à 209) dans le sol jusqu'à ce que le remblai ainsi formé atteigne la hauteur souhaitée.

7. Procédé selon la revendication 5 ou 6, caractérisé en ce que les piquets dans chaque rangée sont décalés verticalement par rapport aux piquets des rangées adjacentes supérieure et inférieure.

8. Procédé selon l'une quelconque des revendications 1 à 4 caractérisé en ce que l'ensemble de piquets comprend deux groupes de piquets (306, 307) ou davantage, les piquets au sein de chaque groupe étant substantiellement parallèles les uns aux autres et chaque groupe définissant une orientation des piquets différente si bien que dans une vue projetée les piquets se croisent de manière réticulaire.

9. Procédé selon l'une quelconque des revendications précédentes caractérisé en ce qu'il comprend en outre l'opération consistant à ajouter un revêtement de surface (402, 409).

10. Procédé selon la revendication 9 caractérisé en ce que les piquets sont enfoncés dans le sol à travers le revêtement.

11. Procédé selon la revendication 10 caractérisé en ce que les piquets enfoncés dans le revêtement sont enterrés dans le sol jusqu'à une profondeur prédéterminée et sont empêchés par le revêtement de pénétrer davantage.

12. Procédé selon l'une quelconque des revendications 9 à 11 caractérisé en ce que le revêtement est maintenu en place par lesdits piquets.

13. Procédé selon la revendication 12 caractérisé en ce que le revêtement est maintenu en place par lesdits piquets (400, 406), le revêtement de surface comprenant des ouvertures (408) par chacune desquelles un piquet respectif est enfoncé et où chaque piquet comporte une tête agrandie radialement (401, 407) de plus grand diamètre que l'ouverture respective afin le piquet soit arrêté par engagement de la tête avec le revêtement.

14. Procédé selon la revendication 13 caractérisé en ce que chaque piquet comprend une tête conique (401) qui peut être engagée à l'utilisation avec un logement identiquement conique (405) du revêtement de surface.

FIG. 1A.

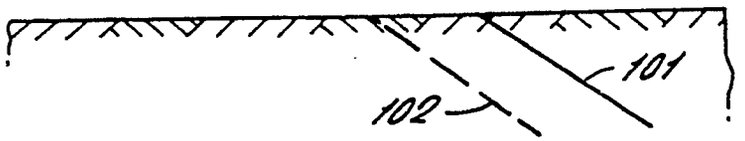


FIG. 1B.

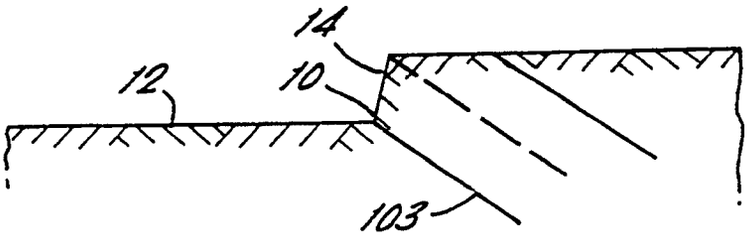


FIG. 1C.

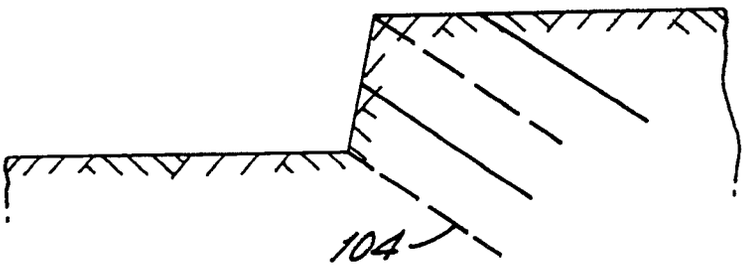


FIG. 1D.

