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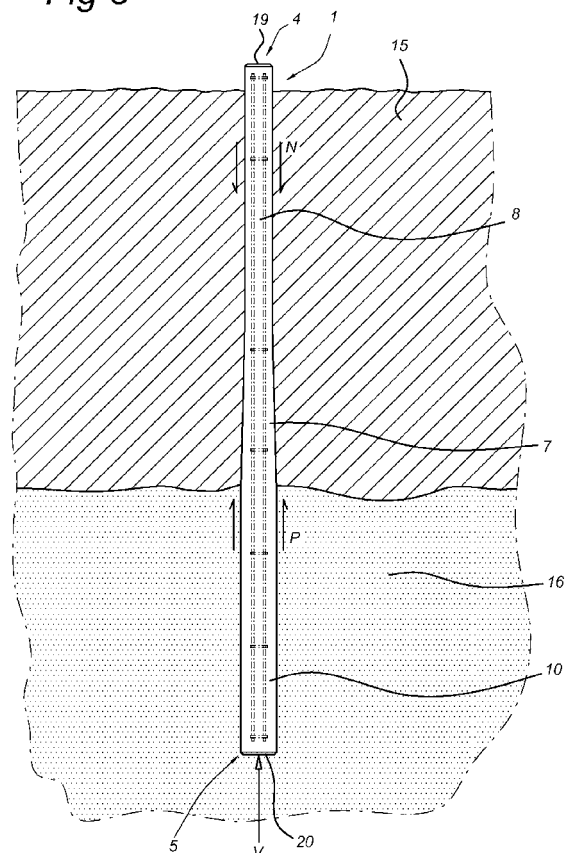
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(54) **Narrowed foundation pile**

(57) A foundation pile (1), intended to be driven into a substrate and to provide skin friction with respect to said substrate, comprises a pile shaft (2) with a head (4) and a base (5) which is to be driven into a substrate. The pile shaft (2) has a narrow or tapered portion (7) with different areas which, viewed in the longitudinal direction, are spaced apart, one area of which has a larger capacity to generate skin friction than another area. The area of the narrowed portion (7) with the larger capacity to generate skin friction is situated at a greater distance from the head (4) than the other area of the narrowed portion (7), in such a manner that the effect of negative skin friction is minimized.

Fig 5



Description

[0001] The invention relates to a foundation pile, intended to be driven into a substrate and to provide skin friction with respect to said substrate, comprising a pile shaft which, at least in cross section, forms a single entity, a head at an end of the pile shaft and a tip or base which is to be driven into a substrate at the other end of the pile shaft, which pile shaft comprises at least a narrowed portion whose cross section changes in the longitudinal direction of the pile shaft.

[0002] Such a foundation pile is known. Its function is to provide the load-bearing capacity to support a structure, building and the like with respect to a relatively weak substrate. To this end, the foundation pile is driven into the ground, for example by means of ramming or vibrating. The depth to which the foundation pile has to be driven into the ground depends on the level at which the load-bearing layer is situated.

[0003] The base of the pile is driven into the load-bearing layer, such as a sand layer, over a certain length. The resistance of the base which occurs in the process provides an important part of the load-bearing capacity of the foundation pile. In addition, the friction of the shaft with respect to the ground, or skin friction, contributes to the load-bearing capacity. This is caused by the effect of positive skin friction which results from surface friction between the pile shaft and the ground.

[0004] However, in addition to positive skin friction, negative skin friction also occurs. Negative skin friction is the result of weak ground settling. If the ground sinks with respect to the foundation pile, the ground, likewise as a result of surface friction, exerts a downward force on the foundation pile. This downward force compromises the nett load-bearing capacity of the foundation pile and may even cause a substantial reduction of the load-bearing capacity.

