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(54) **A pile for deep foundation and method for providing a pile**

(57) The present invention relates to a pile for deep foundation piling, which pile is driven or arranged to be driven into the ground, the pile comprising an upper concrete pile section comprising an upper axial end provided with an upper drive-fit connection member arranged for cooperation with a tube member, such as a steel tube or pipe, having a predetermined radial dimension, and a final upper pile section formed of a tube, such as a steel tube or pipe, having the predetermined radial dimension, wherein a lower axial end of the final upper pile section is attached by drive-fit cooperation with the upper drive-fit connection member of the upper concrete pile section.

The present invention also relates to a method for manufacturing a pile for deep foundation piling.

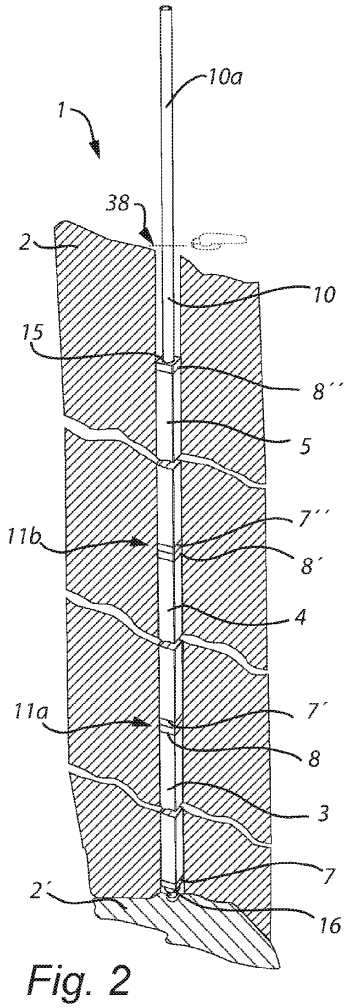

Fig. 2

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Description

Field of the Invention

[0001] The present invention relates to underground foundation reinforcement. In more detail, the present invention relates to a pile for deep foundation piling, and to a method for providing a pile for deep foundation piling, which pile is arranged to be driven into the ground and comprises at least one concrete section having drive-fit connections members arranged to axial ends of the concrete pile section for joining the concrete pile section with a final upper pile section formed of a tube, such as a steel tube or pipe.

[0002] The present invention also relates to a concrete section comprising drive-fit connections members arranged to axial ends of the concrete pile section.

Background Art

[0003] In the field of deep foundation it is known to provide different kinds of piles which are driven into the ground in order to e.g. provide improved load bearing capacity or to support the ground for other reasons. For example, piles may be formed of reinforced concrete, steel, or wood, and are typically driven into the ground using a pile driver. By driving the pile into the ground, the soil is displaced and/or compressed which result in friction between the sides of the pile and the soil which provides increased load-bearing capacity.

[0004] It is further known to join, or splice, pile sections prior to, or during, driving a pile into the ground in order to provide a pile of suitable length.

[0005] For example, according to one piling technique, a steel pile made of steel pipe sections which are joined together during the driving process is formed and driven into the ground until the intended depth, or an underground support portion, such as a more load bearing stratum or rock, is reached by the lower pile end which may be provided with a pile end shoe. When the intended depth is reached, the excess or projecting portion of the final or top steel pile section extending above the ground may be cut off and used as a pile section in an additional steel pile. However, steel piles are disadvantageous in that they e.g. are expensive to manufacture due to e.g. high energy consumption during manufacturing of the steel pile sections and in that the costs the for the raw material is relatively high.

[0006] According to a more cost efficient piling technique, at least in terms of fabrication and raw material of the pile sections, a concrete pile made of prefabricated concrete pile sections which are joined to each other may be driven into the ground with a pile end shoe arranged at a bottom end, wherein the concrete pile sections are joined, or spliced, by joint members integrated with or casted into axial end portions of each concrete pile section. In a similar manner as the steel pile technique, when the intended depth is reached, the excess or projecting portion of the final or top concrete pile section extending above the ground may be cut off. However, the concrete piling technique is disadvantageous in that the cut off excess portion of the concrete pile generates waste material. The cut off excess portion may not be reused in a different concrete pile since the cut off axial end of the excess portion lacks the required joint member. In order to avoid cutting of the concrete pile, the length of the prefabricated concrete pile sections may be matched to the intended drive depth of the pile. However, manufacturing, stock-keeping and transporting a number of different concrete pile sections having different lengths are costly. Furthermore, the final depth of a driven pile may vary unpredictably, also within the same construction site.

Summary of the Invention

[0007] In view of the above-mentioned and other drawbacks of the prior art, a general object of the present invention is to provide an improved pile and an improved method for providing a pile, which pile is more cost efficient and allows for higher utilization of the raw material.

[0008] These and other objects are met by the subject matters provided in the independent claims. Preferred embodiments of the invention are presented in the dependent claims.

[0009] According to a first aspect thereof, the present invention relates to a pile for deep foundation piling, which pile is driven or arranged to be driven into the ground, the pile comprising an upper concrete pile section comprising an upper axial end provided with an upper drive-fit connection member arranged for cooperation with a tube member having a predetermined radial dimension, and a final upper pile section formed of a tube having the predetermined radial dimension, wherein a lower axial end of the final upper pile section is attached by drive-fit cooperation with the upper drive-fit connection member of the upper concrete pile section.

[0010] The invention is based on the realization by the inventors that an improved pile may be realized by providing a pile comprising a combination of concrete pile sections provided with a drive-fit connection member which is relatively cost efficient to manufacture and a final pile section, wherein the final pile section are formed of a tube having a predetermined dimensional shape adapted for drive-fit attachment to the concrete pile section. Hence, the pile may advantageously by provided by driving, forcing, and/or pressing the tube-formed final upper pile section into secure attachment with the drive-fit connection member. Also, by providing the concrete pile sections with drive-fit connection member arranged to cooperate with tube members having the predetermined dimensional shape, the material utilization level and manufacturing cost may be improved. For example, low cost concrete pile sections may be used to form the main part of the pile, while pipe sections may be used to form the final, or top, pile sections. By providing the final pile sec-

tion, the excess or projecting portion of the final or top pile section extending above the ground may be cut off and re-used in a different pile, for example as the final pile section, as one or more joint members, and/or as a bottom pile section.

[0011] Furthermore, by providing a pile having an upper portion formed of the final pile section, such as a steel pile section, the pile length may advantageously be adjusted by cutting of the final pile section more efficiently. Furthermore, the final pile sections allows for an upper pile cut off level which is below the ground level, i.e. at a subsurface level, by cutting the pile section from the inside using e.g. an internal cutting device. For example, a subsurface cut off level reduce the risk of damaging the pile during earth excavating operations following piling operations.

[0012] The pile according to the present invention is further advantageous in that only one type, or length of, concrete pile section is needed to provide piles of varying lengths by joining a plurality of concrete pile sections. Hence, manufacturing, handling, and stock-keeping of the concrete pile sections is facilitated since the need for concrete piles of different lengths may be avoided or reduced. Also, planning and transportation of a plurality of concrete pile sections having different length, due to unpredictable piling depths, may be avoided.

[0013] The concrete pile sections may have a square, octagonal, or a round, or any other suitable cross-section. The concrete pile sections may be reinforced e.g. with reinforcing bar, rebar, and may be pre-stressed.

[0014] For example, the pile may comprise a plurality of intermediate concrete pile sections, each comprising a first and second axial end provided with respective drive-fit connection members, wherein the one or more concrete pile sections may be joined by a joint member in a consecutive manner during an in situ driving process.

[0015] The tube which is used for forming the final steel pile section and e.g. the joint members, may have a square, octagonal, or a round cross-section, or any other suitable cross-section.