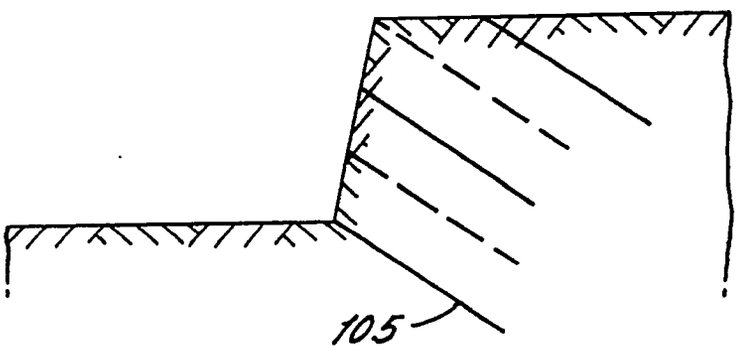


FIG. 1E.

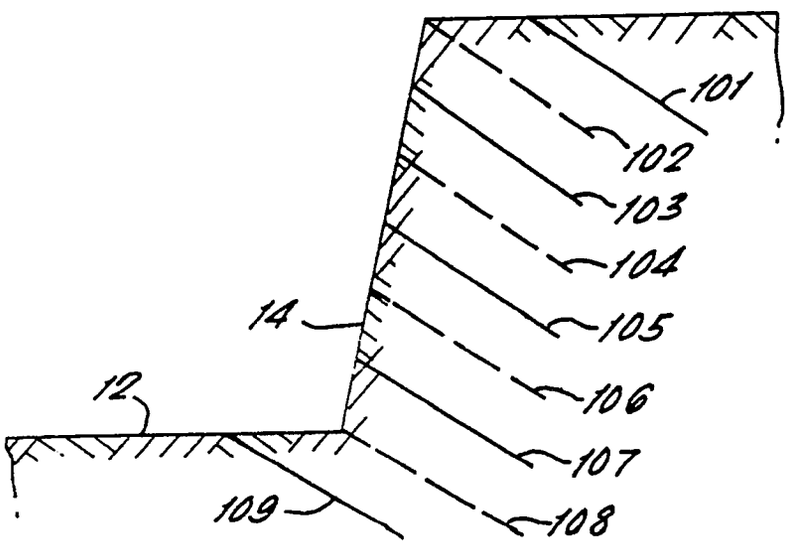


FIG. 2.