[0005] EP-A-758699 discloses a foundation pile whose cross section decreases in the direction of the base. This is intended to increase the load-bearing capacity of the foundation pile by means of a clamping effect with respect to the substrate. Although such clamping may have a positive effect on the load-bearing capacity of the foundation pile, this increases the effect of negative skin friction. This is due to the fact that negative skin friction is caused by settling, and this effect occurs mainly near the head of the foundation pile, in other words in the area where the external surface of the foundation pile is largest. This leads to a relatively large effect on the negative skin friction, as this acts on the large external surface near the head of the pile. A further drawback is that such a pile which narrows outwards near the head requires a relatively large amount of concrete, which increases the cost price.

[0006] It is an object of the invention to provide a foundation pile which offers a satisfactory load-bearing capacity and in which the effect of negative skin friction can be reduced to a minimum. This object is achieved by the

fact that the head portion has a periphery which is smaller than the periphery of the base portion. In this case, the narrowed portion has a cross section with a relatively large periphery and a cross section with a relatively small periphery so that the cross section with a relatively large periphery is situated at a greater distance from the head than the cross section with a relatively small periphery.

[0007] The expression a narrowed portion is understood to mean a portion in which a change occurs in the periphery and/or the surface of successive cross sections. This change may be continuous and may, for example, decrease monotonously in the direction from the base to the head, but it is also possible for the cross section to change in stages or in steps. Near the base, the foundation pile therefore has a relatively large periphery in the zone where positive skin friction occurs. Near the head, the foundation pile has a relatively small periphery in the zone where negative skin friction occurs. In addition, the foundation pile has a corresponding relatively large cross section at the base in order to produce a high resistance at the base.

[0008] The foundation pile with the portions which are configured in this way has several advantages. The area thereof which is subjected to the effects of negative skin friction is relatively small in size. As mentioned above, negative skin friction mainly occurs near the upper portion of the foundation pile and it is exactly this area where the peripheral surface on which the negative skin friction acts is relatively small. Furthermore, the consumption of material for such a foundation pile with relatively small cross section is relatively low, as a result of which the cost price can remain low.

[0009] The narrowed portion may be configured in different ways and the external surfaces thereof may, for example, be curved. The cross section of the narrowed portion may also have various shapes, such as circular, oval, polygonal and the like. In particular, the cross-sectional area of the narrowed portion may decrease monotonously, viewed in the direction from the base to the head.

[0010] With a view to ease of manufacturing, a foundation pile is preferred in which the narrowed portion has a polygonal cross section and wherein at least one of the walls which delimit the polygonal cross section is directed obliquely with respect to the longitudinal direction of the pile shaft. In particular, the narrowed portion may have a square or rectangular cross section in which one and only one of the walls is directed obliquely with respect to the longitudinal direction of the pile shaft.

[0011] Preferably, the narrowed portion has a square or rectangular cross section comprising two opposite walls which are directed obliquely towards one another. The other walls of the narrowed portion may be mutually parallel. Such a foundation pile can be manufactured using a relatively simple mould, e.g. a modified standard mould for foundation piles.

[0012] The connection between in each case two portions is preferably not stepped, that is to say that the end

surface of the narrowed portion and the adjacent end of the prismatic portion then have identical shapes and dimensions (congruent).

[0013] In particular, a prismatic base portion is provided which adjoins the base in such a manner that the narrowed portion adjoins the end of the prismatic base portion which is turned away from the base. Furthermore, a prismatic head portion adjoins the head. This prismatic head portion adjoins the end of the narrowed portion which is turned away from the base. The foundation pile thus has at least two prismatic portions between which the narrowed portion is situated. It is also possible to provide more than two prismatic portions, each of which encloses a narrowed portion.

[0014] As has already been mentioned, the cross section of the various portions may have different shapes. A particularly simple foundation pile which can be manufactured at low cost is configured in such a way that the prismatic portion adjoining the base has a square cross section and the prismatic portion adjoining the head has a rectangular cross section. In this case, two opposite walls may extend evenly across all portions. Furthermore, a plane of symmetry of a prismatic portion adjoining the head and a plane of symmetry of the prismatic portion adjoining the base may coincide. In this case, the foundation pile may be completely symmetrical with respect to a central longitudinal plane.