[0016] According to an exemplifying embodiment, the upper concrete pile section further comprises a lower axial end provided with a lower drive-fit connection member, the pile further comprising one or more lower concrete pile sections, each lower concrete pile section comprising a lower axial end provided with a lower drive-fit connection member and an upper axial end provided with an upper drive-fit connection member, each drive-fit connection members of the upper and lower concrete pile sections being arranged for cooperation with a tube member having a predetermined radial dimension, the lower and upper concrete pile sections being joined to axially neighboring concrete pile section by one or more joints, the one or each joint being formed of the respective lower drive-fit connection member and the upper drive-fit connection member of the neighboring concrete pile sections and a joint member being formed of a tube having the predetermined radial dimension, wherein a first axial end portion of the joint member is attached by drive-fit cooperation with the upper drive-fit connection member and a second axial end portion of the joint member is attached by drive-fit cooperation with the lower drive-fit connection member

[0017] The inventors have further realized that an improved pile may be achieved by providing a pile comprising a combination of concrete pile sections, joint members for joining the concrete pile sections and a final pile section, wherein the joint members and the final pile section are formed of a tube, such as a steel tube or pipe, having a predetermined dimensional shape. Furthermore, by providing the concrete pile sections with drive-fit connector members arranged to cooperate with tube members having the predetermined dimensional shape, the material utilization level and manufacturing cost may be improved. In particular, low cost concrete pile sections may be used to form the main part of the pile, while tube pile sections may be used to form the final, or top, pile sections as well as joint member for joining the concrete pile sections. For example, waste material which is cut off from the final pile section in order to provide a pile of suitable length, may be reused as joint members in a following pile.

[0018] According to an exemplifying embodiment, the pile further comprises an end shoe member arranged to the bottom end of the pile, which end shoe member comprises a tube, such as a steel tube or pipe, having the predetermined radial dimension, wherein an upper axial end portion of the tube is attached by drive-fit cooperation with the lower drive-fit connection member of a bottom concrete pile section. The bottom and upper concrete pile sections may be the same, wherein the pile only comprises one concrete pile section. The pile may also comprise a plurality of concrete pile sections, wherein the end shoe member is attached to the bottom of the axially lowest concrete pile section.

[0019] The end shoe is advantageous in that it facilitates the driving, or insertion, of the pile into the ground. Furthermore, the end shoe protects and prevents cracking of the bottom concrete pile section. For example, the end shoe is formed of a casting member, e.g. of iron, shaped to a point and fitted to a steel tube which is fitted to the lower end of the pile. According to an embodiment the end shoe comprises a drive-fit connection member being arranged for drive-fit attachment or cooperation with a tube member having the predetermined radial dimension.

[0020] The end shoe member and associated tube may also be used for penetrating and/or securing the bottom end of the pile into a subsurface load bearing support stratum which is inappropriate for concrete pile sections, such as moraine or boulder clay.

[0021] According to an exemplifying embodiment, the lower drive-fit connection member of each concrete pile section comprises a first axially receiving cavity, and the upper drive-fit connection member of each concrete pile section comprises a second axially receiving cavity,

which axially receiving cavities have decreased, or inwardly decreasing, radial dimensions for drive-fit cooperation with a tube having the predetermined radial dimension. Hence, a pile section or a joint member having the predetermined radial outer dimension may be driven into a secured engagement with lower or upper drive-fit connection member of any concrete pile section. Thereby, the axially receiving cavities forms cavities which are arranged to receive a tube member which is inserted into the cavity in the axial direction in relation to the pile.

[0022] According to an alternative embodiment, one or both of the lower and upper drive-fit connection members of each concrete pile section comprises an axial tapered protrusion portion, instead of the receiving cavity, which protrusion portion extends away from the concrete pile section and is arranged to be received in the tube having the predetermined dimension such that drive-fit attachment is provided by plastically and/or elastically expanding the end portion of the tube by the tapered protrusion. The radial dimension of the tapered protrusion decrease in an axial direction away from the concrete pile section. Furthermore, the inner radial dimension of the tube is adapted for drive-fit cooperation with the tapered protrusion.

[0023] According to a further exemplifying embodiment, the lower axial end of the final upper pile section is driven into the second axially receiving cavity of the upper drive-fit connection member of the upper concrete pile section.

[0024] Furthermore, according to an exemplifying embodiment, the first axial end portion of the joint member of the or each joint is driven into the second axially receiving cavity of the upper drive-fit connection member and the second axial end portion of the joint member is driven into the first axially receiving cavity of the lower drive-fit connection member. Thereby, the axially receiving cavities forms cavities which are arranged on respective ends of the concrete pile section to receive a tube member which is inserted, or driven, by force into the cavity in the axial direction in relation to the pile section. Hence, two neighboring concrete pile sections may advantageously be joined in a simple manner while providing a durable, strong, and cost efficient joint suitable for supporting both compressive and tensile forces.

[0025] Moreover, according to an exemplifying embodiment, each drive-fit connection member is arranged for drive-fit cooperation with a tube member having a predetermined radial dimension such that the tube is prevented from axial and rotational movements in relation to the drive-fit connection member.

[0026] According to an exemplifying embodiment, each drive-fit cooperation comprises a friction joint formed by plastically and/or elastically deforming the first and second axial end portions of the joint member and the lower axial end of the final upper pile section. The deformation may involve compressing or expanding the first and second axial end portions of the joint member and the lower axial end of the final upper pile section in a transverse direction in relation to the axial direction of the pile.

[0027] Moreover, according to an exemplifying embodiment, each axially receiving cavity is provided with an inner support portion against which the inserted tube, in its inserted position, is arranged to rest. The inner support portion further improves the durability and reliability of the drive-fit joint by ensuring that the tube is driven into the cavity to a desired predetermined axial depth. Hence, the drive-fit cooperation between the drive-fit connector member and the tube may be configured for suitable cracking, buckling, and load bearing properties.

[0028] Furthermore, according to an exemplifying embodiment, the joint member comprises an air release opening arranged for releasing air from the inside of the joint member during joining of two concrete pile sections, such as the upper and lower concrete pile sections, or two lower concrete pile sections. Thereby, excessive pressure build-up inside the joint member tube may be avoided since air is allowed to escape through the air release opening.

[0029] For example, according to an exemplifying embodiment, the air release opening comprises a radial through hole arranged at an axially centered position of the joint member. In other words, the air release opening is provided on the joint member in a location which is centered in relation to the axial extension of the joint member. Furthermore, the air release opening may be adapted to be positioned in an axially centered position between two connected concrete pile sections. Furthermore, the axial length of the joint member may be adapted in relation to the axial depth of the axially receiving cavity such that the end plate support surfaces of two adjacent and joined concrete pile sections meet or are arranged in contact with each other.

[0030] According to different embodiments of the present invention, the concrete pile sections have an essentially square cross-section, for example having the dimensions 20x20 cm, 23,5x23,5 cm, 25x25 cm, 27,5x27,5 cm, or 30x30 cm, $\pm$ 2 or $\pm$ 1 cm on any side. According to further different embodiments, the tube of which the joint member and the final upper pile section are formed of e.g. a pipe, may have an outer diameter between 5 and 30 cm, or between 8 and 20 cm, or between 10 and 17 cm. The outer dimension of the tube may also, according to different embodiments, be about 11,5 cm, 14 cm, or 17 cm, $\pm$ 2 or $\pm$ 1 cm, or anything there between. Furthermore, the length of the concrete pile sections may, according to different embodiments, be between 2 and 35 m, or between 4 and 25 m, or between 4 and 10, or about 5, 9, or 13 m, $\pm$ 2 or $\pm$ 1 m, or anything there between.

[0031] According to a another aspect thereof, the present invention relates to a method for providing a pile for deep foundation piling, which pile is arranged to be driven into the ground, the method comprising:

- providing an upper concrete pile section comprising

an upper axial end provided with an upper drive-fit connection member arranged for cooperation with a tube member having a predetermined radial dimension,

- providing a final pile section formed of a tube having the predetermined radial dimension, and
- axially joining the final pile section to the upper drive-fit connection member of the upper axial end of the upper concrete pile section, which upper concrete pile section forms part of the pile, by driving a lower axial end portion of the final pile section to attached cooperation with the upper drive-fit connection member of the upper concrete pile section.