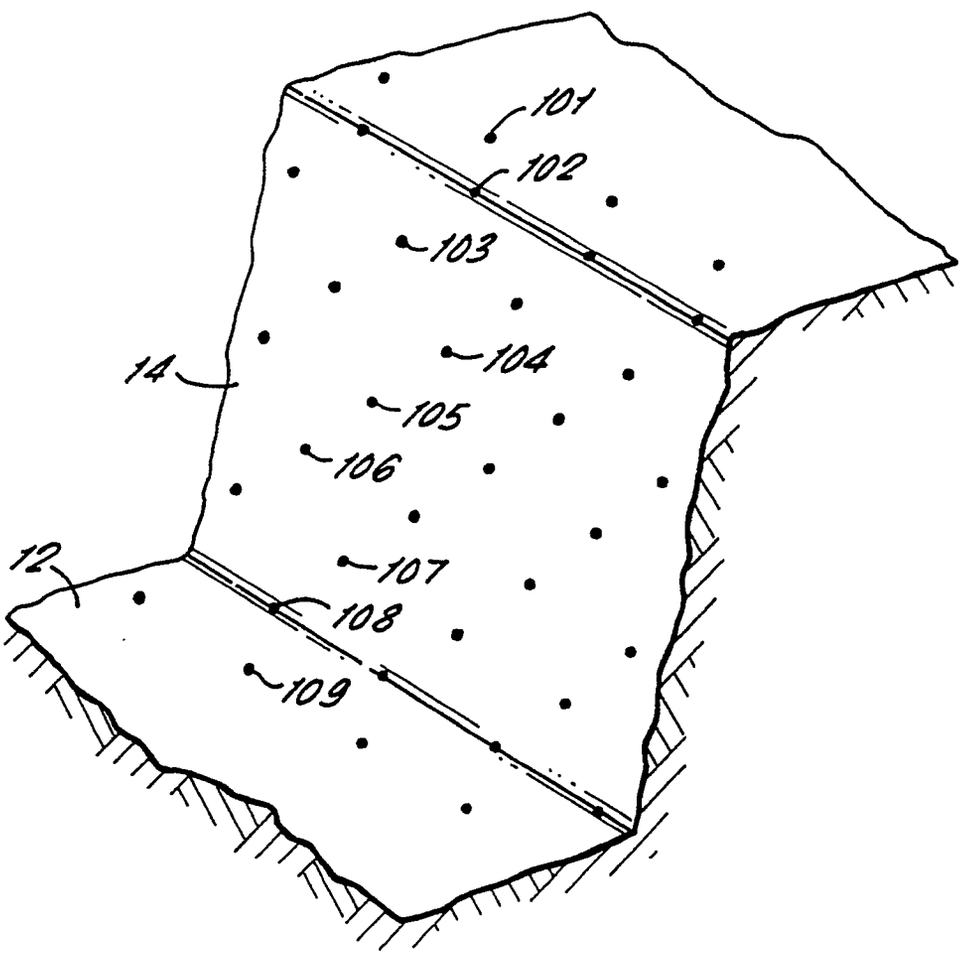


FIG. 3A.

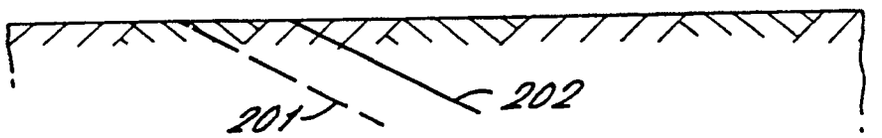


FIG. 3B.

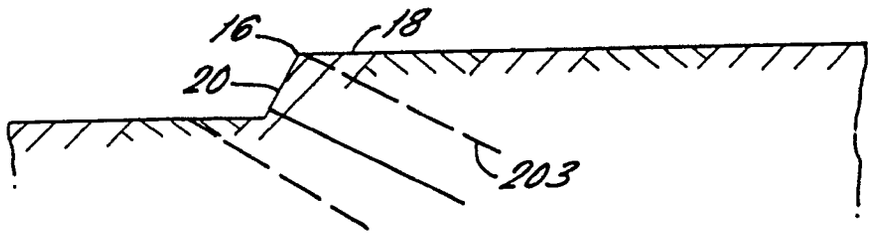


FIG. 3C.

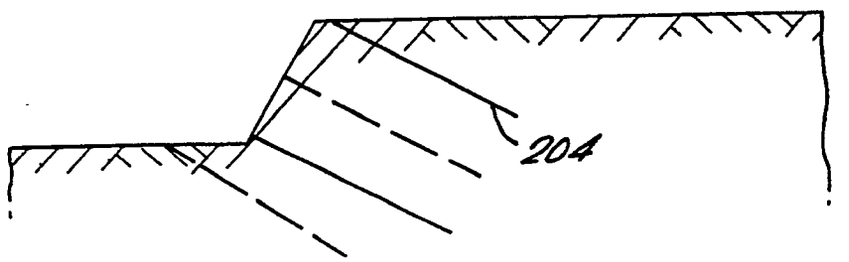


FIG. 3D.