[0015] The foundation pile is preferably configured as a concrete body with a reinforcement which is incorporated in the concrete body. Alternatively, the foundation pile may have a hollow steel body. In that case, the hollow steel body may be configured as having several welded pipe portions, in which case a pipe portion situated closer to the base has an external cross section with a larger periphery than a pipe portion which is situated closer to the head.

[0016] Furthermore, the hollow steel body may be configured as a coupled pile having a pile portion which is situated closer to the base and the cross section of which has a larger periphery than a pile portion which is situated closer to the head.

[0017] The base may be configured as the end of the base portion, that is to say may have the same cross section as the base portion. According to another possibility, the base may be configured as a local widening with respect to the pile shaft in the form of a base piece. It should be noted that the function of such a widened base piece differs from the function of the base portion. The purpose of the widened base piece is to increase the load-bearing capacity of the foundation pile by increasing the resistance of the base in the bottom load-bearing ground layer which is exerted on the surface of the head of the foundation pile. The purpose of the base portion on the other hand is to make the friction of the shaft or (positive) skin friction which acts on the longitudinal walls of the foundation pile as large as possible with respect to the bottom ground layers.

[0018] The foundation pile is configured in such a man-

ner that the head portion has a head end and the base portion has a base end which faces away from the head end, which head end has a projection P19 on a plane of projection at right angles to the longitudinal direction of the pile shaft whose periphery is smaller than the periphery of the projection P20 of the base end on said plane of projection. The base end may be delimited by a free surface which may, for example, be formed by a flat end surface and the bevelled edge which is usually used around said flat surface. The purpose of such a bevelled edge is to prevent sharp edges on the periphery which could easily break away.

[0019] Alternatively, as has already been mentioned before, a base piece may adjoin the base end of the base portion, preferably a base piece which is widened with respect to the head end. The base end of the base portion is then situated at the transition from the base portion to the base piece.

[0020] In practice, the head can be distinguished from the base by a marking on the head. Furthermore, an additional head reinforcement which may, for example, be spiral-shaped is provided in the concrete body of the head in order to offer sufficient strength against the blows or vibrations which are to be applied to the head in order to drive the foundation pile into the ground.

[0021] Furthermore, the invention relates to the use of the foundation pile in a foundation structure, comprising a foundation pile with a pile shaft which forms a single entity in cross section, a head at one end of the pile shaft and a tip or base which is to be driven into a substrate at the other end of the pile shaft, which pile shaft comprises at least a narrowed portion having a cross section which changes in the longitudinal direction of the pile shaft, a prismatic head portion which adjoins the head and a prismatic base portion which adjoins the base. This foundation structure is configured in such a manner that the relatively high area of the narrowed portion and/or the head portion is/are subjected to negative skin friction, and the relatively low area of the narrowed portion and/or the base portion is/are subjected to positive skin friction.

[0022] Negative skin friction occurs at the location of the relatively high area of the narrowed portion and of a prismatic portion adjoining this area. Due to the configuration of the foundation structure, the magnitude of the negative skin friction is limited, so that as much benefit as possible is derived from the positive skin friction. In addition, the foundation pile and the substrate may also be in mutual equilibrium due to the resistance of the base.

[0023] In this case, a cross section with a relatively large periphery of the narrowed portion and/or a cross section with a relatively large periphery of the base portion of the foundation pile is situated in the area of the substrate where positive skin friction occurs, while a cross section with a relatively small periphery of the narrowed portion and/or a cross section with a relatively small periphery of the head portion is situated in an area of the substrate where negative skin friction occurs.