[0032] Accordingly, an improved method for providing a pile, which pile is more cost efficient and allows for higher utilization of the raw material, is provided. The method for providing or manufacturing a pile is further advantageous in similar manner as described above in relation to the pile for deep foundation piling.

[0033] According to an exemplifying embodiment, the upper concrete pile section further comprises a lower axial end provided with a lower drive-fit connection member arranged for cooperation with a tube member having a predetermined radial dimension, the method further comprising:

- providing one or more lower concrete pile sections, each lower concrete pile section comprising a lower axial end provided with a lower drive-fit connection member and an upper axial end provided with an upper drive-fit connection member, each drive-fit connection member being arranged for cooperation with a tube member having a predetermined radial dimension,
- providing at least one joint member for axially connecting the upper and lower concrete pile sections, which joint member is formed of a tube member having the predetermined radial dimension, and
- axially joining the upper concrete pile section to at least one lower concrete pile section to form the pile by driving a first axial end portion of the joint member to attached cooperation with the upper drive-fit connection member of the at least one lower concrete pile section, and driving a second axial end portion of the joint member to attached cooperation with the lower drive-fit connection member of the upper concrete pile section.

[0034] Thereby, piling, or in situ piling, using only one type of similar sized tubes for joint members and for the final upper pile section, and only one type of concrete pile section, is provided. Furthermore, any rest material generated during the manufacturing of a first pile may advantageously be reused during the manufacturing of a second pile.

[0035] According to an exemplifying embodiment, the method further comprises releasing air from the inside of the joint member during joining the upper concrete pile section to the lower concrete pile section via an air release opening of the joint member. For example, air is released in a radial direction through the joint member via the air release opening.

[0036] Furthermore, the lower drive-fit connection member of each concrete pile section may, according to an exemplifying embodiment, be formed of a first axially receiving cavity, and the upper drive-fit connection member of each concrete pile section is formed of a second axially receiving cavity, which axial receiving cavities have decreased radial dimensions for drive-fit cooperation with a tube having the predetermined radial dimension.

[0037] Moreover, according to an exemplifying embodiment of the method, the step of axially joining the final pile section to the upper concrete pile section comprises driving the lower axial end portion of the final pile section into the second axially receiving cavity of the upper drive-fit connection member of the upper concrete pile section. Hence, the final pile section may advantageously be axially forced or pressed into the axially receiving cavity such that it is securely attached to concrete pile section.

[0038] According to yet an exemplifying embodiment of the method the step of axially joining the upper concrete pile section to the at least one lower concrete pile section comprises driving the first axial end portion of the joint member into the second axially receiving cavity of the lower concrete pile section and driving the second axial end portion of the joint member into the first axially receiving cavity of the upper concrete pile section.

[0039] According to a another aspect thereof, the present invention relates to a concrete pile section for a pile for deep foundation piling, during which piling the pile is arranged for being driven into the ground. The concrete pile section comprises a first and second end joint arranged at opposite axial ends of the concrete pile section, each end joint comprising an end plate comprising a support surface facing away from the concrete pile section, and a drive-fit connection member arranged in a radially center position in relation to the end plate, which drive-fit connection member has an axially tapered shape arranged for drive-fit cooperation with a tube member, such as a steel tube or pipe, having a predetermined radial dimension. According to an embodiment, the end joint and drive-fit connection member is arranged for connection of a tube, such as a steel tube or pipe, forming part of the load bearing structure of pile.

[0040] Generally, other objectives, features, and advantages of the present invention will appear from the following detailed disclosure, from the attached dependent claims as well as from the drawings are equally possible within the scope of the invention.

Brief Description of Drawings

[0041] Embodiments of the invention will now be de-

scribed, by way of example, with reference to the accompanying drawings, wherein:

Fig.1 is a schematic perspective view of a pile for deep foundation piling according to an embodiment of the present invention, which pile is partially driven into the ground.

Fig. 2 is a schematic perspective view of a pile for deep foundation piling according to an embodiment of the present invention.

Fig. 3 is a schematic perspective view of a concrete pile section, a joint member and an end shoe member according to an embodiment of the present invention.

Fig. 4 is a schematic cross-sectional view of an axial end of a concrete pile section according to an embodiment of the present invention, which axial end is provided with a drive-fit connection member for cooperation with a tube having a predetermined radial dimension.

Fig. 5 is a schematic cross-sectional view of an axial end of a concrete pile section according to an embodiment of the present invention, which axial end is provided with a drive-fit connection member for cooperation with a tube having a predetermined radial dimension.

Fig. 6 is a schematic perspective view of an end joint for being integrated, or casted into, an axial end of a concrete pile section, seen from above, according to an embodiment of the present invention.

Fig. 7 is a schematic perspective view of an end joint for being integrated, or casted into, an axial end of a concrete pile section, seen from below, according to an embodiment of the present invention.

Fig. 8 is a schematic cross-sectional view of an axial end of a concrete pile section according to an alternative embodiment of the present invention, which axial end is provided with an end joint comprising a drive-fit connection member for cooperation with a tube having a predetermined radial dimension.

Fig. 9 is a schematic cross-sectional view of an end joint comprising a drive-fit connection member according to an embodiment of the present invention.

[0042] It should be understood that the drawings are not true to scale and, as is readily appreciated by a person skilled in the art, dimensions other than those illustrated in the drawings are equally possible within the scope of the invention.

Detailed Description of Embodiments of the Invention

[0043] In the drawings, similar, or equal elements are referred to by equal reference numerals.

[0044] In Fig.1 and Fig. 2, two different schematic perspective views of a pile 1 for deep foundation piling according to an embodiment of the present invention are illustrated. In Fig. 1, the pile is manufactured on site while it is driven into the ground 2 towards a subsurface load bearing support stratum 2'. In Fig. 2 the pile has reach its intended position wherein a bottom end of the pile 1 has reach the support stratum 2'. The pile 1 extends in a main axial direction.

[0045] Pile 1 comprises a plurality of concrete pile sections, 3, 4, 5, or more, which are consecutively joined after each other in the axial direction at joints 11 a, 11 b, or more, to form the a main portion of the pile 1. Each pile section extends in the axial direction and has an upper and a lower end arranged in axially opposite configuration to each other in the axial direction.

[0046] In more detail, pile 1 comprise lower pile sections 3, 4 which form the axially bottom end concrete pile sections of the pile, and an upper concrete pile section 5 which is attached to and arranged above the lower concrete pile section 3, 4. All concrete pile sections 3, 4, 5 are substantially identical and may be manufactured according to one manufacturing process. Furthermore, each concrete pile section 3, 4, 5 comprises a respective lower axial end 6, 6', 6" each provided with a respective lower drive-fit connection member 7, 7', 7" and a respective upper axial end 8, 8', 8" each provided with a respective upper drive-fit connection member 9, 9', 9", wherein each drive-fit connection member is arranged for drive-fit cooperation and attachment with a tube member having a predetermined radial dimension D. Each concrete pile section is further symmetric in relation to an axially centre plane having a normal direction coinciding with a main axial direction of the concrete pile section.

[0047] As further illustrated, the concrete pile sections 3, 4, 5 are joined end to end via joints 11 a, 11b each formed by a lower drive-fit connection member 7, 7', 7" and an upper drive-fit member 9, 9', 9" of two adjacent concrete pile sections, such as concrete pile section 3 and 4 or concrete pile section 4 and 5, or further concrete pile sections attached and axially stacked on top of each other. Furthermore, each joint 11 a, 11 b comprises a joint member 12 formed of a tube, such as a steel tube or pipe, having a predetermined outer radial dimension D, wherein attachment between the joined concrete pile sections are achieved by drive-fit cooperation between the respective drive-fit connection members of the concrete pile sections and the joint member 12 which is arranged between the concrete pile sections. In more detail, a first axial end portion 13 of the joint member 12 is driven into drive-fit cooperation with the upper drive-fit connection member and a second axial end portion 14 of the joint member 12 is driven into drive-fit cooperation with the lower drive-fit connection member of respective joint.