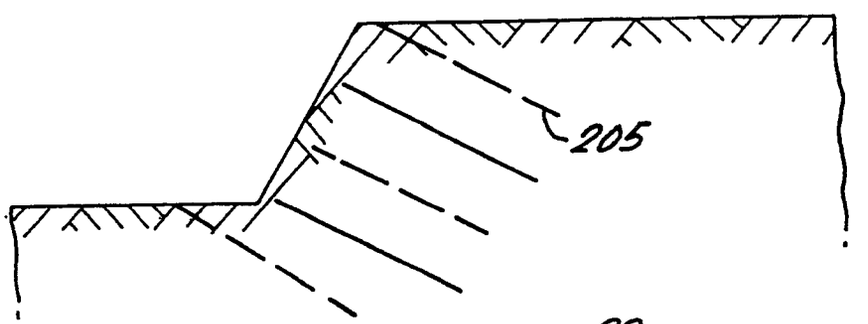


FIG. 3E.

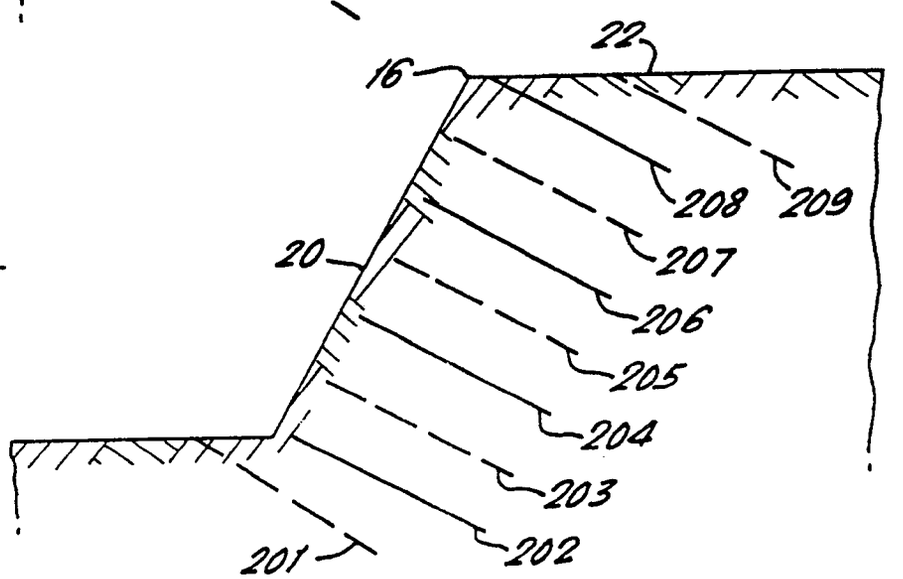


FIG. 4.