[0024] The invention furthermore relates to a founda-

tion structure, comprising a foundation pile as described above with a pile shaft which forms a single entity in cross section, a head at one end of the pile shaft and a tip or base which is to be driven into a substrate at the other end of the pile shaft, which pile shaft comprises at least a narrowed portion having a cross section which changes in the longitudinal direction of the pile shaft, a prismatic head portion which adjoins the head and a prismatic base portion which adjoins the base. The relatively high area of the narrowed portion and/or the head portion adjoining said high area is/are subjected to negative skin friction, and the relatively low area of the narrowed portion and/or the base portion adjoining said low area is/are subjected to positive skin friction.

[0025] Below, the invention will be explained in more detail with reference to an exemplary embodiment illustrated in the figures, in which:

Fig. 1 shows a view along I in Fig. 3 of a foundation pile.

Fig. 2 shows a view along II in Fig. 3 of a foundation pile.

Fig. 3 shows a view along III in Fig. 1 of a foundation pile.

Fig. 4 shows a view along IV of Fig. 1 of the foundation pile.

Fig. 5 shows a foundation pile driven into the ground.

[0026] The foundation pile 1 shown in Figs. 1-5 consists of a pile shaft 2 in the form of a concrete body 17 which incorporates a reinforcement 3 which consists of rods and is not shown in any more detail in a manner known per se. Such a reinforcement serves to reinforce the foundation pile and is completely covered by the concrete body 17. The pile shaft 2 has a head portion 8 with a head 4 and a head end 19 onto which, for example, a piling cap or a vibrating device is placed for the purpose of driving the foundation pile into a substrate. In this case, the tip or base 5 at the other end of the pile shaft 2 is placed on the substrate and subsequently driven therein.

[0027] Furthermore, the pile shaft 2 has a base portion 6 with a base 5 and a base end 20. In the embodiment illustrated in full lines, both the head end 19 and the base end 20 consist of the bevelled edge 18 extending all around and the area 21 and 22, respectively, situated in between, both of which are flat in this case. The projection of the head end 19 onto an imaginary plane at right angles to the longitudinal direction of the pile shaft 2 is denoted by P19 and thus has a periphery which is equal to the periphery of the head portion 8. The projection of the base end 20 onto an imaginary plane at right angles to the longitudinal direction of the pile shaft 2 is denoted by P20 and thus has a periphery which is identical to the periphery of the base portion 6. The periphery of the projection P19 of the head end 19 is smaller than the periphery of the projection P20 of the base end 20.

[0028] According to a variant, the base 5 may be configured to have a widened base piece 23, as is illustrated

with broken lines in Figs. 1-4. Said base piece 23 has a larger cross section than the base portion 6 in order to produce the desired resistance of the base. In this embodiment, the base end 20 of the base portion 6 is situated at the transition between the base portion 6 and the base piece 23. With this variant as well, the foundation pile has a base portion 6 with a relatively large periphery and a head portion 8 with a relatively small periphery in order to reduce the effect of negative skin friction.

[0029] The foundation pile 1 thus consists of different portions. A prismatic portion 6, which in the longitudinal section of the foundation pile has a constant cross section, adjoins the base 5. Joined thereto is the narrowed portion 7 which, in the direction viewed from the base 5 towards the head 4, has cross sectional areas of decreasing size. Thereafter, another prismatic portion 8 follows which has a constant cross section in the longitudinal direction of the foundation pile.

[0030] As can also be seen in the end view from Fig. 3, the surface of the head 4 is smaller than the surface of the base 5. It can also be seen in said Fig. 3 that the foundation pile 1 has two surfaces 9, 10 which face away from each other and extend flatly along all portions. This is in contrast to the other two surfaces 11, 12 which have a slightly bent course at the location of the transitions 13 and 14, respectively, between the prismatic portion 6 near the base 5 and the narrowed portion 7, and between the narrowed portion 7 and the prismatic portion 10 near the head 4.