[0048] With reference to Fig. 1, the pile 1 is being manufactured on site wherein the pile 1 is being driven into the ground while, in an alternating process, additional concrete pile sections, such as upper concrete pile section 5, are jointed at the upper end of the pile 1. According to an embodiment, the pile 1 may be manufactured by providing the lower axial end 6 of the first, or lower, con-

crete pile section 3 with an end shoe member 16, which end shoe member comprises a tube having the predetermined radial dimension D. Next, the lower concrete pile section 3 and associated end shoe member is driven into the ground 2 by a pile driver (not shown) until the lower concrete pile section is essentially fully inserted into the ground. A further lower concrete pile section 4, which forms and intermediate pile section, is joined to the upper axial end 8 of the lower concrete pile section 3 at a joint 11a by pressing, or forcing, in an axial direction, the lower 3 and 4 concrete pile sections into drive-fit cooperation with an intermediately arranged joint member 12. Next, the pile 1 may be driven further into the ground by the pile driver, after which further concrete pile sections or a final upper pile section 10, as shown in Fig. 2, is attached to the upper axial end of the upper concrete pile section. In the illustrated embodiment in Fig. 1, however, a further concrete pile section 5, which forms the upper concrete pile section, is attached by drive-fit attachment at joint 11 b in a similar manner as described with reference to joint 11 a, after which the pile 1 may be further driven into the ground 2.

[0049] With reference to Fig. 2 the pile has been driven into the ground to its intended depth and a final pile section 10 formed of a e.g. steel tube having the predetermined outer radial dimension D adapted for drive-fit cooperation with the concrete pile sections' drive-fit connection members. As illustrated in the depicted embodiment, a lower axial end 15 of the final upper pile section 10 is attached by drive-fit cooperation to the upper drive-fit connection member 8" of the upper intermediate concrete pile section 5. However, according to various embodiments, the pile may be formed with only one or a plurality of concrete pile sections, Hence, the pile 1 may be arranged into different lengths depending on the number of lower concrete pile sections which are provided.

[0050] As further illustrated in Fig. 2, the final, or top, pile section 10 comprises an excess, or projecting, portion 10a extending above the ground 2 which may be cut off at a suitable level, such as level 38, depending on the intended use and function of the pile 1. The final pile section 10 may be cut off using cutting wheel or similar device, or an internal cutting device for cutting the final pile section from the inside at the intended level. Hence, by using an internal cutting device, the final pile section's cut off level may be below the surface of the ground which may be advantageous in some situations.

[0051] As illustrated in and described above with reference to Fig. 1 and 2, each axial end of the concrete pile sections 3, 4, 5 is arranged to cooperate via drive-fit attachment with the final pile section 10 to form the upper portion of the pile 1, and with the joint member 12 to provide secure attachment of the concrete pile sections to each other via joints 11a, 11 b wherein the final pile section 10 and the joint member 12 and may be formed of the same type of pipe having the predetermined outer radial dimension D. Hence, only one type of tube member, or pipe, is required in order to provide pile 1. Furthermore, different sections of the pile may be joined to each other without the use of additional parts or joining means. A pile driver may advantageously be used for driving the sections into drive-fit cooperation with each other on site which facilitate and improves the manufacturing process.

[0052] In Fig. 3, a schematic perspective view of an upper and/or lower concrete pile section 3, a joint member 12 and an end shoe member 16 is illustrated. The concrete pile section 3 is a reinforced precasted concrete pile section which comprises reinforcing bars 24 which are casted, or integrated, into the concrete body 25 of the concrete pile section 3. The reinforcing bars 24 are arranged essentially parallel to each other and extend axially along a main axial direction of the concrete pile section 3. Additional spiral reinforcing bar 26 are arranged, or wound, around the reinforcing bars 24 in a spiral, or helix, configuration extending in the axial direction. The wounding of the spiral reinforcing bar 26 is closer at the axial lower and upper portions of the concrete pile section 3.

[0053] The concrete pile section 3 is further provided with a first end joint 21 arranged at the lower axial end 6 and a second end joint 22 arranged at the upper axial ends 8 of the concrete pile section 3. Each end joint 21 and 22 comprises a respective end plate 23 comprising a support surface facing away from the concrete pile section 3 in the axial direction. Each end joint 21, 22 is further provided with respective drive-fit connection members 7 and 9 which are arranged in a radially center position in relation to the respective end plates 23. As further illustrated, with reference to the drive-fit connection member 9, the drive-fit connection members are formed of respective axial receiving cavities 18 and 19 which have an axially tapered shape arranged for drive-fit cooperation with a tube member having the predetermined radial dimension D. Depending of the use of the concrete pile section as the upper or a lower concrete pile section, a lower axial end of a final upper pile section, or a first axial end portion 13 of a joint member 12, is arranged to be inserted and driven into the second axially receiving cavity 19, wherein a second axial end portion 14 of the joint member 12 is arranged to be inserted and driven into a first axially receiving cavity of a further concrete pile section (not shown) in order to form a joint between two concrete pile sections. As illustrated, the joint member 12 comprises a through hole which forms an air release opening 20 for releasing air from the inside of the joint member 12 during joining of two neighboring concrete pile sections. The air release opening is provided at an axially center position which may be defined as a center location on the joint member in relation to its extension in the axial direction and extends through the pipe wall of the joint member 12. Thereby the air release opening 20 will be positioned at the joint between two joined concrete pile sections.

[0054] As further illustrated in Fig. 3 an upper axial end portion 17a of a tube 17 of end shoe member 16 is ar-

ranged to be inserted and driven into the first axially receiving cavity 18, which tube 17 has the predetermined outer radial dimension D. Thereby, also the end shoe may be secured by and at least partly formed of a similar type tube material as the joint member 12 and final pile section 10. The tube 17 may also comprise a through hole which forms an air release opening for releasing air from the inside of the tube 17 during joining of the end shoe member 16 to the lowest concrete pile section of the pile, arranged in similar manners as described with reference to air release opening 20. If the pile only comprises one concrete pile section, the upper concrete pile section also forms the lower concrete pile section which forms the bottom end of the pile to which the end shoe member 16 may be attached.

[0055] End joints 21 and 22 further comprise a respective set of side walls 27 which extend from the respective end plate in a direction towards the axial center of the concrete pile section 3. As shown, at least one side wall 27 comprises inspection holes 28 for ensuring concrete filling level during the casting process of the concrete pile section and end joints 21 and 22. The inspection holes indicates that the concrete, prior to hardening, sufficiently fills the intended space inside the side walls without leaving e.g. air pockets, or corresponding implications. Each end joint 21 and 22 further comprises fixing bars 34 for fixing and securing the end joint to the concrete pile section 3, which fixing bars bar may be casted, or integrated, into the casted concrete body 25 during a precast manufacturing process of the concrete pile section.

[0056] In Fig. 4 and 5 schematic cross-sectional views of an axial end of a concrete pile section 3 according to two different embodiments of the present invention are illustrated. Also, joint members 12 are illustrated. The concrete pile section 3 may be used as the upper concrete pile section and/or as lower concrete pile sections of a pile. Although only the upper axial end of the concrete pile section is illustrated and described, the lower axial end of the concrete pile section 3 may be arranged in a corresponding manner.