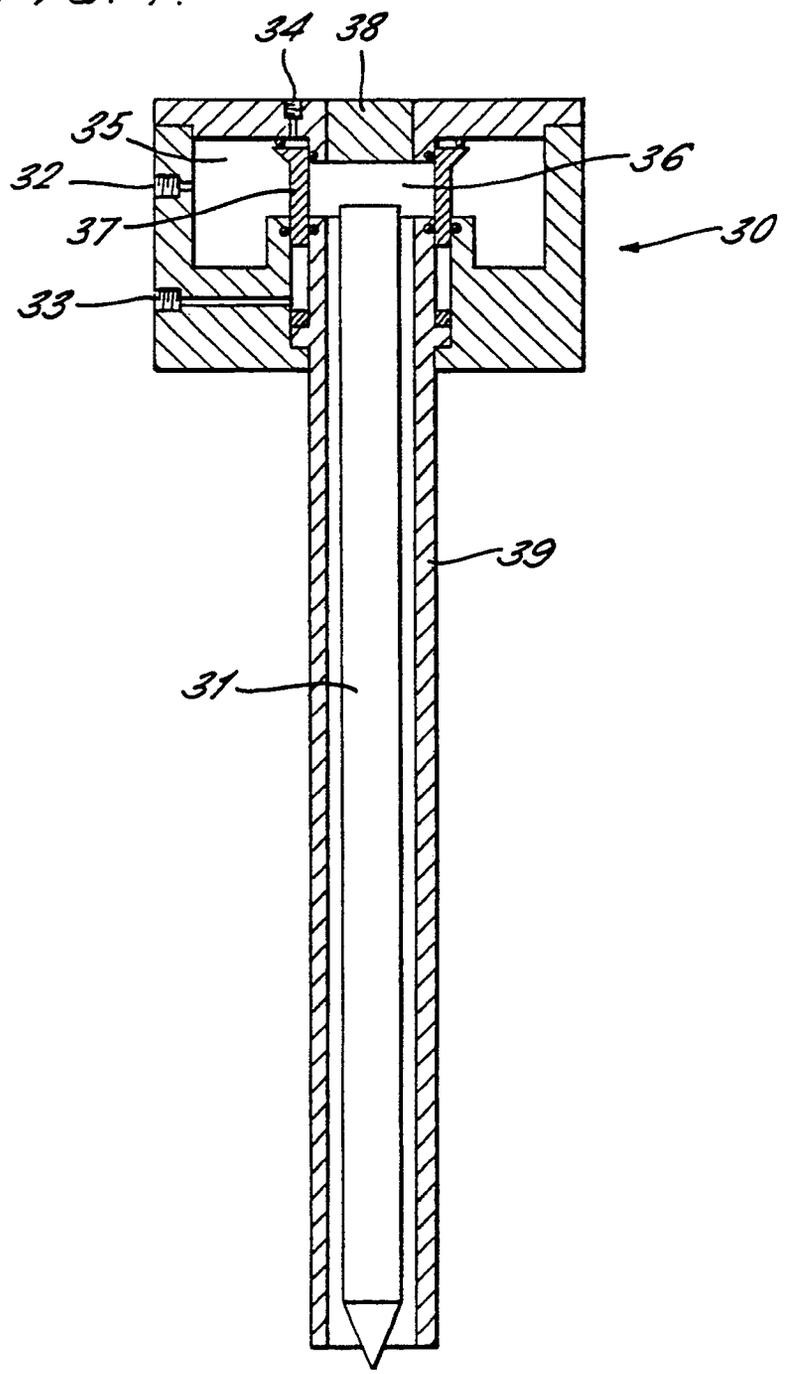


FIG. 5.

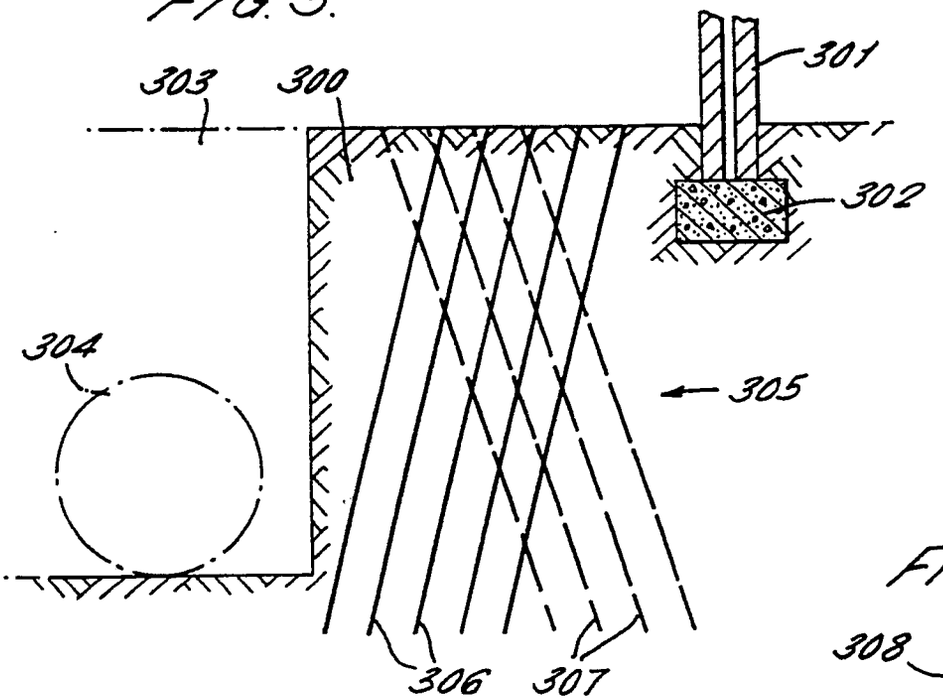


FIG. 6.