[0031] As is illustrated in Fig. 5, the foundation pile 1 is accommodated in a substrate 15. The prismatic portion 10 near the base 5 of the foundation pile has penetrated into a load-bearing layer 16, preferably a sand layer. The depth to which the prismatic portion 10 has penetrated into said sand layer 16 is preferably approximately eight times the transverse dimension of the base 5. The foundation pile experiences a certain resistance of the base V in the sand layer 16, as a result of which an upwardly directed force is exerted on the foundation pile which supplies a significant part of the load-bearing capacity of the foundation pile. Along the section of the foundation pile 1 which extends between the sand layer 16 and the surface of the substrate 15, the effect of friction of the shaft or skin friction occurs. Negative skin friction N which results from the settling of the substrate 15 may occur in particular in the upper section of the foundation pile. This negative skin friction leads to a downwardly directed force on the foundation pile and reduces the load-bearing capacity of the foundation pile 1. The positive skin friction P which applies an upwardly directed force to the foundation pile and which occurs along the deeper section of the foundation pile 1 does provide a positive contribution to the load-bearing capacity.

[0032] However, due to the fact that the upper section of the foundation pile 1 has a smaller periphery, the surface on which the effect of a negative skin friction occurs is relatively small. Thus, the effect of negative skin friction on the total load-bearing capacity of the pile is reduced.

The nett load-bearing capacity can thus be significantly increased, for example by 10 % to 15 %. A further advantage of the reduced periphery of the foundation pile 1 is that less concrete material is needed. The concrete material is thus used very efficiently to achieve a relatively high load-bearing capacity. In addition, the costs of the pile can remain relatively low, due to the limited consumption of material.

List of reference numerals

[0033]

1.	Foundation pile
2.	Pile shaft
3.	Reinforcement
4.	Head
5.	Base
6.	Prismatic base portion
7.	Narrowed or tapered portion
8.	Prismatic head portion
9., 10.	Flat surfaces of concrete body
11., 12.	Bent surfaces of concrete body
13., 14.	Transitions between portions
15.	Substrate
16.	Load-bearing layer
17.	Concrete body
18.	Bevelled edge
19.	Head end
20.	Base end
21.	Flat area of head end
22.	Flat area of base end
23.	Base piece
V	Resistance of base
P	Positive skin friction
N	Negative skin friction
P 19	Projection of head end
P20	Projection of base end

Claims

1. Foundation pile (1) intended to be driven into a substrate and to provide skin friction with respect to said substrate, comprising a pile shaft (2) which, in cross section, forms a single entity, a head (4) at an end of the pile shaft and a tip or base (5) which is to be driven into a substrate at the other end of the pile shaft, which pile shaft (2) comprises at least a narrowed or tapered portion (7) whose cross section changes in the longitudinal direction of the pile shaft (2), a prismatic head portion (8) which adjoins the head (4) and a prismatic base portion (6) which adjoins the base (5), **characterized in that** the head portion (8) has a periphery which is smaller than the periphery of the base portion (6).
2. Foundation pile (1) according to Claim 1, wherein

the narrowed portion (7) has a cross section with a relatively large periphery and a cross section with a relatively small periphery and the cross section with the relatively large periphery of the narrowed portion is situated at a greater distance from the head than the cross section with the relatively small periphery of the narrowed portion, and preferably the periphery of the cross section of the narrowed portion (7) decreases monotonously in the direction from the base (5) to the head (4).