[0057] In Fig. 4, the end joint 22 comprises a drive-fit connection member 9 formed of a receiving cavity 19, an end plate 23 with a support surface facing away from the concrete pile section 3 in the axial direction, and side walls 27 which extend from the end plate along the outer sides of the concrete body 25. The concrete body extends into the space between the receiving cavity 19 and the side walls 27. The side walls 27 protect the axial end of the concrete pile section during handling, transportation, pile manufacturing, and piling process. The receiving cavity 19 is formed by an axially inwardly extending cavity having an opening through end plate 23, which opening is arranged in a radial centered position in relation to the concrete pile section 3. At its opening, the receiving cavity 19 has a radial dimension D' which is adapted to receive a tube having the predetermined radial dimension D, such as the lower axial end of the final pile section 10 depicted in Fig. 2, or the illustrated lower axial end 13 of joint member 12. Inner walls 35 of the cavity extend in an inwardly tapered configuration from the opening towards a support portion 29 arranged to support and transfer axial loads from the tube, such as the final pile section, the joint member, or end shoe member, when it is fully driven into cavity 19. The support portion 29 also ensures that the tube is driven into the cavity to a predetermined depth such that further insertion is prevented. At the support portion 29, the inner radial dimension of the receiving cavity is D", which is smaller than D'. Hence, a suitable drive-fit connection between receiving cavity 19 and the tube is provided, wherein the tube is at least partially plastically and/or elastically compressed into secure drive-fit attachment in the receiving cavity 19. Moreover, during drive-fit attachment, the drive-fit connection member may at least be partially plastically and/or elastically expanded.

[0058] The difference d between D" and D' may for example be between 0 and 15 %, or between 0 and 10 %, or between 0,1 and 5 % of the radial dimension D. Furthermore, the radial dimension D" and D' may be essentially the same but less than the radial dimension D such that drive-fit cooperation between the tube having the radial dimension D and the receiving cavity is realized. The drive-fit attachment does not require welding and may be water tight/resistant.

[0059] As illustrated, the receiving cavity 19 is formed of a tubular member 30 which also comprises an opposite tapered inner portion 31 into which a stop member 32 is secured via drive-fit attachment. The tapered configuration of the inner portion 31 is arranged such that the radial dimension decreases in a direction from an inner axial end of the tubular member 30 towards an axially centered portion of the tubular member 30 at which the support portion 29 is arranged. The stop member 32 is driven into the opposite tapered inner portion 31 such that an outer axial end of the stop member 32 forms the support portion 29. At its axially inner end, the stop member 32 is sealed by an inner bottom plate 33 which prevent concrete from entering into the receiving cavity during the casting process of the concrete pile section.

[0060] The end joint 22 further comprises fixing bars 34 secured to the tubular member 30, which fixing bars extend axially into the concrete body 25 and provides secure attachment of the end joint 22 to the concrete pile section 3.

[0061] The tubular member 30 may further be provided with deformation layer, or zone, 38 arranged radially outside the side wall of the tubular member for absorbing expanding deformations in e.g. the radial direction, of the tubular member 30 when a tube is driven into drive-fit attachment in the tubular member 30, such that the risk of cracking of the concrete body 25 which is adjacent radially outside the tubular member 30 may be reduced or avoided.

[0062] In Fig. 5, the end joint 22 is arranged in a similar manner as described in relation to Fig. 4, unless stated otherwise. As illustrated in this alternative embodiment

of the joint member 22, the tubular member 30 does not comprise an opposite tapered inner portion. Instead, the tubular portion is provided with a bottom plate 33 which forms the support portion 29 which stops the inserted tube at the intended depth during a drive-fit attachment procedure.

[0063] The end joint 22 depicted in e.g. Fig. 4 and 5 may also be used in combination with a wood joint member for axially joining a concrete pile section, or a portion of a concrete pile section, with a wood pile section. For example, the wood joint member comprises a tube comprising an end portion arranged to driven to drive-fit cooperation with the drive-fit connection member of the end joint, and an opposite end portion of the wood joint member which comprises attachment members for attachment to a wood pile section, such as hock members, or barbed hock members provided with barbs to be partially inserted in the end portion of the wood pile section.

[0064] In Fig. 6 and 7, two schematic perspective views of an end joint 22 comprising a drive-fit connection member 9 are illustrated, which end joint 22 is arranged for being integrated, or casted into, an axial end of a concrete pile section. The end joint 22 comprises an end plate 23 including a support surface facing in an axial direction, and a drive-fit connection member 9 arranged in a radially center position in relation to the end plate 23, which drive-fit connection member has an axially tapered shape arranged for drive-fit cooperation with a tube member having a predetermined radial dimension D. According to the depicted embodiment, the axially tapered shape is formed of a receiving cavity 19 for receiving and securing a tube by drive-fit cooperation. The end joint 22 is further arranged as described in relation to Fig. 4.

[0065] In Fig. 8, a schematic cross-sectional view of an alternative embodiment of the axial end 8 of a concrete pile section 3, and associated joint member 22, is illustrated. The joint member 22 comprises a drive-fit connection member 9 arranged for cooperation with a tube member having a predetermined radial dimension D. The drive-fit connection member 9 is formed of a protrusion portion extending axially away from the end joint 22 from end plate 23, and is adapted for drive-fit cooperation with an inner radial dimension of a tube by insertion into an axial end of the tube. As illustrated, in order to achieve drive-fit cooperation and efficient provision of piles formed of concrete pile sections 3, the protrusion portion is cone shaped, or tapered, and comprises tilted side walls 35, such that the radial dimension of the protrusion portions decrease in the axial direction away from the end plate 23.

[0066] In Fig. 9, the end joint 22 is arranged in a similar manner as described in relation to Fig. 4, unless stated otherwise. As illustrated in this alternative embodiment of the joint member 22, the inner radial dimensions D" of the tubular member 30 are essentially the same along the main part of the axially receiving cavity such that a tube member having dimension D may be driven into secure drive-fit attachment.

[0067] It should be noted that the invention has mainly been described above with reference to a few embodiments. However, as is readily appreciated by a person skilled in the art, other embodiments than the ones disclosed above are equally possible within the scope of the invention, as defined by the appended patent claims.

[0068] The tube members, i.e. the pile sections formed of a tube and joint members, may be formed of steel and/or corresponding high strength material which may be cut into desired length and used in combination with the drive-fit connection members of the concrete pile sections for forming a pile, wherein the tube members form part of the load bearing structure of the pile. In a similar manner, the concrete pile sections may be formed of a corresponding material which enables cost efficient manufacturing using casting techniques, involving e.g. integrating reinforcing bars, wherein the end joints according to the present invention are attached to the axial ends of the pile section.

[0069] The above references to drive-fit connection members and drive-fit attachment and cooperation between different members of the pile may also be referred to as press-fit or force-fit connection members and press-fit or force-fit attachment, respectively.

[0070] The above references to lower, bottom, top, upper, etc. pile portions or members, may be defined in relation to ground in a standard situation when a pile according to the present invention is or has been driven into the ground, which references are only used for denoting and identifying different structural portions and members of a pile. However, the pile may be driven into the ground at an angle, or in an essentially horizontal direction, or any angle therebetween. The pile may also be manufactured off site and transported to the piling site in an assembled, or partly assembled, configuration.

[0071] It is further noted that, in the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. A single device or other unit may fulfill the functions of several items recited in the claims. The mere fact that certain features or method steps are recited in mutually different dependent claims does not indicate that a combination of these features or steps cannot be used to advantage.

Claims

1. A pile (1) for deep foundation piling, which pile is driven or arranged to be driven into the ground (2), the pile comprising

   - an upper concrete pile section (5) comprising an upper axial end (8") provided with an upper drive-fit connection member (9") arranged for cooperation with a tube member having a predetermined radial dimension, and
   - a final upper pile section (10) formed of a tube

having the predetermined radial dimension,

wherein a lower axial end (15) of the final upper pile section (10) is attached by drive-fit cooperation with the upper drive-fit connection member of the upper concrete pile section.