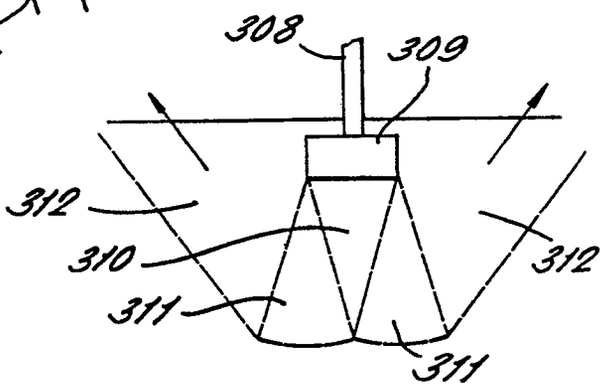
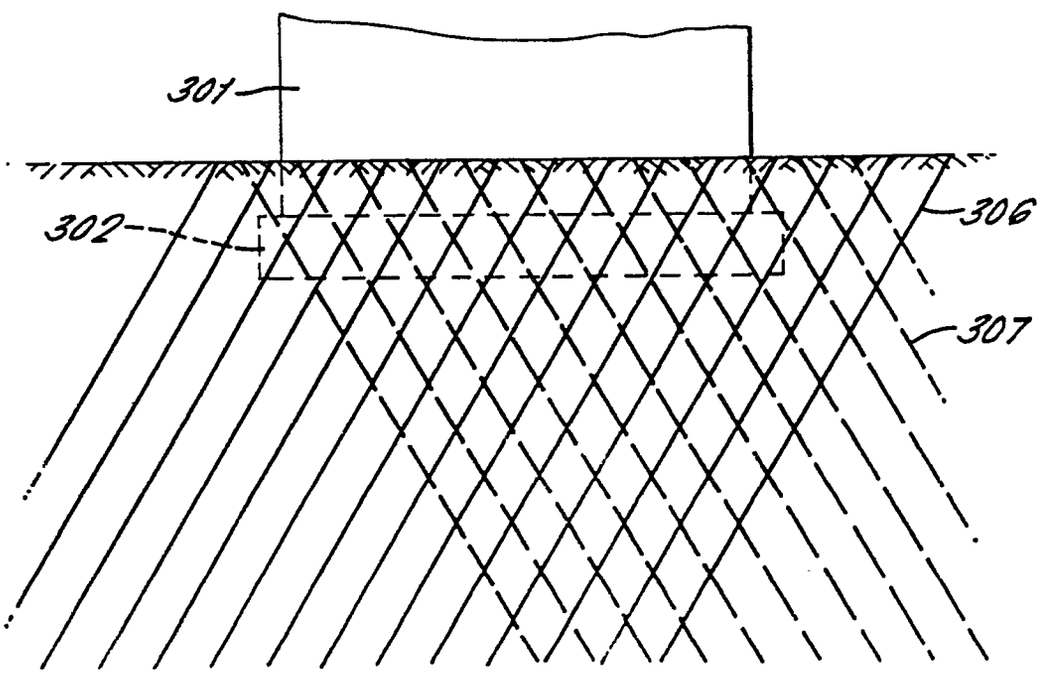


FIG. 7.