3. Foundation pile (1) according to one of the preceding claims, wherein the narrowed portion (7) has a polygonal cross section and at least one of the walls (11, 12) which delimit the polygonal cross section is directed obliquely with respect to the longitudinal direction.
4. Foundation pile (1) according to Claim 3, wherein the narrowed portion (7) has a square or rectangular cross section and one and only one of the walls is directed obliquely with respect to the longitudinal direction.
5. Foundation pile (1) according to Claim 4, wherein the narrowed portion (7) has a square or rectangular cross section comprising two opposite walls (11, 12) which are directed obliquely towards one another.
6. Foundation pile (1) according to one of Claims 3-5, wherein two opposite walls (9, 10) of the narrowed portion (7) are mutually parallel.
7. Foundation pile (1) according to one of the preceding claims, wherein the prismatic portion (6) adjoining the base (5) has a square cross section and the prismatic portion (8) adjoining the head (4) has a rectangular cross section.
8. Foundation pile (1) according to Claim 8, wherein a wall, preferably two opposite walls (9, 10), extend(s) evenly across all portions.
9. Foundation pile (1) according to one of Claims 7-9, wherein the prismatic portion (6) adjoining the base (5) has a length which is more than 2 times, preferably more than 3 times and more preferably 4 times a transverse dimension of said portion.
10. Foundation pile (1) according to one of the preceding claims, wherein the transition between a prismatic portion (6, 8) and a narrowed portion (7) is not stepped and the end surface of the narrowed portion and the adjacent end surface of the prismatic portion have identical shapes and dimensions (congruent).
11. Foundation pile (1) according to one of the preceding claims, wherein the head portion (8) has a head end

(19) and the base portion (6) has a base end (20) which faces away from the head end, which head end has a projection (P19) on a plane of projection at right angles to the longitudinal direction of the pile shaft (2) whose periphery is smaller than the periphery of the projection (P20) of the base end (20) on said plane of projection.

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12. Foundation pile (1) according to Claim 11, wherein the base end (20) has a free surface (18, 21) or a base piece (23) which adjoins the base end (20) of the base portion (6), preferably a base piece which is widened with respect to the head end.

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13. Use of a foundation pile according to one of the preceding claims in a foundation structure, which foundation pile comprises a pile shaft (2) which forms a single entity in cross section, a head (4) at one end of the pile shaft and a tip or base (5) which is to be driven into a substrate at the other end of the pile shaft, which pile shaft (2) comprises at least a narrowed portion (7) having a cross section which changes in the longitudinal direction of the pile shaft (2), a prismatic head portion (8) which adjoins the head (4) and a prismatic base portion (6) which adjoins the base (5), **characterized in that** the relatively high area of the narrowed portion (7) and/or the head portion (8) is/are subjected to negative skin friction, and the relatively low area of the narrowed portion (7) and/or the base portion (6) is/are subjected to positive skin friction.

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14. Use of a foundation pile according to Claim 13, wherein a cross section with a relatively large periphery of the narrowed portion (7) and/or a cross section with a relatively large periphery of the base portion (6) of the foundation pile is situated in the area of the substrate where positive skin friction occurs, and a cross section with a relatively small periphery of the narrowed portion (7) and/or a cross section with a relatively small periphery of the head portion (8) of the foundation pile is situated in the area of the substrate where negative skin friction occurs.

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15. Foundation structure, comprising a foundation pile according to one of Claims 1-12 with a pile shaft (2) which forms a single entity in cross section, a head (4) at one end of the pile shaft and a tip or base (5) which is to be driven into a substrate at the other end of the pile shaft, which pile shaft (2) comprises at least a narrowed portion (7) having a cross section which changes in the longitudinal direction of the pile shaft (2), a prismatic head portion (8) which adjoins the head (4) and a prismatic base portion (6) which adjoins the base (5), **characterized in that** the relatively high area of the narrowed portion (7) and/or the head portion (8) is/are subjected to negative skin

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friction, and the relatively low area of the narrowed portion (7) and/or the base portion (6) is/are subjected to positive skin friction.