2. The pile (1) according to claim 1, wherein the upper concrete pile section further comprises a lower axial end (6") provided with a lower drive-fit connection member (7"), the pile further comprising
one or more lower concrete pile sections (3, 4), each lower concrete pile section comprising a lower axial end (6, 6') provided with a lower drive-fit connection member (7, 7") and an upper axial end (8, 8') provided with an upper drive-fit connection member (9, 9'), each drive-fit connection members (7, 7', 7", 9, 9', 9") of the upper and lower concrete pile sections being arranged for cooperation with a tube member having a predetermined radial dimension,
the lower and upper concrete pile sections (3, 4, 5) being joined to axially neighboring concrete pile section by one or more joints (11 a, 11 b),
the one or each joint being formed of the respective lower drive-fit connection member (7', 7") and the upper (9, 9') drive-fit connection member of the neighboring concrete pile sections (3, 4, 5) and a joint member (12) being formed of a tube having the predetermined radial dimension, wherein a first axial end portion (13) of the joint member is attached by drive-fit cooperation with the upper drive-fit connection member and a second axial end portion (14) of the joint member is attached by drive-fit cooperation with the lower drive-fit connection member.

3. The pile (1) according to claim 2, further comprising an end shoe member (16) arranged to the bottom end of the pile (1), which end shoe member comprises a tube having the predetermined radial dimension, wherein an upper axial end portion (17) of the tube of the end shoe member is attached by drive-fit cooperation with the lower drive-fit connection member (7) of a bottom concrete pile section (3, 4, 5).

4. The pile (1) according to any one of claims 2 or 3, wherein the lower drive-fit connection member (7, 7', 7") of each concrete pile section (3, 4, 5) comprises a first axially receiving cavity (18), and the upper drive-fit connection member (9, 9', 9") of each concrete pile section (3, 4, 5) comprises a second axially receiving cavity (19), which axially receiving cavities have decreased radial dimensions in relation to the predetermined radial dimension for drive-fit cooperation with a tube having the predetermined radial dimension.

5. The pile (1) according to claim 4, wherein the lower axial end (15) of the final upper pile section (10) is driven into the second axially receiving cavity of the upper drive-fit connection member (9") of the upper concrete pile section (5).

6. The pile (1) according to claim 4 or 5, wherein the first axial end portion (13) of the joint member of the or each joint (11 a, 11 b) is driven into the second axially receiving cavity of the upper drive-fit connection member and the second axial end portion (14) of the joint member is driven into the first axially receiving cavity of the lower drive-fit connection member.

7. The pile (1) according to any one of the preceding claims, wherein each drive-fit connection member (7, 7', 7", 9, 9', 9") is arranged for drive-fit cooperation with a tube member having a predetermined radial dimension such that the tube is prevented from axial and rotational movements in relation to the drive-fit connection member.

8. The pile (1) according to any one of claims 2-7, wherein each drive-fit cooperation comprises a friction joint formed by plastically and/or elastically deforming the lower axial end (15) of the final upper pile section (10) and/or the first and second axial end portions (13, 14) of the joint member (12), respectively.

9. The pile (1) according to any one of claims 2-8, wherein the joint member (12) comprises an air release opening (20) arranged for releasing air from the inside of the joint member during joining of two concrete pile sections of the upper and lower concrete pile sections (3, 4, 5).

10. A method for providing a pile (1) for deep foundation piling, which pile is arranged to be driven into the ground, the method comprising:

- providing an upper concrete pile section (5) comprising an upper axial end (8") provided with an upper drive-fit connection member (9") arranged for cooperation with a tube member having a predetermined radial dimension,
- providing a final pile section (10) formed of a tube having the predetermined radial dimension, and
- axially joining the final pile section to the upper drive-fit connection member (9") of the upper axial end of the upper concrete pile section (5), which upper concrete pile section forms part of the pile (1), by driving a lower axial end portion (15) of the final pile section to attached cooperation with the upper drive-fit connection member (9") of the upper concrete pile section.

11. The method according to claim 10, wherein the upper

concrete pile section further comprises a lower axial end (6") provided with a lower drive-fit connection member (7") arranged for cooperation with a tube member having a predetermined radial dimension, the method further comprising:

- providing one or more lower concrete pile sections (3, 4), each lower concrete pile section comprising a lower axial end (6, 6') provided with a lower drive-fit connection member (7, 7") and an upper axial end (8, 8') provided with an upper drive-fit connection member (9, 9'), each drive-fit connection member (7, 7', 7", 9, 9', 9") being arranged for cooperation with a tube member having a predetermined radial dimension,
- providing at least one joint member (12) for axially connecting the upper and lower concrete pile sections, which joint member is formed of a tube member having the predetermined radial dimension, and
- axially joining the upper concrete pile section (5) to at least one lower concrete pile section (4) to form the pile by driving a first axial end portion (13) of the joint member to attached cooperation with the upper drive-fit connection member (9') of the at least one lower concrete pile section (4), and driving a second axial end portion (14) of the joint member to attached cooperation with the lower drive-fit connection member (7") of the upper concrete pile section.

12. The method according to claim 11, further comprising releasing air from the inside of the joint member (12) during joining of the upper concrete pile section (5) to the lower concrete pile section via an air release opening (20) of the joint member (12).

13. The method according to any one of claims 11-12, wherein the lower drive-fit connection member (7, 7', 7") of each concrete pile section is formed of a first axially receiving cavity (18), and the upper drive-fit connection member of each concrete pile section (9, 9', 9") is formed of a second axially receiving cavity (19), which axial receiving cavities have decreased radial dimensions for drive-fit cooperation with a tube having the predetermined radial dimension.

14. The method according to any one of claims 13, in which the step of axially joining the final pile section to the upper concrete pile section comprises driving the lower axial end portion (15) of the final pile section (10) into the second axially receiving cavity (19) of the upper drive-fit connection member (9") of the upper concrete pile section (5).

15. The method according to any one of claims 13 or 14, in which the step of axially joining the upper concrete pile section to the at least one lower concrete pile section comprises driving the first axial end portion (13) of the joint member into the second axially receiving cavity (19) of the lower concrete pile section and driving the second axial end portion (14) of the joint member into the first axially receiving cavity (18) of the upper concrete pile section.

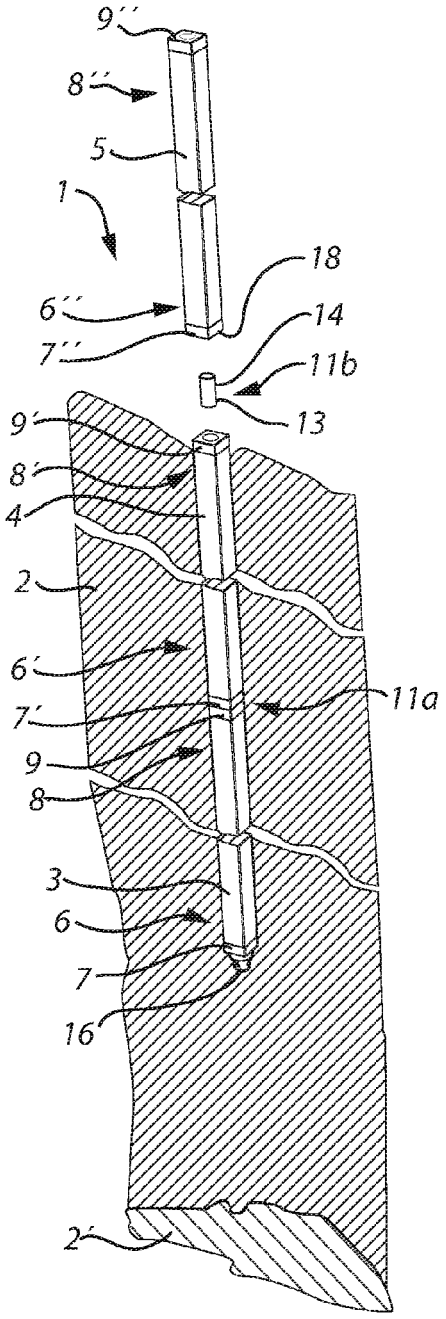
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Fig. 1