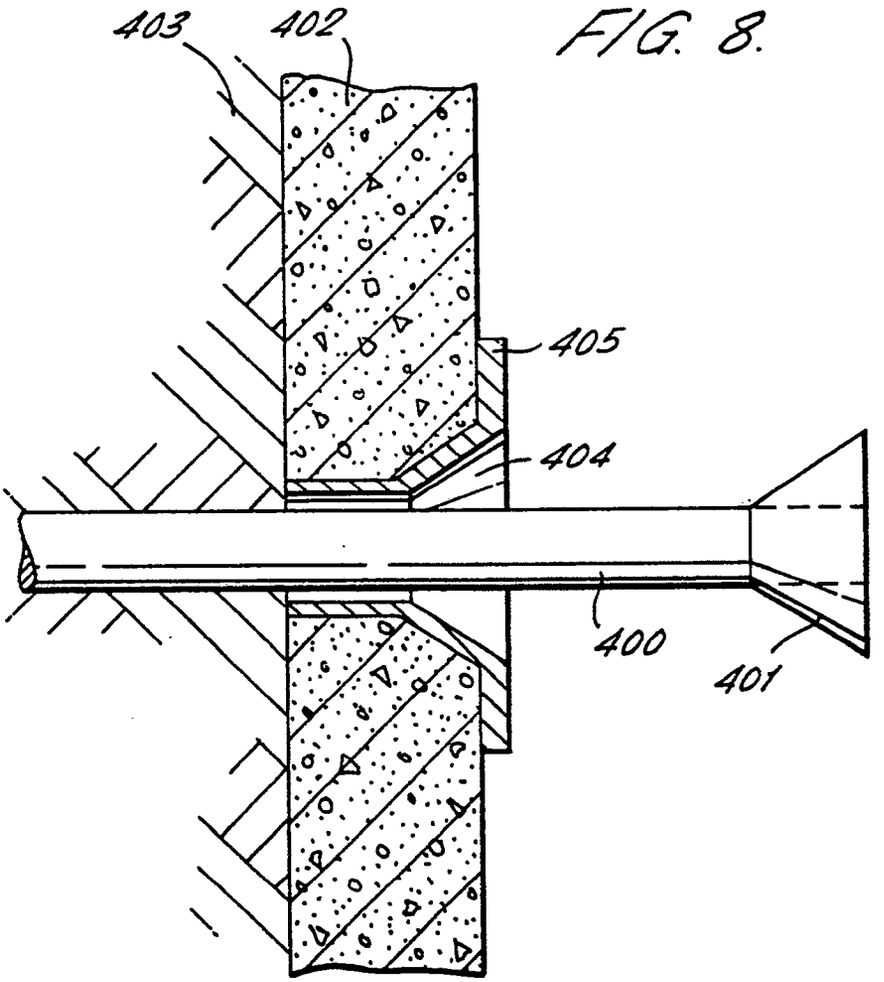


FIG. 8.

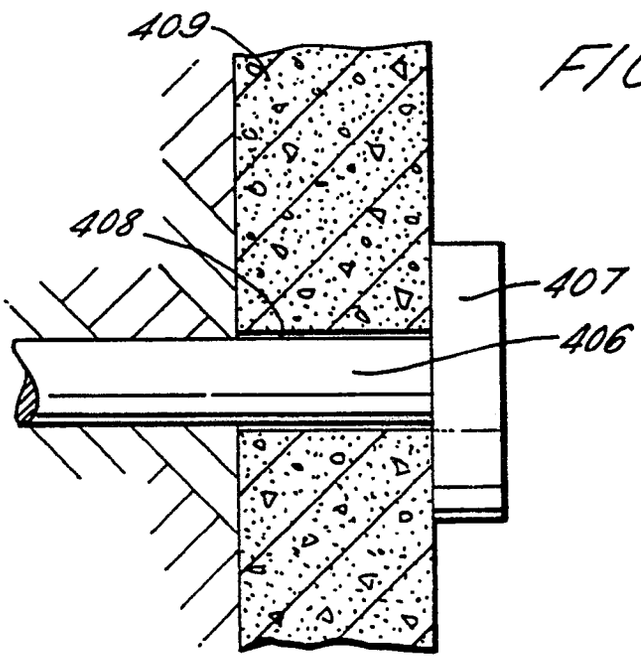


FIG. 9.