Fig 1

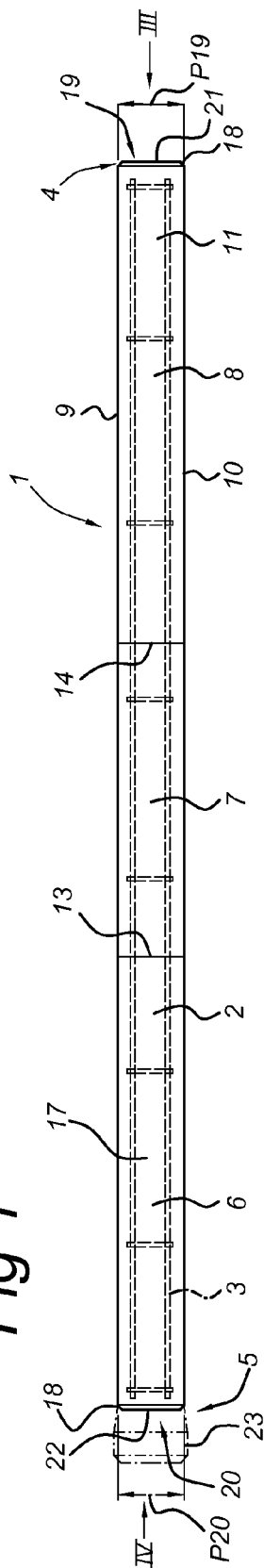


Fig 2

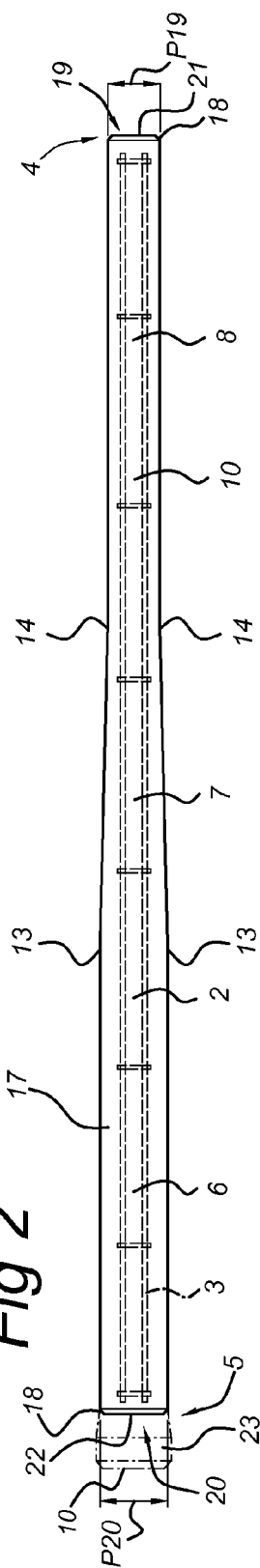


Fig 3

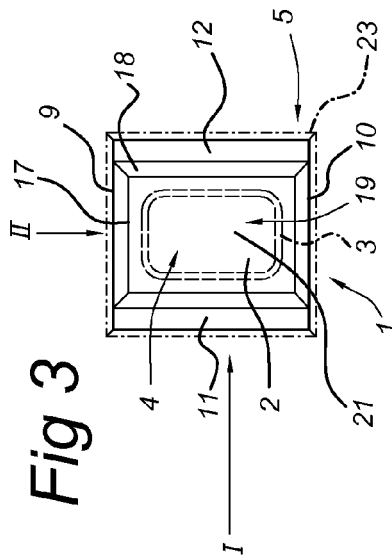


Fig 4

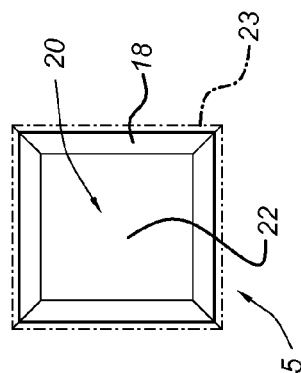
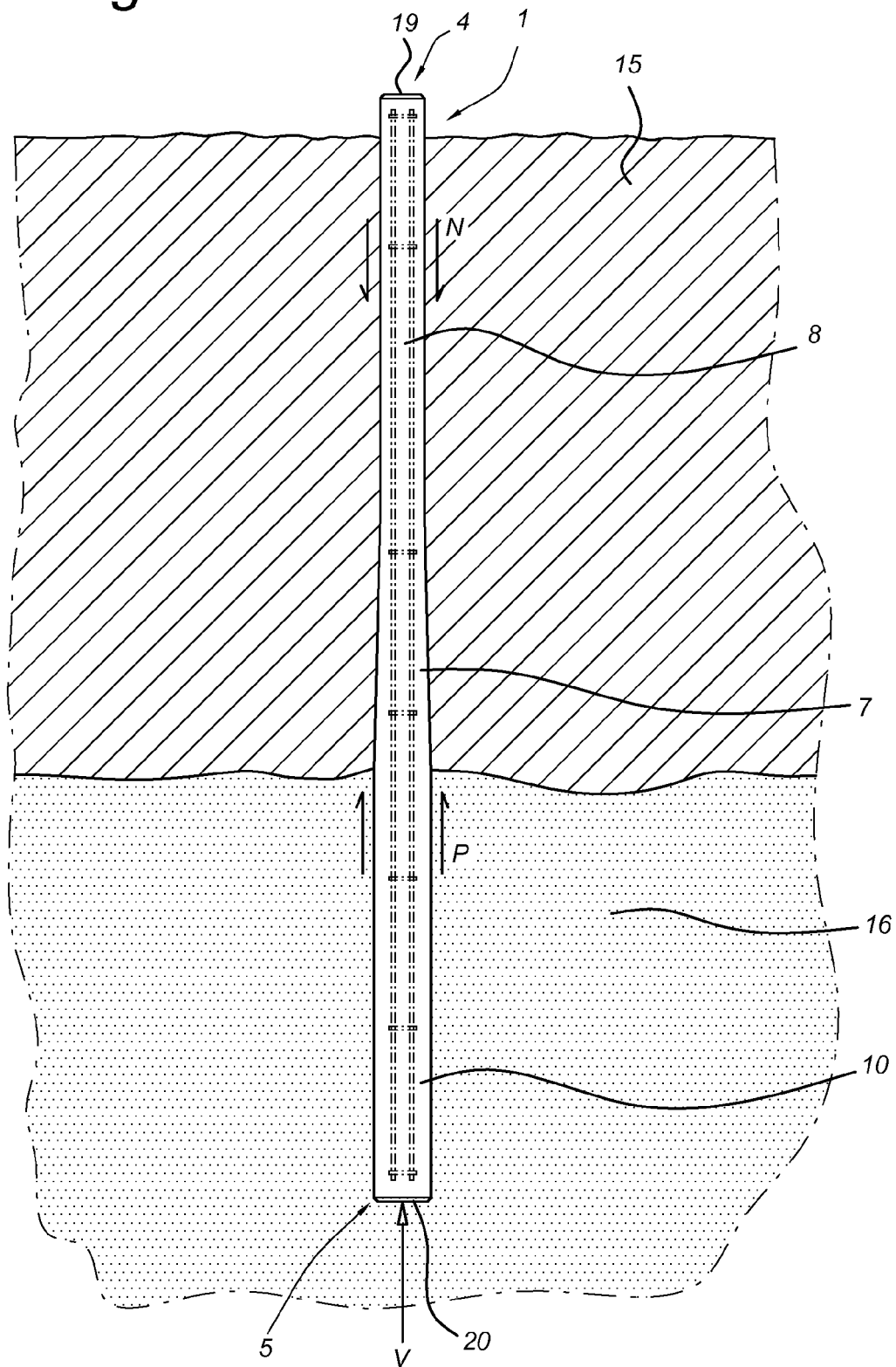


Fig 5





EUROPEAN SEARCH REPORT

Application Number
EP 12 17 3440

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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 25 September 2012	Examiner Leroux, Corentine
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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EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 12 17 3440

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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