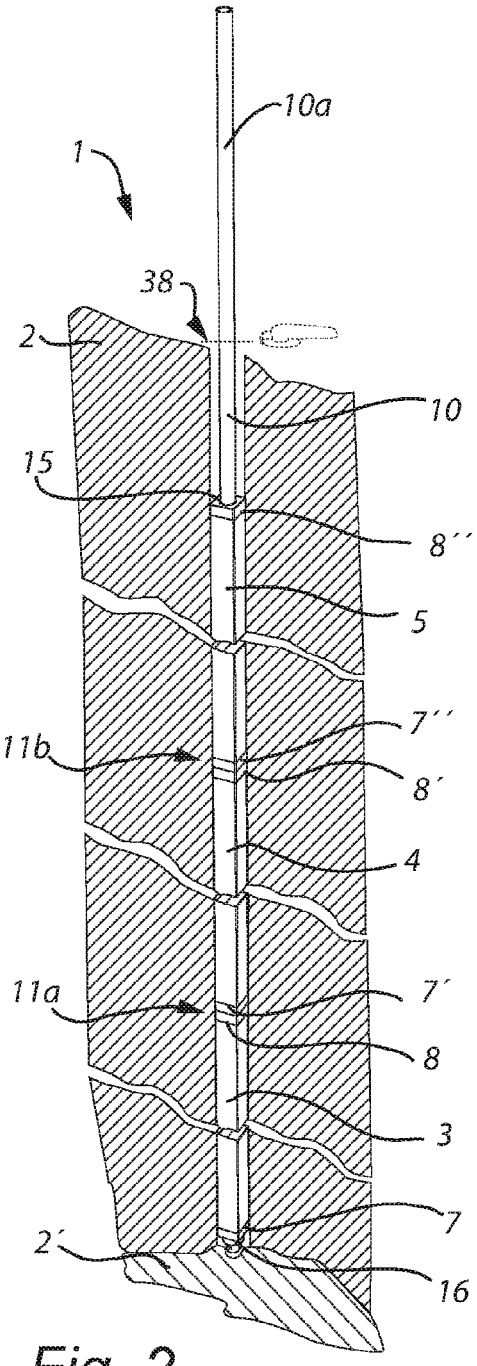
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Fig. 2

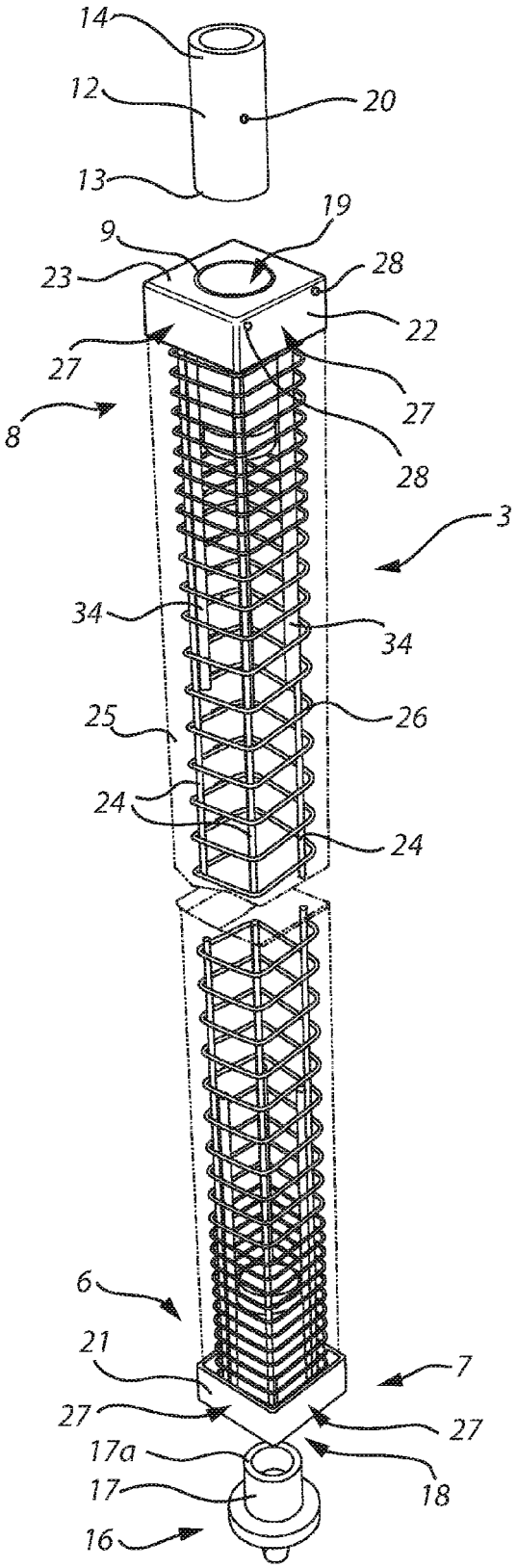
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Fig. 3

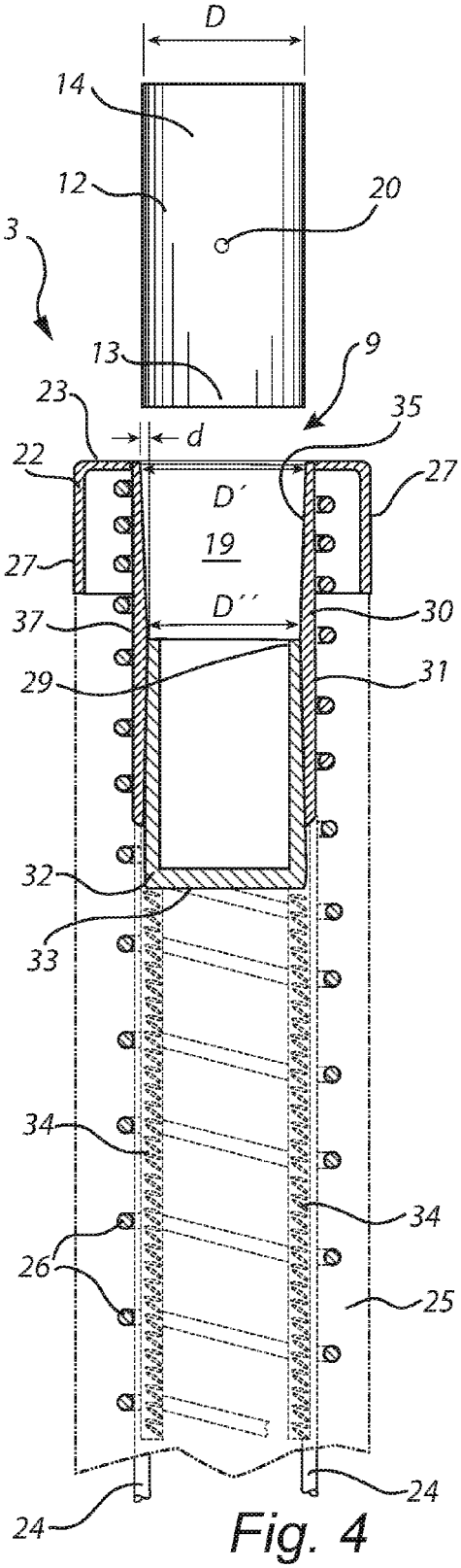
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Fig. 4

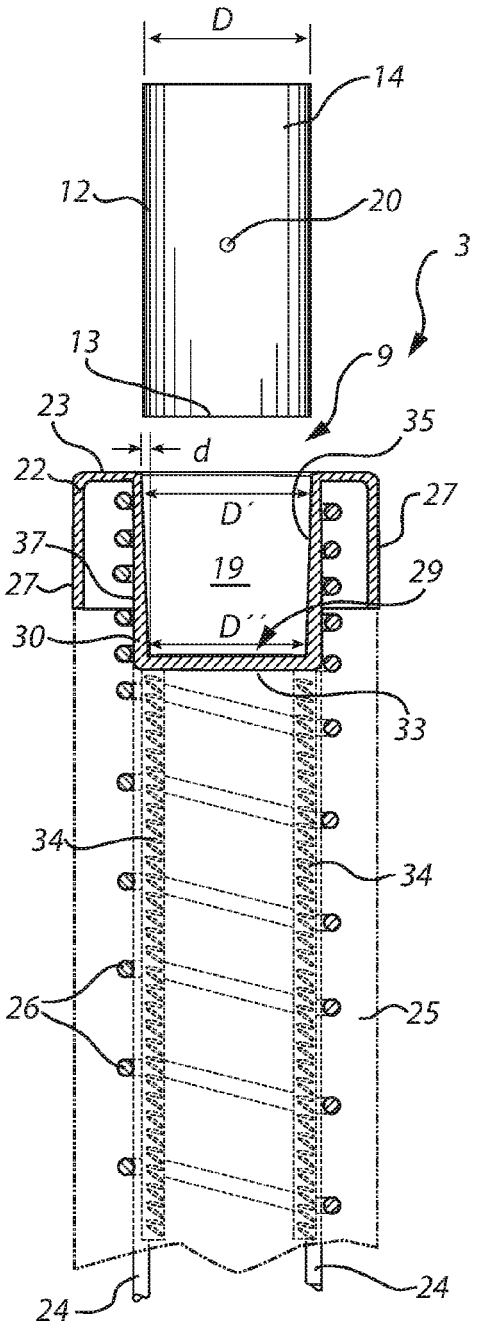
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Fig. 5

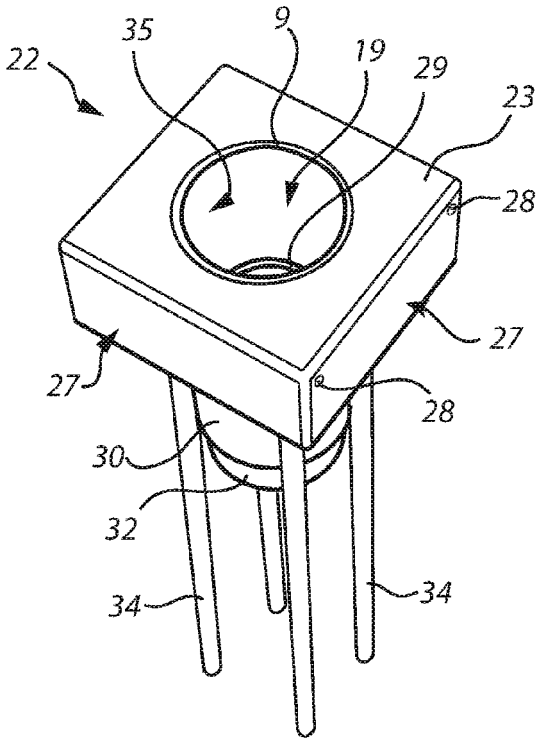

Fig. 6

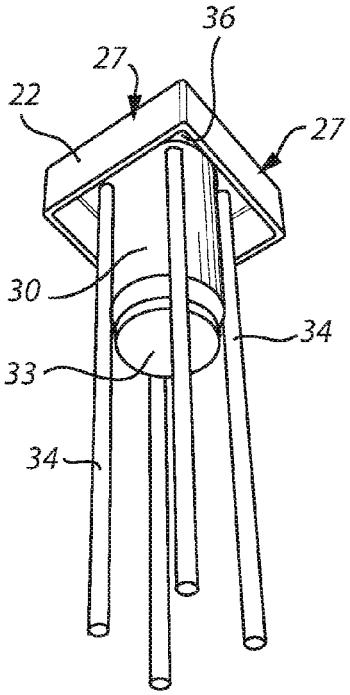

Fig. 7

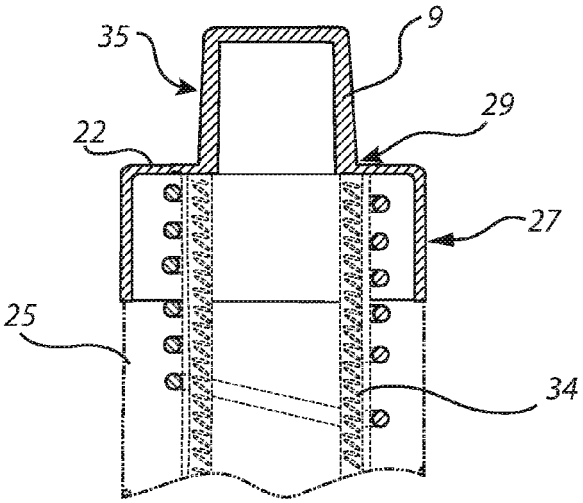

Fig. 8

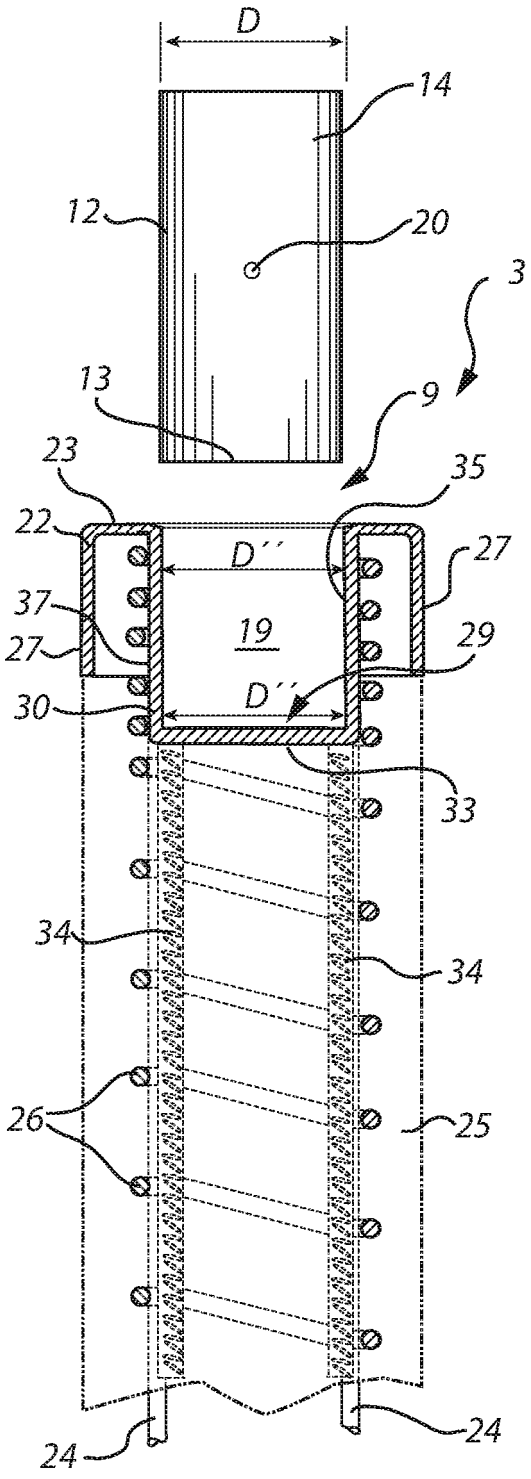

Fig. 9

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EUROPEAN SEARCH REPORT

Application Number
EP 11 18 2227

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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			TECHNICAL FIELDS SEARCHED (IPC) E02D

1 The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	29 May 2012	Friedrich, Albert

CATEGORY OF CITED DOCUMENTS

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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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29-05-2012

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